FUNCTIONAL EVALUATION OF THE BEHAVIOR OF MASTICATORY MUSCLES IN ZYGOMATICO MAXILLARY COMPLEX FRACTURE

A Dissertation submitted in
partial fulfillment of the requirements
for the degree of

MASTER OF DENTAL SURGERY

BRANCH – III
ORAL AND MAXILLOFACIAL SURGERY

THE TAMIL NADU DR. M.G.R. MEDICAL UNIVERSITY
CHENNAI – 600 032

2012 - 2015

CERTIFICATE

This is to certify that **Dr. MAYA. S,** Post Graduate student (2012–2015) in the Department of Oral and maxillofacial Surgery, Tamil Nadu Government Dental College and Hospital, Chennai – 600 003 has done this dissertation titled **"FUNCTIONAL EVALUATION OF THE BEHAVIOR OF MASTICATORY MUSCLES IN ZYGOMATICOMAXILLARY COMPLEX FRACTURE"** under my direct guidance and supervision in partial fulfillment of the regulations laid down by **The Tamil Nadu Dr. M.G.R. Medical University,** Chennai – 600 032 for **M.D.S.,** (Branch–III) Oral and Maxillofacial Surgery degree examination.

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DECLARATION

I, **DR. S. MAYA,** do hereby declare that the dissertation titled "**FUNCTIONAL EVALUATION OF THE BEHAVIOUR OF MASTICATORY MUSCLES IN ZYGOMATICOMAXILLARY COMPLEX FRACTURE**" was done in the Department of Oral and Maxillofacial Surgery, Tamil Nadu Government Dental College & Hospital, Chennai-600 003. I have utilized the facilities provided in the Government Dental College for the study in partial fulfillment of the requirements for the degree of Master of Dental Surgery in the specialty of Oral and Maxillofacial Surgery (Branch III) during the course period 2012-2015 under the conceptualization and guidance of my dissertation guide, **Prof. Dr. P. SRIMATHI**, M.D.S. I declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Tamil Government Dental College & Hospital. I also declare that no part of this work will be published either in the print or electronic media except with those who have been actively involved in this dissertation work and I firmly affirm that the right to preserve or publish this work rests solely with the prior permission of the Principal, Tamil Nadu Government Dental College & Hospital, Chennai 600 003, but with the vested right that I shall be cited as the author(s).

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And

Miss Dr. S. MAYA, aged 28 years currently studying as final year **Post Graduate student** in the Department of Oral and Maxillofacial Surgery, Tamil Nadu Government Dental College and Hospital, Chennai -3 residing at Virugambakkam, Chennai. (hereafter referred to as the ‘PG and co- investigator’)

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Title of the work: "Functional evaluation of the behavior of masticatory Muscles in Zygomaticomaxillary Complex Fracture

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"Advised to proceed with the study"

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ACKNOWLEDGEMENT

With immense gratitude, I thank my esteemed Guide, **Dr.P.Srimathi,M.D.S.,** Professor, Department of Oral & Maxillofacial Surgery, Tamilnadu Govt Dental College and Hospital for her relentless encouragement, support and guidance in successfully completing the study. Her never ending patience and affable personality has been a source of encouragement throughout my post graduate period. Her meticulous and systematic way of providing constructive viewpoints has inspired my entire approach towards the subject and its practice.

I offer with profound respect and my heartfelt thanks to **Dr.B. Saravanan, M.D.S, PhD,** Professor and HOD, Department of Oral & Maxillofacial Surgery for his unrestricted help, valuable guidance and advice throughout the post graduate period.

I am greatly thankful to ***Dr. S. PremKumar M.D.S,*** Principal-In-Charge, Tamilnadu Govt. Dental College and Hospital, for his support during the course of the study.

I express my sincere thanks to ***Dr.D.DuraiRaj,* M.D.S,** Professor, Department of Oral and Maxillofacial Surgery, for his encouragement and guidance, throughout my Post-Graduation period.

I extend my sincere thanks to **Dr. J. Balaji, M.D.S, Dr. Arun Kumar and Dr. G. Suresh Kumar,** Associate Professors, Department of Oral and Maxillofacial Surgery, for their valuable guidance and encouragement, throughout my post-graduation period.

I express my special thanks to **Dr. D. Karthikeyan M.D.S, Dr. Davidson Rajiah, Dr. D. Rohini, M.D.S, Dr. K. KamalaKannan, M.D.S, Dr. M. Arulmozhi, M.D.S,** Assistant professors of my department for their encouragement and timely help during the course of study.

I extend my profound gratitude to **Prof. Dr. K. Padma**, M.D., Director, Department of Physiology, Madras Medical College and Assistant Professor **Dr. Anantha Subramaniam, M.D** for permitting me to utilize the Electromyogram equipment used in this study.

I dedicate this study to my parents **Mr. P.K. Saranathan, Mrs. Jayasree Saranathan** for their unwavering support in all my endeavours. Any accomplishment in my life would not be possible without their constant love and prayers. I also offer my heartfelt thanks to my friends for their moral support.

Last but not the least I humbly bow to the Almighty whose blessings have given me the spiritual strength without which this endeavour would not have been possible.

ABSTRACT

BACKGROUND: The purpose of this study is to functionally evaluate the behaviour of the masticatory muscles (Masseter and Temporalis) following Zygomaticomaxillary Complex fractures by assessing bite force, electromyography and mandibular movements.

MATERIALS AND METHODS: Group I consisted of twenty patients with unilateral Zygomatico Maxillary Complex fractures who were treated surgically with one, two or three point fixations at the frontozygomatic, infra orbital or zygomatico maxillary buttress region as per clinical and radiological assessments. Group II control group included twenty normal patients. The muscle activity was functionally evaluated before and after the surgery for a period of six months. The evaluation consisted of bite force measurement, EMG analysis and measurements of mandibular movements.

RESULTS: There was an increase in bite force and EMG activity throughout the evaluated post-operative period but at the end of six months, majority of the patients were still below the control levels. Maximum mouth opening increased considerably after the surgery. The number of fixation points (one, two or three point fixation) did not influence the muscle activity.

CONCLUSION: The masticatory musculature, according to bite force and EMG returned to near normal levels by the third month after the surgery. The study supports the current clinical concept of minimized fixation in treating Zygomatico Maxillary Complex fractures.

KEY WORDS: Zygomatico maxillary complex fracture, Bite force, Masseter, Temporalis, Electromyography

ABBREVIATIONS

ANOVA	Analysis of Variance
EMG	Electromyogram
FZ	Fronto Zygomatic
MMF	Maxillo Mandibular Fixation
MVC	Maximum Voluntary Clench
SG	Strain Gauge
TMD	Temporo Mandibular Disorders
ZMB	Zygomatico Maxillary Buttress
ZMC	Zygomatico Maxillary Complex
ZOC	Zygomatico Orbital Complex
ZS	Zygomatico Sphenoid
ZT	Zygomatico Temporal

CONTENTS

INTRODUCTION

The foundation of a beautiful face lies in the design of the facial skeleton. Modern hallmarks of beauty are defined by bold facial contours that are accentuated by a youthful midface configuration. An essential component of midface skeleton is the prominent cheekbones which forms a part of Zygomatico Maxillary Complex. The midface itself consists of a bony lattice with a system of relatively strong, vertically oriented struts[1]. They are thought to be a mechanical adaptation to masticatory forces. The midfacial bones in isolation are fragile but gain strength from each other via the buttress which Manson[2] (1980) alluded to when describing the vertical and horizontal struts that support the facial skeleton.

The zygoma is the cornerstone of the buttress system and its prominence, the malar eminence, is often the recipient of blunt trauma. Any force applied to the malar eminence or zygoma is transmitted through this series of connections in the bony lattice that comprises the midface. Starkhammer and Olofsson (1982) reported that the zygomatic region is involved in 42% of facial fractures[3]. Concomitant fractures are common, particularly those of the anterior wall of the maxillary sinus as this represents one of the weakest areas in the facial skeleton[4]. The most common etiologic factors involved in these injuries are interpersonal violence, road traffic accidents, falls, and sports injuries.

The integrity of zygoma is maintained by the muscles which are attached to it. Muscles that act directly on the zygoma include the masseter, anterior temporalis, and, to a lesser extent, the zygomaticus minor and major as well as part of the orbicularis oculi muscle[5]. The force vectors that act on the ZMC during normal function undergo a change affecting the equilibrium of these muscles during the ZMC fractures which results in displacement of the fracture segments leading to facial asymmetry and functional limitations.[6]

The masseter muscle is assumed as the primary cause of postreduction displacement of the fractured ZMC[7] as it is capable of exerting sufficient inferiorly directed force on the fractured zygoma to cause movement, even after surgical insertion of fixation devices.

In addition, studies by Oyen et al (1996)[8] showed that the tensile strain exerted by anterior temporalis muscle fibers may either displace the reduced zygomatic complex in a vertically downward direction or cause distraction osteogenesis, resulting in gradual elongation of the lateral orbital rim and inferior rotation of the zygomatic complex.

Hence stable reduction and fixation of fractures of the zygomatic complex is essential to avoid long term aesthetic, sensory, and ocular consequences. Stability after reduction depends on both the nature of the fracture and the method of fixation. Fractures that are incomplete at the frontozygomatic suture are relatively stable, whereas comminuted fractures and those that are displaced laterally are the least stable[4]. The reason for this disparity is multifactorial and includes factors like the type of injury being treated, ie, simple, comminuted fractures or grossly displaced fractures. Often reduction by itself does not provide stability. Hence fixation of the fracture is required to avoid relapse, undesirable aesthetic and ocular consequences. In contrast, unnecessary plating has its disadvantages as in increased operating time, cost, and morbidity[9].

Improved outcome of unstable fractures of the zygomatic complex has been reported after exposure and fixation at three or four points. This is attributable to increased accuracy of the reduction, which is facilitated by the surgeon being able to see more fracture points.

Several studies have been conducted for determining the behaviour of masseter and temporalis in patients with derangement of the stomatognathic system. Functional evaluation of the masseter muscle has been performed by Dal Santo[7] (1992) where calculation of muscle force was based on measured bite force, electromyogram, and radiographic determination of muscle vectors. A high EMG activity of the temporalis muscle was noticed in patients with isolated Zygomatico maxillary complex fracture. According to Ribiero et al[10] (2011) this is a pattern that is characteristic of individuals with stomatognathic system dysfunctions. Hence bite force and electromyography demonstrate the functional state of the masticatory system that results principally from the action of jaw elevator muscles modified by the craniomandibular mechanics.

The purpose of this study is to evaluate behaviour of the masticatory muscles (Masseter and Temporalis) following Zygomaticomaxillary Complex fractures by assessing bite force, electromyography and mandibular movement.

AIM AND OBJECTIVES

AIM

The purpose of this study is to functionally evaluate the behaviour of the masticatory muscles (Masseter and Temporalis) following Zygomaticomaxillary Complex fractures by assessing bite force, electromyography and mandibular movements.

OBJECTIVES

To functionally evaluate the behaviour of the masticatory muscles (Masseter and Temporalis) in Zygomaticomaxillary Complex fractures, prior and subsequent to surgical treatment, by measuring the following over a period of six months.

1. Bite force at the molar (bilateral) and incisor region
2. Surface electromyographic activity of masseter and temporalis muscles bilaterally
3. Mandibular movements (mouth opening, lateral excursive movement, protrusion)

REVIEW OF LITERATURE

INCIDENCE AND ETIOLOGY

A.D.Hitchin and S.T. Shuker in 1973[9] reviewed 10 year records of patients with zygomatic bone fractures treated at the Eastern Regional Board (Scotland) hospital. The results showed that the incidence of zygomatic fractures on the left side was high when the injury was sustained due to fights, fall and sports while the right side bone was most commonly fractured when the injury was as a result of road traffic accidents.

Kristensen S, Tveteras K in 1986[11] did a retrospective study of 109 patients with 111 zygomatic fractures in order to analyze late complications and to evaluate the different radiographic classifications. The etiology was violence in 39% and road traffic accidents in 28%. Associated fracture of the craniofacial skeleton occurred in 42% of the patients. 72 patients were available for the follow-up study. 16% of the operated patients showed malar flattening, 34% of the patients had sensory disturbances, 6% had enophthalmos and 1% had diplopia

Covington.D.S, Parks.D.H in 1994[12] presented a 10 year retrospective review of 259 zygoma fractures and highlighted the changes in epidemiology and treatment. Majority of the injuries (80. 6%) with a high incidence of multiple facial fractures (43.2%) was a result of motor vehicle related trauma. The proportion of fractures receiving open reduction and internal fixation (ORIF) remained relatively constant (46.3%) with a trend towards the use of the lateral maxillary buttress for fixation. The need for orbital floor exploration decreased by almost half, possibly reflecting improved preoperative radiological evaluation

Behcet Erol et al in 2004[13] gave a retrospective analysis of the demographic distribution, treatment modalities, and complications of maxillofacial fractures in 2901 patients. The results showed that facial fractures were most frequent in males (77.5%) and in the 0-10 year age group; they were more frequent during summer (36.3%); and the most common aetiology was traffic accidents (38%). 77.9% of cases were treated with conservative methods, and 22.1% with one or more internal fixation techniques. The most favoured technique was miniplate osteosynthesis and the complication rate associated with internal fixation was 5.7%

CLASSIFICATION OF ZMC FRACTURE

Knight JS, North JF in 1961[14] classified zygomatic fractures based on the direction of displacement as seen in Waters' view radiograph. They classified 120 zygomatic fractures into 6 groups and hypothesized that stability after reduction might be related to the direction of displacement. The 6 groups are as follows,

Group 1 : Nondisplaced fractures

Group 2 : Arch fractures

Group 3 : Unrotated body fractures

Group 4 : Medially rotated body fractures

Group 5 : Laterally rotated body fractures

Group 6 : Complex fractures, these have additional fractures across the body of the zygoma

P.M.Finly, K.P.Wardbooth, K.F.Moos in 1984[15] followed the Henderson classification system in their study to analyze the complication encountered during the treatment of unstable zygomatic complex fractures with antral packs and external pins. The Henderson system of classification is as follows

Type 1 – Undisplaced fracture

Type 2 – Zygomatic arch fracture only

Type 3 – Tripod fracture with fronto-zygomatic suture intact

Type 4 – Tripod fracture with separation of fronto- zygomatic suture

Type 5 – Pure blow-out fracture

Type 6 – Orbital rim fracture

Type 7 – Comminuted fracture

In Types 1, 2, 5 and 6, there is no displacement of the body of zygoma. In types 3, 4 and 7 there is displacement of the fracture and it requires fixation to stabilize the fragments.

Manson PN, Markowitz B, Mirvis S, Dunham M, Yaremchuk M in 1990[16] studied the pattern of segmentation and displacement in the CT scan and classified fracture patterns as low, middle, or high energy. Exposure and fixation relate directly to the fracture pattern for each anatomic area of the face. Fractures with little comminution and displacement required conservative treatment; middle-energy injuries were treated by standard surgical approaches and rigid fixation. For highly comminuted fractures accompanied by instability and marked alterations in facial architecture only multiple surgical approaches to fully visualize the "buttress" system provided alignment and fixation. Classification of facial fractures by anatomic location and pattern of comminution and displacement define refined guidelines for exposure and fixation.

Zingg M, Laedrach K, et al in 1992[17] presented a treatment guideline based on a simple classification of zygomatic fractures. They analyzed 1025 zygomatic fractures and presented results on the indications for closed and open reduction, consistent methods for three-dimensional alignment and fixation, and the management of concomitant infraorbital rim and orbital floor fractures. Their classification system is based on anatomic points and divides fractures into 3 categories: category A includes isolated fractures of 1 of the 3 processes of the zygomatic bone. These processes are the temporal process, which forms the zygomatic arch (A1), the frontal process, which forms the lateral orbital wall (A2), and the maxillary process, which forms the infraorbital rim (A3). Category B represents fractures of all 3 processes, rendering the zygomatic bone detached from the facial skeleton. Category C is the same as type B, but with fragmentation, including the body of the zygoma

ASSESSMENT OF ZMC FRACTURES

G.R.Ogden and J.G.Cope in 1988[18] analyzed the fractures involving the zygomatic complex to understand whether postoperative radiograph is necessary in the management of these fractures. According to the authors, preoperative radiographs are absolutely essential for the proper assessment of the extent of injury of facial skeleton. They concluded their study by saying that in order to avoid unnecessary patient exposure to ionizing radiation the clinical judgment alone is sufficient for post-operative evaluation.

Al-Qurainy A and Stassen LFA et al in 1991[19] carried out a study to identify the risk factors involved to determine the prognosis for the restoration of the binocular vision. They concluded that early surgical reconstruction of midfacial fracture with conservative management of concomitant mobility disorders resulted in very few patients having diplopia in the long run.

ANATOMY OF MUSCLES ORIGINATING IN ZYGOMA

Sicher H and Du Brul FL, 1970[20] described the anatomy of the muscles taking their origin in zygoma. The superficial portion of the Masseter arises from the lower border of the zygomatic bone and the zygomatic process of maxilla. The deep fibers arise from the entire length of the zygomatic arch in the inner surface and the lower border at its most posterior part.

The Temporalis muscle arises from the temporal fossa and the lateral surface of the skull. Some fibers may arise from the most posterior part of the temporal surface on the frontal process of the zygomatic bone.

A separate entity called the zygomaticomandibular muscle has been described by the authors. The most superficial and shortest fibers of the temporalis muscle and the deep portion of the masseter are fused inseparable and work as a separate unit.

Levator labii superioris (quadrates) muscle arises in a long line from the frontal process of maxilla laterally to the zygomatic bone. According to its origin, it is divided into three parts. The first part arises from the frontal process of maxilla; the second part from the infraorbital margin extending to the zygomatic process of the maxilla; the third part from the most prominent part of the zygomatic bone. Zygomaticus Major muscle arises from the temporal process of the zygomatic bone and the Zygomaticus Minor muscle arises from the body of the zygoma.

MUSCLES IMPLICATED IN ZMC FRACTURES

Paul N Manson, 2007[21] stated that zygomatic fractures include any injury that disrupts to various degrees the five articulation of the zygoma with the adjacent craniofacial skeleton. Displacement and comminution is determined by the direction and magnitude of the forces of injury and the action of masseter, which is attached to the temporal process of the zygoma.

STUDIES SUPPORTING THE ROLE OF MASSETER IN ZMC FRACTURES

Karlan MS and Cassisi NJ, 1979[22] conducted a four-part study of the cosmetic results of common zygomatic fracture reduction techniques. They concluded that masseteric contraction may cause late displacement in poorly fixed fractures. Hence alignment of the fracture at three points and fixation at two stable points provide the most accurate and satisfactory postoperative results. Two-point interosseous fixation at the "buttress" fracture and the frontozygomatic fracture is suitable for routine surgery

Kaastad E and Freng A, 1989[23] conducted a study where 159 ZMC fractures were reduced using a bone hook into what appeared to be a stable position during surgery. One week later, after resolution of edema, patients were examined, and 32 (20%) were found to have malar asymmetry requiring open reduction and internal wire fixation, thus implicating the role of masseter in the post reduction displacement. However, according to Ellis III, 1996, the one drawback with this study was that there were no postoperative images used to prove that the ZMC had been properly reduced at time of surgery.

Rinehart GC and Marsh JL, 1989[24] conducted a study where 16 zygoma fractures were sequentially fixated with three miniplates, two miniplates, one miniplate, and three interosseous wires across the orbital rim and arch "fractures". Static and oscillating loads simulating maximal physiologic masticatory stresses were applied to the fixated zygoma along the lines of action of the masseter muscle by means of a tensometer. The stability and adequacy of each pattern of fixation were recorded. The authors concluded that double-miniplate fixation across the orbital rim of simulated noncomminuted zygoma "fractures" is sufficient to withstand static and oscillating loading similar to physiologic masticatory forces. Neither single-miniplate fixation nor triple-wire fixation are sufficient to stabilize the zygoma against similar forces.

Davidson J, Nickerson D, Nickerson B, 1990[25] analyzed different methods of internal fixation of simple displaced fractures of the zygoma in an attempt to define the simplest method(s) of achieving post reduction stability. Twenty-five combinations of interfragmentary wiring and miniplate and screw fixation of fractured zygomas on human skulls were compared for post reduction rotational stability against stresses simulating the muscular forces that act to displace the zygoma once it has been reduced. Analysis of the data suggested that while three-point fixation using either miniplates or interosseous wires allows for virtually no displacement but two-point fixation and in some cases one-point fixation provides acceptable stability. In general, stable fixation is achieved by methods that involve the use of at least one miniplate and must incorporate the frontozygomatic suture line as one of the points of fixation.

Deveci M, Eski M, Gurses S, 2004[26] compared the three plating systems (miniplate, microplate and modified plate) for stability to withstand the rotational forces of the zygoma and the massetric pull. According to the results obtained, microplates were not effective in stabilizing the frontozygomatic suture when the masseter muscle forces are within physiological range. Miniplates stabilize zygomatic complex fractures to certain extent. Modified microplates, which have no undulation along the plate border, have a higher resistance to rotation than that of the conventional plates

Cyrus Mohammadinezhad, 2009[27] did a study to evaluate the minimally invasive therapy in cases of zygomatic fractures. Different methods of internal fixation of simple displaced zygomatic fractures, such as wiring, miniplate, and screw fixation were compared for post reduction rotational stability caused by muscular forces. They showed that treatment of an isolated zygomatic bone fracture according to aesthetic and functional requirements can be achieved by insertion of a single miniplate at the lateral rim of the orbit.

STUDIES REJECTING THE ROLE OF MASSETER IN ZMC FRACTURE

Dal Santo F, Ellis E, Throckmorton GS, 1992[7] compared masseter muscle force in 10 male controls with 10 male patients who had sustained unilateral ZMC fractures. Calculation of muscle force was based on measured bite force, electromyogram, and radiographic determination of muscle vectors. The results showed that the masseter muscle develop significantly less force in patients with a ZMC fracture than in controls. After fracture, the masseter force slowly increases, but at 4 weeks after surgery, most patients were still well below control levels. The results of this study cast doubt on the role of the masseter muscle in post reduction displacement of the fractured ZMC, and indicate that minimal amounts of fixation may be necessary for such injuries.

Edward Ellis III, 1996[28] analysed 48 patients with isolated, unilateral ZMC fractures who were treated with a variety of surgical approaches and fixation sites that had at least 6 weeks follow-up. Stability of the repositioned ZMC was assessed by comparing the immediate post operative images with those obtained at least 5 weeks later. No patient in this study showed post surgical change in position of the reduced ZMC. Furthermore, the author disputes the clinical studies implicating the masseter's role in post reduction displacement because in those studies there is no radiographical data available to validate if adequate reduction has been achieved intraoperatively to compare with a radiograph taken months later to prove that postsurgical displacement had occurred. According to the author, in these clinical studies, the ZMC fractures were never properly positioned at surgery.

ROLE OF TEMPORALIS IN ZMC FRACTURES

Oyen OJ, Tsay TP, 1991[29] demonstrated the transmission of greater forces to the region of the frontal process of the zygoma, with these forces being two fold greater on the working side compared with the balancing side during mandible lateral movements.

Oyen OJ, Melugin MB, Indresano AT, 1996[8] conducted an animal study to analyze the tensile stains produced in the frontozygomatic region. The authors showed that there was a transmission of forces to the ZOC, especially to the lateral wall of the orbital ridge, after the stimulation of maximum masticatory force in these animals. Tensile strains predominated in the region of the frontal process of the zygoma, with balancing side strains twice as large as working side strains. This study supports the use of compression plate osteosynthesis for improved stabilization of fractures in this region.

Stassen, L. F., and Kerawala, C., 1999[30] concluded that the functional forces exerted by the temporalis muscle may cause delayed postoperative distraction at the frontozygomatic suture. This was demonstrated when the authors conducted a surgical exploration of this area during a malar osteotomy for a poorly reduced zygoma and observed a normal but elongated (by approximately 5mm) lateral orbital rim. Hence the temporalis muscle may contribute to distraction of a reduced but unfixed fracture of the zygomatic complex.

Kovács AF, Ghahremani M, 2001[31] demonstrated that a symmetric reconstruction of the malar prominence could be achieved by the FZS fixation. The results of the experimental findings in human skulls comparing different methods of internal fixation showed that one miniplate at the FZS line was the minimum requirement for stable fixation

Barry CP, Ryan WJ, Stassen LF, 2007[6] conducted a cadaveric study and postulated that the functional forces exerted by the temporalis on the zygomatic complex cause postoperative distraction at the frontozygomatic suture. The anatomical evidence that the anterior fibers of the temporalis muscle take origin below the frontozygomatic suture, from the posterior aspect of the frontal process of the zygomatic bone supports the theory that the tensile strain at the frontozygomatic suture can exert a vertical downward force on the zygomatic complex. Furthermore, the authors hypothesize that the tensile strain exerted by these fibers may either displace the reduced zygomatic complex or cause distraction osteogenesis, resulting in gradual elongation of the lateral orbital rim and inferior rotation of the zygomatic complex. Hence internal fixation of all fractures of the zygomatic complex, even those that are considered clinically stable is required, if permanent flattening of the cheekbone is to be avoided.

Kun Hwang, 2010[32] analyzed cases treated by lateral brow incision and 1-point fixation and introduced the criteria for application of this selective approach. The result was that the 3-point fixation provided the best stability, but at least 1 miniplate fixation of only the frontozygomatic suture was also acceptable in providing stability of the fractured zygoma.

IMPORTANCE OF BITE FORCE MEASUREMENT

Duygu Koc, Arife Dogan, and Bulent Bek, 2010[33] postulated that maximum voluntary bite force is an indicator of the functional state of the masticatory system and the level of maximum bite force results from the combined action of the jaw elevator muscles modified by jaw biomechanics and reflex mechanisms. However, the reliability of these measurements depends on a number of factors, such as presence of pain and temporomandibular disorders, gender, age, cranio-facial morphology, and occlusal factors. In addition to these physiological factors, recording devices and techniques are important factors in bite force measurement.

Ribeiro MC et al, 2011[10] stated that in facial trauma, it is not possible to make comparisons involving preoperative measurements, and these patients must instead be studied over time and compared with a control group consisting of healthy individuals with normal occlusion and dentition. There is great variability in this type of study, because fractures are never identical and there is variation in aetiology, among other factors. In addition to the difference in the fracture pattern from patient to patient, there are also differences regarding the ZOC and the types of fracture treatments used, which range from conservative treatments to the many possible surgical techniques with internal fixation.

BITE FORCE MEASUREMENTS IN VARIOUS STOMATOGNATHIC DISORDERS

Ringqvist M, 1973[34] studied the isometric bite force in condylar fractures and concluded that factors expected to reduce maximum bite force include pain or discomfort on biting, an increased mandibular plane angle secondary to an open bite resulting from the bilateral condylar fractures, decreased intrinsic strength or size of the muscles of mastication as a result of an extended duration of MMF, and possible effects on the central nervous system to reduce loading of the fractured condylar processes.

Osborn JW, Barager FA, 1985[35] predicted the pattern of human muscle activity during clenching by simulating symmetric vertical bite forces. Theoretical biomechanical models suggest that the muscles with the highest mechanical advantage will be recruited at the highest rate during isometric bites. Although the increases in relative temporalis activity and temporalis mechanical advantage in the patients were not statistically significant, the trend suggests that physically increasing the mechanical advantage of a jaw muscle may increase its rate of recruitment

Dal Santo F, Ellis E III, Throckmorton GS, 1992[7] evaluated patients with zygomatic complex fracture and showed that bite force was slightly reduced in the fracture group compared with the control group and that there was an increase in bite force in the fracture group throughout the evaluated postoperative period. Only one of the patients achieved values equal to those of the control group during the 14-week postoperative period. Regarding bite force, the control group presented a mean value of 49.5 kgf for the right side and 48.9 kgf for the left side.

Tate GS, Ellis E III, Throckmorton GS, 1994[36] evaluated bite-force values bilaterally in the region of the molars and incisors in 35 patients with mandibular angle fractures who were treated surgically. The authors showed that bite force values increased during the evaluation period but were reduced compared with the control group. The authors also reported a statistically significant difference when the 6-week period was compared with the later periods, but bite-force values remained lower than those of the control group.

Talwar RM, Ellis E 3rd, Throckmorton GS, 1998[37] studied bilateral fractures of the condyle and found a relative increase in both anterior and posterior temporalis muscle activity, as compared with masseter activity. The differences on muscle activity ratios attained significance at 6 weeks period. The results suggested that patients reduced the loads on their fractured joints exclusively by reducing their tolerated maximum occlusal force. These results are similar to those for other fractures of the mandible.

Throckmorton GS, Ellis E III, Buschang PH, 2000[38] studied the factors of craniofacial morphology that best predict maximum bite forces and jaw muscle strength (based on EMG/force slopes) in patients selected for various orthognathic surgical procedures and concluded that measurements reflecting relative differences between anterior and posterior facial height strongly correlated with maximum bite force. Furthermore, the force measured during the preoperative period may be masked because the patient is under the influence of orthodontic forces that reduce bite force.

Ohkura K, Harada K, Morishima S, Enomoto S, 2001[39] concluded that bite-force values increase with time in patients submitted to orthognathic surgery, although the patients did not achieve the same values as the control group during the 3-year period.

Gerlach KL, Schwarz A, 2002[40] performed a bite force study in the region of the molars, canines, and incisors in 22 patients with mandible fractures treated with the Champy technique. Those authors showed that the maximum bite force achieved by the group treated in the first week was 31% that of the control group and that the force reached 58% in the sixth and final week of the evaluation.

Kogawa EM, Calderon PS, Lauris JRP, Araújo CRP, Conti PCR, 2006[41] evaluated the maximum bite force in 200 women with temporomandibular disorder patients. Authors concluded that the presence of masticatory muscle pain and/or TMJ inflammation can play a role in maximum bite force.

Pereira-Cenci T, 2007[42] compared the maximum bite forces in subjects with temporomandibular disorders to a control group and also evaluated its association with age, gender, height and weight. Within the limitations of this study, it is possible to conclude that bite force was not affected by temporomandibular disorders

Gonzalez Y, Iwasaki LR, McCall WD, Jr, Ohrbach R, Lozier E, Nickel JC, 2011[43] evaluated the reliability of EMG activity in relation to static bite-force. Eighty-four subjects were subjected to 5 unilateral static bites of different forces at different biting positions on molars and incisors, at two separate sessions, while surface EMG activities were recorded from temporalis, masseter, and suprahyoid muscles bilaterally. The authors concluded that the slopes of the EMG activity versus bite-force for a given biting situation were reliable for temporalis and masseter muscles.

Ribeiro MC et al, 2011[10] studied the bite force in patients treated for isolated fractures of the zygomatic complex. The results showed that bite force was reduced immediately after surgery and then increased throughout the evaluation period. Mean bite force in the first molar region was 38.5% that of the control group in the first week, increasing to 59.5% in the eighth week (the second month). 6 months after surgery the bite-force values in the region of first molars were close to 70% of the control group values, and in the region of the central incisors the bite-force values were very close (95.4%) to those of the control group.

EFFECT OF BITE FORCE IN INCREASING LEVELS OF VERTICAL DIMENSION

Manns A, Miralles R, Palazzi C, 1979[44] studied EMG, bite force, and elongation of the masseter muscle under isometric voluntary contractions and variations of vertical dimension. In series 1, recordings of EMG activity when maintaining bite force constant (10 and 20 kg) show that EMG is high when the bite opening is 7 mm, decreases from 15 to 20 mm, and then increases again as jaw opening approaches maximum opening. In series 2, recordings of bite force maintaining

EMG constant show that bite force increases up to a certain range of jaw opening (around 15 to 20 mm) and then decreases as we approach maximum jaw opening. The authors conclude that there is for each experimental subject a physiologically optimum muscular elongation of major efficiency where the masseter develops highest muscular force with least EMG activity.

FATIGUE AT CONSTANT BITE FORCE

Sforza C, Zanotti G, Mantovani E, Ferrario VF, 2007[45] Studied the surface EMG of the masseter and temporalis anterior muscles was measured in ten healthy young adults performing a unilateral molar (right side) clench. The subjects clenched on a bite force transducer at a fixed force level of 13 kg (127 N) as long as they could (endurance). Endurance time ranged between 79 and 470 s.

EMG ACTIVITY OF MASSETER AND TEMPORALIS IN STOMATOGNATHIC DISORDERS

Hagberg C, Hagberg M, 1988[46] studied the surface EMG activity of masseter and anterior temporalis muscles for nine females while biting on a bite force transducer up to maximal effort (100% maximal voluntary contraction; MVC). For the anterior temporal muscles no increase in mean MF (Mean Frequency) was found above 20-25% MVC. A similar decrease in mean MF was found for the masseter muscles and the anterior temporal muscles for the force level 60-100% MVC.

Dal Santo F, Ellis E III, Throckmorton GS, 1992[7] studied the EMG activity of masseter in ZMC fractures and concluded that the EMG activity were slightly reduced in the fracture group compared with the control group and that there was an increase in EMG for patients in the fracture group throughout the evaluated postoperative period. Only one of the patients achieved values equal to those of the control group during the 14-week postoperative period.

Silva MA, Issa JP, Vitti M, Silva AM, Semprini M, Regalo SC, 2006[47] studied the electromyographical activity of the masseter muscles bilaterally in twenty individuals with temporomandibular joint dysfunction (TMD). The results showed that individuals with TMD, dentulous or not, presented elevated muscular activity in rest position and individuals with TMD, dentulous, presented higher electromyographical activity than the individuals with TMD and lacking posterior teeth.

Moreno I, Sánchez T, Ardizone I, Aneiros F, Celemin A, 2008[48] studied the surface electromyography recordings of masseter, anterior and posterior temporalis and digastric muscles; in three different tests: clenching at maximum intercuspation, swallowing and chewing. The results obtained show that: men achieve a higher masseter activity at maximum effort than women; Angle class II show higher activity than other classes for the temporalis muscle in deglution, while class III show higher activity than other classes for all muscles in maximum effort; the presence of a posterior crossbite affects the behaviour of anterior temporalis and masseter muscles.

Castroflorio T, Bracco P, Farina D, 2008[49] concluded that Surface electromyography (EMG) allows the non-invasive investigation of the bioelectrical phenomena of muscular contraction. Furthermore technological advances in signal detection and processing have improved the quality of the information extracted from the surface EMG and furthered the understanding of the anatomy and physiology of the stomatognathic apparatus.

Ribeiro MC et al, 2011[10] studied the EMG activity of the masseter and anterior temporalis in patients treated for isolated zygomatic complex fractures. The results showed that the EMG activity increased and later declined, which may have occurred because of the technique used or the particularities of each sample. It was verified that the masseter muscles presented a 30% increase in EMG activity compared with the control for the right masseter, and a 2.1% increase for the left. As for the temporal muscles, the results showed a 31.7% higher activation for the right temporal muscle and 38.3% for the left. The EMG activity in the temporal muscles was high, a pattern that is characteristic of individuals with stomatognathic system dysfunctions

Frongia G, Ramieri G, De Biase C, Bracco P, Piancino MG, 2013[50] evaluated through clinical and electromyographic (EMG) assessments, the electric activity of masseter muscle and anterior temporalis muscles during clenching, before and after orthodontic treatment and surgery for correction of mandibular excess and found significant difference in the value of activity index. According to the authors, the evaluation of EMG activity after surgery may be considered a sign of good adaptation of the neuromuscular system to the new occlusal condition and a good method for detecting non responding patients who might require further treatment.

MANDIBULAR MOVEMENTS IN ZYGOMATIC FRACTURES

Ribeiro MC et al, 2011[10] measured the mandibular movements and concluded that there was no effect on mandibular mobility, apart from maximum mouth opening, which returned to the normal level during the first month after surgery. As per the authors, further studies with larger samples and standardization of the treatment used should be performed to confirm this pattern of recovery.

SURGICAL ANATOMY

The term zygoma is derived from the Greek Ζυγόμα zygoma meaning "yoke"(i.e. a structure that connects various parts together), where it articulates with the temporal, maxillary, frontal and sphenoid bones. It is a diamond or pyramidal shaped bone, the lateral part of which is convex forming the malar eminence, commonly called as cheek bone. The malar (cheek) symmetry is often the most useful external indicator of accurate reduction. In the frontal view, the area posterosuperior to the intersection of a line drawn from the lateral oral commissure to the ipsilateral lateral canthus and another line drawn from the tragus to the inferior edge of the nasal ala represents the most prominent area of the malar eminence[51]. This is approximately 2 cm inferior to the lateral canthus.

ARTICULATIONS OF THE ZYGOMA

The importance of zygoma lies in that, it contributes to the width and projection of the face. The structural integrity of the zygoma is defined by its articulation with four other bones of the face.

1. Superiorly by the frontal bone
2. Medially by the maxilla
3. Posteriorly by the greater wing of the sphenoid bone within the orbit.
4. Laterally, the temporal process of the zygoma joins the zygomatic process of the temporal bone to form the zygomatic arch.

The articulations are at the zygomaticofrontal (ZF) suture, zygomaticomaxillary suture (ZMB), zygomaticosphenoid (ZS) suture and zygomaticotemporal (ZT) suture respectively[52]

The thickest bone is found within the frontozygomatic suture and is an excellent site for the application of wires or plates for fixation[53]. The zygomaticosphenoidal suture is curvilinear, and provides a valuable guide to accurate three-dimensional alignment of the ZMC[54]. Zygomatic fractures are called tetrapod fractures due to its separation from the facial skeleton along these four suture lines.

BUTTRESS SYSTEM OF THE MIDFACE

Buttresses are the vertical and horizontal struts that support the facial skeleton. The horizontal pillars are formed by the frontal bar (composed of the supraorbital rims and nasal process of the frontal bone), the zygomatic arch, infraorbital rims, and the nasal bridge and finally the alveolar process of the maxilla. The vertical pillars are formed first medially by the piriform rims which continue superiorly as the frontal process of the maxilla. Secondly the zygomatic buttresses which continue superiorly with the lateral orbital rims form the lateral pillars and finally the most caudal pillars are the pterygoid plates.[55]

IMPORTANCE OF ZYGOMATIC BUTTRESS

The zygomatic buttress is one of the important vertical buttresses of the face. It consists of the zygomatic arch, zygomatic body and the infraorbital rim. The zygomaticomaxillary buttress absorbs the greatest occlusal forces of mastication as evidenced by the presence of thick cortical bone in the lateral maxillary zygomatic region when compared with the more fragile medial maxillary wall[56]

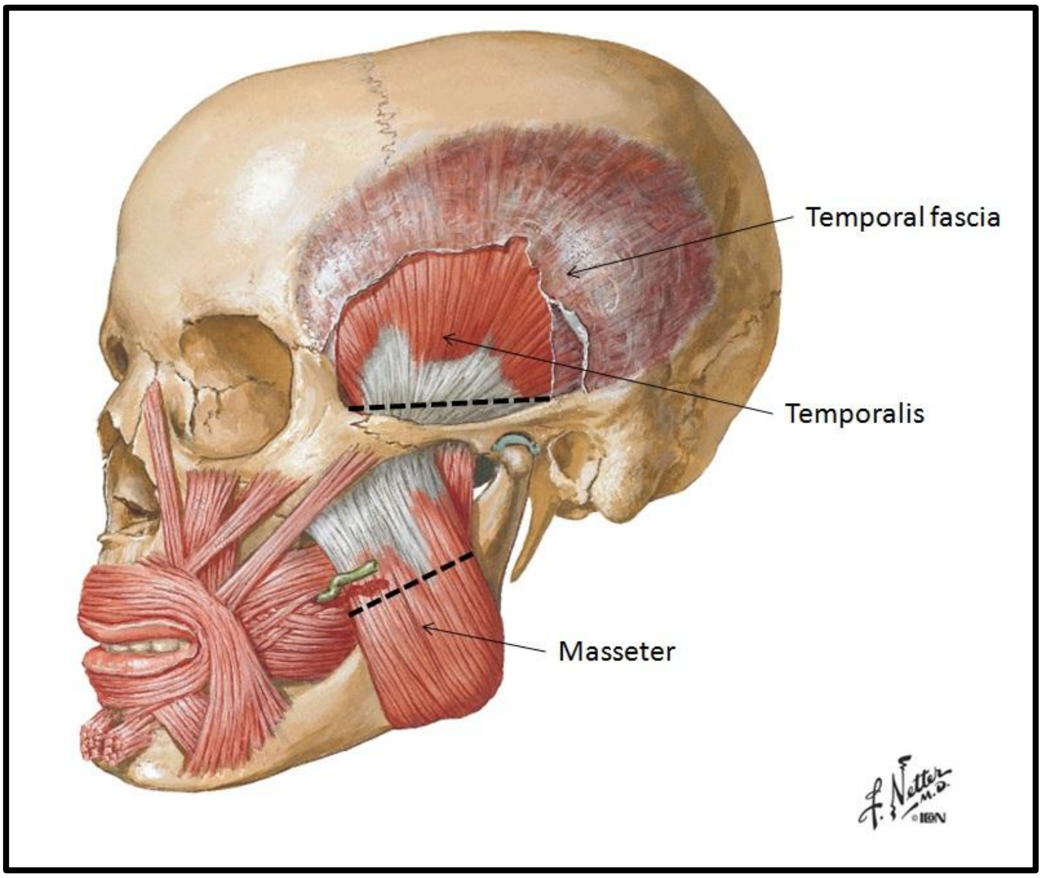
The zygomaticomaxillary complex provides key structural support to the orbit, separating the orbital contents from the temporal fossa laterally and maxillary sinus inferiorly. The zygomatic bone forms a major portion of the floor and lateral wall of the orbit. Disruptions of the orbital floor cause enophthalmus and vertical dystopia. An anatomical reduction of a simple ZMC fracture usually results in restoration of normal orbital volume and bony floor support[54].

ATTACHMENTS OF THE ZYGOMA AND APPLIED ANATOMY

Tendinous attachment of the zygoma includes the medial and lateral canthal tendons and the suspensory ligament of Lockwood which maintains the vertical and horizontal globe positions repectively. An important landmark, the Whitnall's tubercle is located approximately 9 mm inferior to the frontozygomatic suture and 3mm posterior to the lateral orbital rim[54]. It anchors essential structures like lateral canthal tendon, check ligament of the lateral rectus muscle, suspensory ligament of Lockwood, and lateral extension of the levator aponeurosis. Fractures above the Whitnall's tubercle results in hypoglobus and produces a characteristic "hooding of the globe".

Surrounding the bones of the zygoma are the *muscles and fascia* that helps to prevent the displacement of fracture fragments. The temporal muscle passes deep to the zygomatic arch within the temporal fossa and attaches superiorly to the squamous portion of the temporal bone. The temporal fascia attaches along the superior edge of the zygomatic arch. The masseter muscle attaches along the inferior border of the zygomatic arch providing firm inferior pull on fracture fragments against the unyielding temporal fascia (Figure 1).

FIG 1: MASTICATORY MUSCLES ATTACHED TO THE ZYGOMATIC COMPLEX



Thus a stabilizing effect is achieved that tends to maintain the contour of the arch despite the lack of rigid fixation or wires[57]. The muscles of facial expression namely Orbicularis oculi, Levator labii superioris, Zygomaticus major and minor muscles have their origin in zygoma but does not play a major role in zygomatic fracture displacement.

NEUROANATOMY OF THE ZYGOMA

The facial nerve is an important anatomical structure that passes through the lateral facial soft tissue. Most importantly, the zygomatic branch of the facial nerve crosses over the zygomatic arch at the midpoint and lies between in a plane deep to the superficial temporal fascia and lateral to the zygomatic periosteum. This anatomic relationship is significant in case of exposure of zygomatic arch for fixation[58].

The maxillary division of the trigeminal nerve provides sensory innervations to the zygoma. The infraorbital nerve, the terminal branch of maxillary nerve which exits the infra orbital foramen 10mm inferior to the rim is most commonly affected in ZMC fractures producing sensory alterations in the ipsilateral nose, upper lip, lower eyelid and maxillary teeth. The incidence of long-term sensory disturbances within the distribution of the infraorbital nerve is reported to be approximately 45%[59]. The zygomaticotemporal and zygomaticofacial nerve supply sensation to the skin over the anterior temple area and malar eminence respectively and is the focus of pain postoperatively after zygomatic trauma and reconstruction[60].

BIOMECHANICS OF ZMC FRACTURE

Among the midface fractures, zygoma fractures are the most frequent due to its projection from the facial skeleton making it vulnerable to the ravages of force. Whenever a blunt force is applied to the zygoma or the malar eminence, it tends to fracture along the four sutural lines. Hence there is an inbending at the area of contact and an out bending at an area of weakness away from the impact site (ZM, FZ sutures and Zygomatic arch).

FACIAL BUTTRESSES IN FRACTURES OF THE MIDFACE

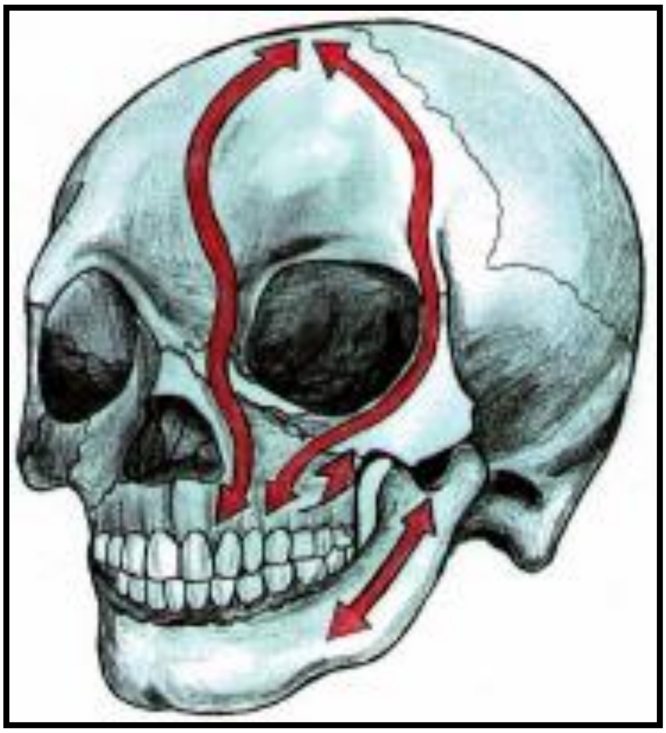
Buttresses are structures built against or projecting from a wall and serves to reinforce and support the wall. The facial skeleton is composed of low stress bearing areas composed of thin fragile bones surrounding the pneumatic cavities which can crumble when subjected to forces. These fragile bones are surrounded by high stress bearing buttresses which absorbs the force and lends stability and strength. Sicher and Tandler have divided the buttress system as vertical and horizontal. Since majority of the forces are masticatory in nature, the vertical buttress system is well developed in humans. (Figure 2A, 2B**)**

FRACTURE PATTERN IN ZYGOMA

In general the weaker bones with which the zygoma articulates absorb the strong impact forces directed to the zygoma and undergo fragmentation. The weakest bone is the orbital floor, which can collapse into the maxillary sinus. In contrast the frontozygomatic region is a strongest buttress and it typically separates cleanly.

FIG 2A: FORCE VECTORS ALONG THE HORIZONTAL BUTTTRESS OF THE FACE

FIG 2B: FORCE VECTORS ALONG THE VERTICAL BUTTRESSES OF THE FACE



In isolated zygoma fractures, the fracture line usually starts from the FZ, passes to the lateral wall of orbit and to the anterior orbital floor to the infra orbital rim. This anterior portion of the fracture passes through the infraorbital foramen causing injury (commonly neuropraxia) to the infraorbital nerve. Traversing over the anterior maxillary sinus, the fracture passes to the ZM buttress continuing to the dorsolateral maxillary wall and then back into the inferior orbital fissure. The zygomatic arch typically fractures near its mid point in a single or in two places resulting in a central fragment susceptible to displacement and rotation. Fracture of the body of zygoma is less common.

ROLE OF MUSCLE IN FRACTURE DISPLACEMENT

The ZMC fracture instabilities are directly due to the masseter muscles action, and temporal muscles besides fiber association of the facial expression muscles. In the study by Rinehart et al, there was no rotation of the zygomatic bone when simulating action of masseter muscle forces were applied in ZMC fractures fixed in two points: frontozygomatic suture and infraorbital ridge[24].

Furthermore, the periosteum of the zygoma forms a star shaped fascia with the superficial temporal fascia, the masseteric fascia and the orbital septum which tends to counteract displacement. This explains the fact that the fractures of the zygomatic arch are stable after reduction and does not require fixation[61].

Most commonly, the zygoma is displaced medially by the laterally acting forces. In case of a partial intrusion there is only an angulation at the FZ region and depression of the zygomatic buttress into the maxillary sinus.

In total medial displacement of the zygoma, there is complete detachment at the FZ region. In addition, the zygoma is completely depressed into the orbital region leading to reduction in size of the orbit leading to exophthalmus. When there is involvement of the floor of the orbit, the orbital tissue prolapses into the maxillary sinus leading to enophthalmus. This telescoping intrusion of the zygoma into the maxilla and orbit can lead to disruption of the orbital fat and musculature leading to disturbances in mobility and double vision.

Inferior displacement of the zygoma occurs when the force impinges on the body of zygoma obliquely from above. A more severe inferior displacement is prevented by the broadly attached temporal fascia

Frontal impact as well as lateral impact force can cause fracture of the zygomatic arch. Sometimes a lateral impact force can cause total medial displacement of the zygoma. Both these conditions cause impingement of the fractured bone on the coronoid process causing restriction of mouth opening.

FRACTURE BIOMECHANICS IN REDUCTION AND FIXATION

Fracture biomechanics of the zygomatic bone has led to many studies warranting the need for fixation after surgical reduction.

According to many authors safe stability is reached through a three-point fracture fixation, due to muscle action over the ZMC[62]. Zingg et al (1992) report that a fixation in two points is sufficient for ZMC fractures stabilization[15]. Nevertheless, Fain et al. (1981) obtained success in the conduction of fixation in only one point of the frontozygomatic suture, because this is the area where the tension forces act directly[62].

MATERIALS AND METHODS

The study was conducted after getting approval from the Institutional Ethical Committee. This study assessed twenty patients for Bite force measurement who underwent Open Reduction and Internal Fixation for Zygomatico Maxillary Complex Fractures at the Department of Oral and Maxillofacial Surgery, Tamil Nadu Government Dental College and Hospital, Chennai. Electromyography studies to assess the muscle activity of masseter and temporalis was performed at the Department of Physiology, Madras Medical College, Chennai

INSTRUMENTS AND EQUIPMENTS:

1. Surgical Armamentarium (Figure 3)
2. Bite Force assessment device (Figure 4)
3. Bite blocks 5X12, 10X12, 15X12, 20X12 mm (Figure 5)
4. Electromyogram equipment and surface electrode (Figure 6,7)
5. Digital vernier caliper (Figure 8, 9)

BITE FORCE DEVICE

Instrument Design

Bite force measurements were recorded using a strain gauge based force transducer which can measure bite force upto 100 kg (100kgf capacity). The dimension of the force sensor is 10 mm in height, 12 mm in width and 40 mm in length. The force sensor is enclosed in a stainless steel casing of dimension 130 X 39 X 24 mm consisting of four strain gauges. This is in turn is connected to a Wheatstone bridge circuit which converts the change in resistance into voltage.

The resulting output voltage is proportional to the applied force recorded in kilogram which can be viewed on the digital display.

Principle:

1. Force transducers based on strain gauges have a so-called spring element or loaded member where the forces to be measured are applied
2. The spring element deforms and strain is produced on the surface. The task of the spring element is therefore to convert the forces to be measured into strain for reproducibility and linearity.
3. The actual sensor element is the Strain Gauge (SG), which consists of an insulation layer, the so-called holder, with a measuring grid attached to it. Such strain gauges are bonded to the spring element at suitable points. In general, four strain gauges are used, installed so that two are stretched and two are compressed when force is applied. The function of the strain gauge is to convert the strain into changes in resistance.
4. These four SG are connected in a Wheatstone bridge circuit. Wheatstone bridge is supplied with an excitation voltage. An output voltage occurs when the four resistances are different. The output signal depends on the change in resistance of the SG and therefore directly on the applied force.

ELECTROMYOGRAM EQUIPMENT

Electromyography was performed using 4 channels of the Aleron 401 EMG machine. The machine is set at a sweep speed of 2 to 500 ms/div in 13 steps sampled with a 14 bit analog digital convertor. The output in millivolt (mV) is measured as the muscle activity.

Surface differential active electrodes (in red and black colours) made of solid stainless steel of 10mm in diameter are placed on the designated muscle and secured with tape. Ground electrode (green colour) of 30 mm diameter is placed on the forehead and secured with tape.

Electrode placement in Masseter:

The patient is asked to clench his teeth and the masseter muscle palpated. Two active electrodes approximately 2 cm apart are placed over the muscle mass with the lower electrode placed just above the angle of mandible. **(**Figure 17)

Electrode placement in Anterior Temporalis:

The patient is asked to clench his teeth and the temporalis muscle palpated. Two active electrodes approximately 2 cm apart are placed over the muscle mass so that they run parallel to the muscle fibers. The lowest electrode is placed just above the zygomatic arch or opposite the lateral canthus of the eye. **(**Figure 18)

DIGITAL VERNIER CALIPER

The Digital Caliper is a precision instrument that can be used to measure internal and external distances extremely accurately. The instrument made of hardened stainless steel has a range of 0 - 150 mm and an accuracy of +/- 0.03mm/0.001”. The LCD display gives the reading in millimeters or in inches. The display is turned on with the on/off button. The external jaws of the caliper should then be brought together until they touch and then the zero button should be pressed. The mandibular range of movements can be measured by placing the internal jaws of the caliper on the incisal ends of the teeth. The distance between the incisal edges of the upper and lower teeth can thus be measured.

Figure 3: ARMAMENTARIUM

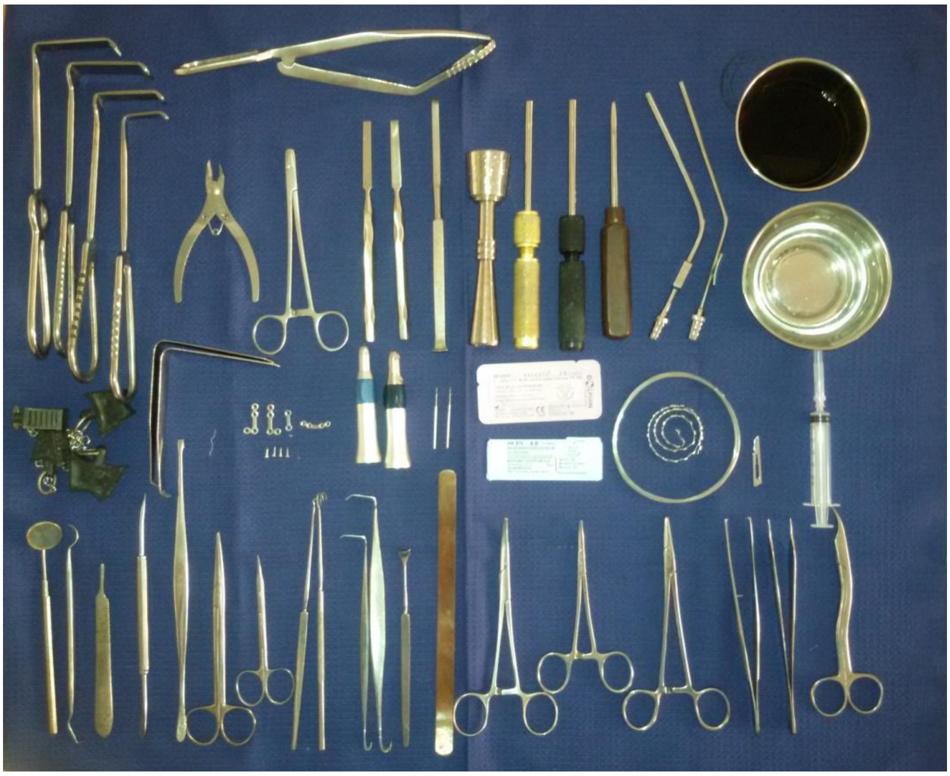


Figure 4: BITE FORCE APPARATUS

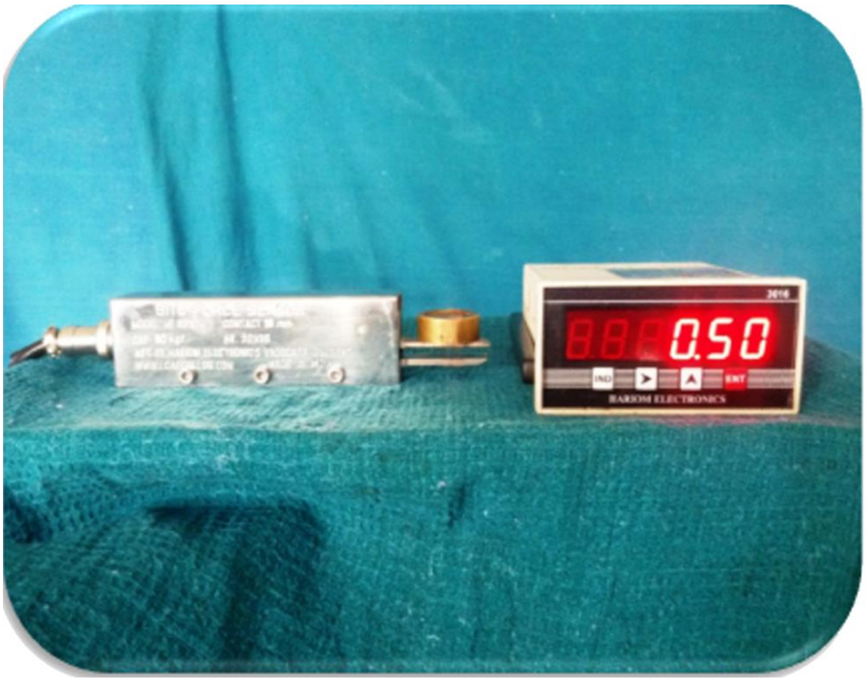


Figure 5: ACRYLIC BITE BLOCKS – 5 mm, 10 mm, 15 mm, 20 mm

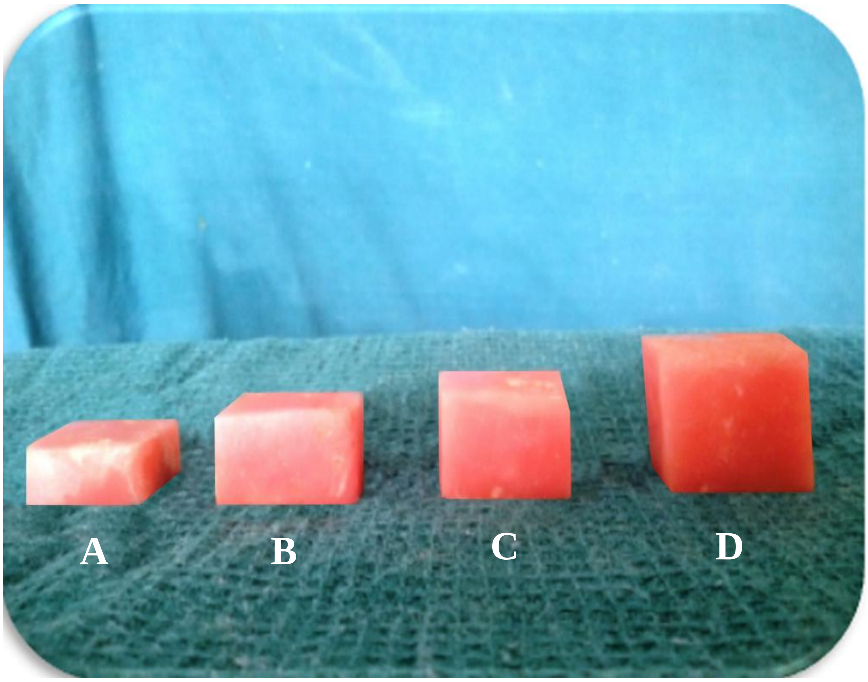
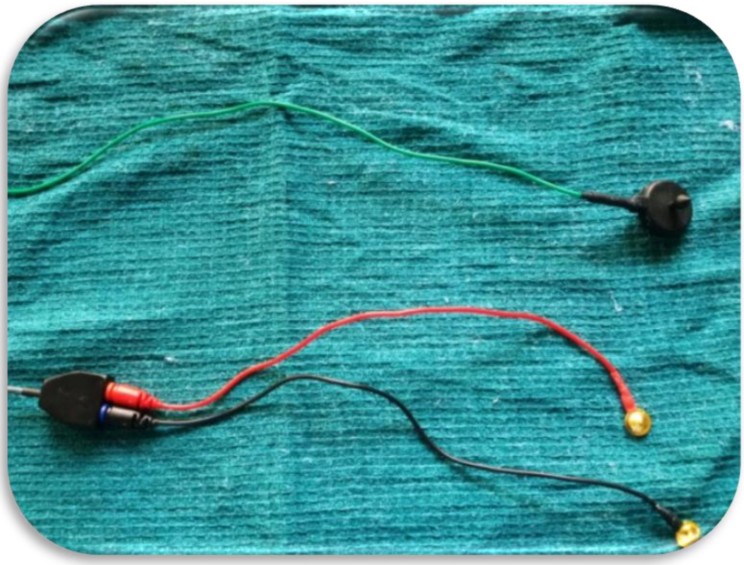


Figure 6: EMG MACHINE

Figure 7: EMG SURFACE ELECTRODES



Green – Ground electrode

Red and black – Active electrodes

Figure 8: DIGITAL VERNIER CALIPER

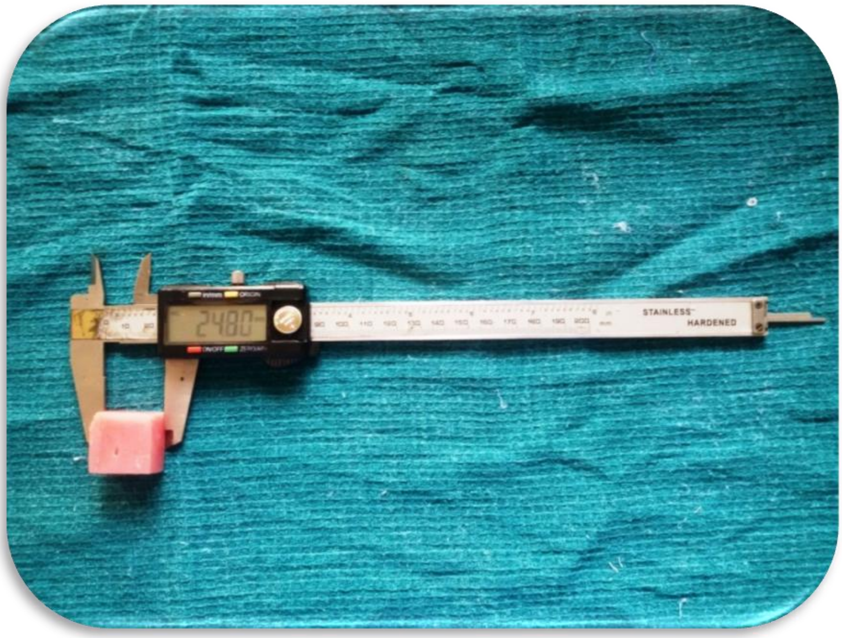
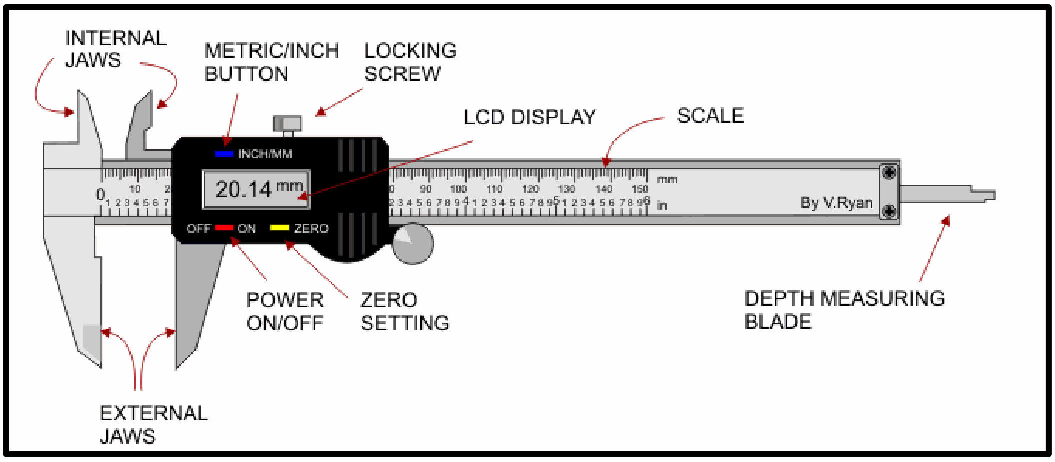


Figure 9: PARTS OF A DIGITAL VERNIER CALIPER



CRITERIA FOR PATIENT SELECTION

INCLUSION CRITERIA

1. Unilateral isolated Zygomaticomaxillary Complex fracture
2. All healthy Individuals between 15- 55 yrs of age, of both sexes
3. Dentulous patients – Molars/second premolar and incisors in good condition
4. Patient available for follow-up for a period of 6 months

EXCLUSION CRITERIA

1. Bilateral zygomaticomaxillary complex fractures
2. Severely Comminuted/ infected fractures
3. Zygomaticomaxillary complex fractures associated with other facial bone fractures
4. Medically compromised patients and who have muscular and neurogenic diseases
5. Patients with head injuries
6. Extensive facial lacerations, abrasions
7. Edentulous patients
8. Fractured teeth, pulpitis and periodontally compromised teeth, malocclusion (anterior or lateral cross bite)
9. Patients who underwent radiotherapy

STUDY DESIGN: Prospective

SAMPLE SIZE:

1. Group I: 20 patients with unilateral fracture of Zygomatico maxillary complex
2. Group II: 20 healthy adults included in the control group

Ethical approval was obtained for the study from the Institutional Ethical Committee and informed consent obtained from each patient in the regional language (Tamil) explaining the nature of the surgical procedure and the study.

DIAGNOSIS AND TREATMENT PLANNING

Twenty patients (sixteen male and four female) were diagnosed with Zygomatico Maxillary Complex Fracture using the following methods.

1. Clinical Examination showing a palpable step in the orbital rim, zygomatic arch or zygomatic buttress
2. Radiological Examination showing evidence of displacement – Digital Paranasal Sinus View, Digital Submentovertex View, CT scan of facial bone in axial and coronal section

Fractures requiring reduction and fixation were identified using the classification system of Larsen and Thomsen (1968)

1. **Group A fractures**: Showing minimum or no displacement requiring no intervention
2. **Group B fractures**: Unstable fracture - great displacement and disruption of FZ suture and comminuted fracture requiring reduction and fixation
3. **Group C fractures**: Fractures of all other kinds which required reduction but no fixation

SURGICAL PROCEDURE

All patients were treated one week from the day of injury. After ruling out head and cervical spine injury, selected cases were planned for open reduction and internal fixation under local anesthesia.

Zygomatic arch fracture was reduced extraorally via Dingman's approach or intraorally via Keen's approach. Fixation of the reduced fracture was performed in the following manner:

1. One point fixation at Zygomatico Frontal region (or) Zygomaticomaxillary buttress
2. Two point fixation at both Zygomatico Frontal region and Zygomaticomaxillary buttress
3. Three point fixation at Zygomatico Frontal region, Zygomaticomaxillary buttress and Infraorbital rim

FOLLOW-UP AND OBSERVATION

All the patients were evaluated:

1. One day prior to the surgery
2. First post operative day
3. One week post operatively
4. One month post operatively
5. Three month postoperatively
6. Six month postoperatively

PARAMETERS FOR EVALUATION

1. BITE FORCE MEASUREMENT

The bite force transducer is cleaned with alcohol and disposable latex finger cots are positioned on the biting plate for biosafety measurements. The patients are given detailed instructions and bite tests were performed before actual recordings to ensure the reliability of the procedure.

A. Maximum Voluntary Clench: The patient was asked to bite directly on the bite sensor 3 times with maximum force (maximum voluntary clench), with 2-minute intervals between recordings. The highest value is taken as the reading for maximum voluntary clench. Evaluations were performed on the first molar (right and left) and central incisor regions. **(**Figure 10, 11, 12**)**

B. Bite Force at increasing vertical dimension of the bite plane: Measurement of the bite force was performed by gradually increasing the height of the bite plane by 5 mm. The patient is asked to clench on a four different heights of the bite plane (made of acrylic) at: 15 mm, 20 mm, 25 mm and 30 mm and the bite force was recorded on the first molar (right and left) and central incisor regions. **(**Figure 13, 14, 15, 16**)**

C. Endurance (Fatigue Test) at bite force in 10 mm vertical dimension:

The patient is asked to clench on the bite sensor of 10 mm vertical dimension and the time taken to reach and sustain the force at maximum voluntary clench is recorded. This is measured as the endurance time of the masseter muscle calculated in seconds.

Figure 10: BITE FORCE MEASUREMENT IN RIGHT MOLAR

Figure 11: BITE FORCE MEASUREMENT IN LEFT MOLAR

Figure 12: BITE FORCE MEASUREMENT IN INCISOR

Figure 13: BITE FORCE AT 15 MM VERTICAL DIMENSION

Figure 14: BITE FORCE AT 20 MM VERTICAL DIMENSION

Figure 15: BITE FORCE AT 25 MM VERTICAL DIMENSION

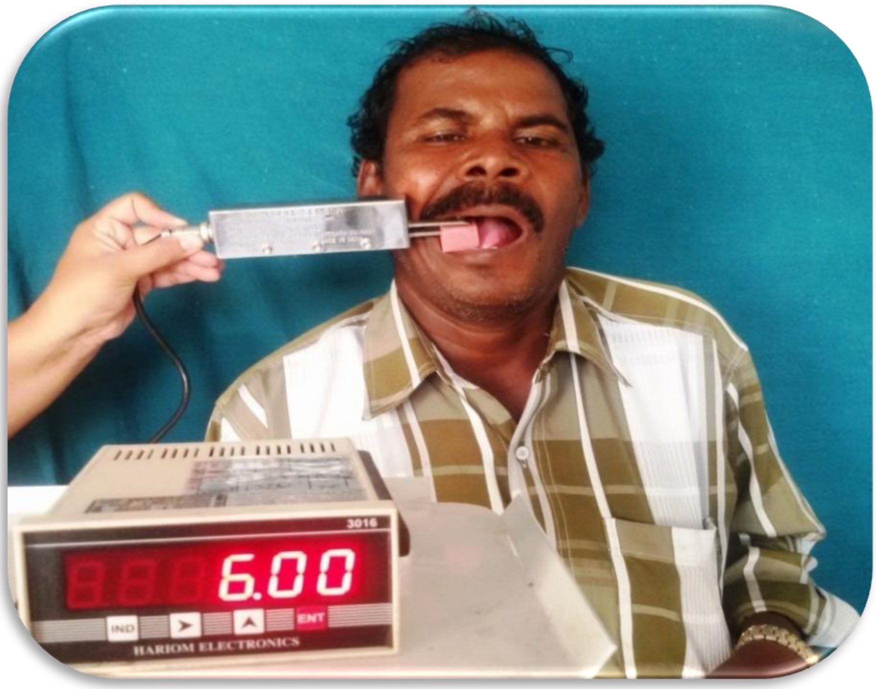


Figure 16: BITE FORCE AT 30 MM VERTICAL DIMENSION

2. SURFACE ELECTROMYOGRAPHIC ACTIVITY OF MASSETER AND TEMPORALIS MUSCLES RECORDED BILATERALLY

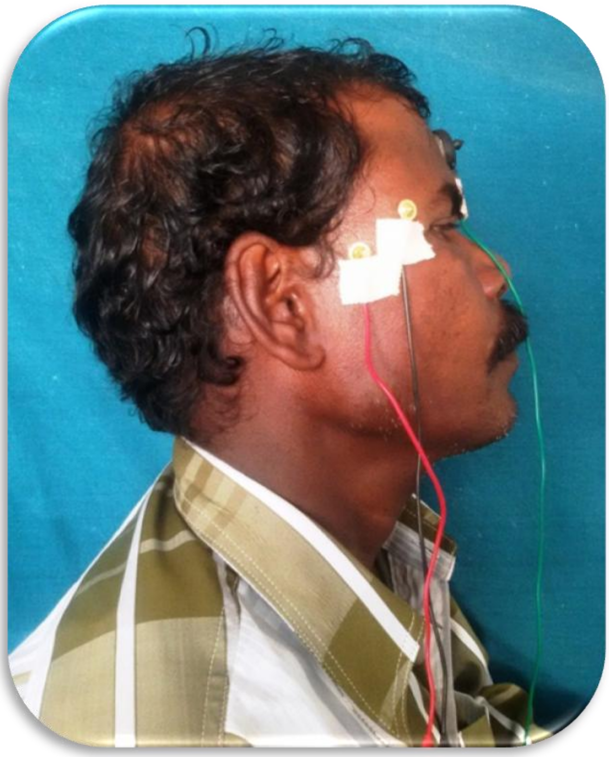
The skin region where the surface electrodes are to be placed was cleaned with alcohol and shaved if necessary for adaptation of the electrodes. Intramuscular EMG requires the use of surface electrode to be positioned over the ventral region of both the masseter muscles and in the anterior portion of both the temporal muscles.

The muscular activity was measured by using EMG recordings of the masseter and temporalis at rest and during activities under the following clinical conditions: The maximum peak value is recorded from the EMG potentials.

1. Rest for 10 seconds
2. Opening the mouth passively
3. Right lateral movements
4. Left lateral movements
5. Protrusion
6. Closing the mouth passively
7. Clenching (maximum voluntary clench)

Figure 17: EMG ELECTRODE PLACEMNT IN MASSETER MUSCLE

Figure 18: EMG ELECTRODE PLACEMENT IN TEMPORALIS MUSCLE



3. MANDIBULAR MOVEMENTS (MOUTH OPENING, LATERAL EXCURSIVE MOVEMENT, PROTRUSION)

Mandible range of motion was based on the methodology proposed by Cattoni et al. and Ferreira, and Felício & Trawitzki. Using the digital caliper the following mandibular movements are measured:

A) Mid line - with the teeth in occlusion – Check whether or not the lines between the central upper and lower incisive teeth match. When the lines do not coincide, the amount of deviation is measured on the horizontal plane, using a vernier caliper.

B) Maximum mouth opening - Measure the distance between the incisive faces of the upper and lower teeth. **(**Figure 19)

C) Mandible protrusion - Horizontal trespass between the occlusal face of the upper central incisor and the distal face of the lower central incisor. **(**Figure 20**)**

D) Mandible lateralization to the right - The horizontal distance of the line between the lower central incisive teeth to the line between the upper central incisive teeth after right-side mandible shifting. **(**Figure 21**)**

E) Mandible lateralization to the left - The same procedure carried out to measure mandible lateralization to the right is used to obtain the value for mandible lateralization to the left. **(**Figure 22**)**

Figure 19: MOUTH OPENING MOVEMENT

Figure 20: PROTRUSIVE MOVEMENT

Figure 21: RIGHT LATERAL MOVEMENT

Figure 22: LEFT LATERAL MOVEMENT

SURGICAL PROCEDURE

1. **PREPARATION**

The patient's face was prepared and draped taking sterile aseptic precautions.

2. **INJECTION OF LOCAL ANESTHETIC AND VASOCONSTRICTOR**

2% Lignocaine with 1:200000 adrenaline is injected into the subcutaneous tissue over the lateral orbital rim, zygomatico-temporal region and infra orbital rim region to aid in hemostasis as well as anesthetize these areas. Intra-oral injection is used to anesthetise the zygomatic buttress and infra orbital nerve block is performed.

3. **INCISION**

Incision is made with No. 15 Bard Parker blade. Incision is planned based on the fracture sites to be exposed.

a. Lateral eyebrow or Supra orbital eyebrow incision: This incision is performed to gain access to the lateral orbital rim mostly at the frontozygomatic suture area. A 2 cm incision is made parallel to the hair line of the eyebrow to avoid cutting hair shafts. The incision is made to the depth of the periosteum in one stroke and another incision through the periosteum completes the sharp dissection.

b. **Infraorbital skin crease incision:** This incision is performed to gain access to the infraorbital rim and orbital floor. This incision is placed transcutaneously over the infraorbital region in the natural skin crease, 4.5 mm inferior to the gray line.

The incision passes through the Orbicularis oris muscle to the periosteum of the infraorbital rim.

c. Maxillary vestibular approach: This incision is made 3-5 mm superior to the mucogingival junction in the maxillary buccal sulcus in the first molar region. The incision traverses the mucosa, submucosa, facial muscles and periosteum. This incision provides good exposure to the midface particularly to the zygomatic buttress and body of the zygoma.

4. **EXPOSURE AND REDUCTION OF THE FRACTURE**

The fracture site is exposed after sharp subperiosteal dissection. Elevation of the depressed zygoma is brought about by two methods.

a. Dingman's technique through the supraorbital incision: Once the exposure of the fracture at the frontozygomatic area is accomplished, Rowe's zygoma elevator is inserted posterior to the zygoma along its temporal surface. The instrument is used to lift the zygoma anteriorly, laterally and superiorly while one hand palpates the infraorbital rim and the body of zygoma.

b. Keen's technique via the maxillary vestibular approach: Once exposure of the zygomatic buttress is accomplished, Rowe's zygoma elevator is inserted behind the infratemporal surface of the zygoma, and using superior, lateral and anterior force, the zygoma is reduced.

An audible click may sometimes be heard once the reduction is accomplished. Next, under direct vision, the fracture site is inspected for adequate reduction. The index finger of the operator hand is used to palpate over the infraorbital rim and the zygomatic bone to fully appreciate the reduction of the zygoma

5. **FIXATION**

Internal fixation is carried out using stainless steel mini plates and screws.

a. Fixation along the lateral orbital rim is performed with one miniplate (diameter 2 mm) and two screws (diameter 2 mm, length 6 mm).
 (Figure 23, 24)
b. Fixation along the infra orbital rim is performed with one orbital miniplate which is 'C' shaped (diameter 1.5 mm) and four screws (diameter 1.5 mm, length 6 mm). (Figure 25, 26)
c. Fixation along the zygomatic buttress is performed with one miniplate which is 'L' shaped (diameter 2 mm) and four screws (diameter 2 mm, length 6 mm). (Figure 27, 28)

6. WOUND CLOSURE

The surgical site is irrigated with povidone iodine and saline. Simple interrupted suturing is performed with resorbable 3-0 vicryl material. Sub cuticular skin closure is done with non resorbable synthetic 3-0 polyamide material. Compression bandage is applied over the surgical site.

7. IMMEDIATE POST-OPERATIVE PHASE

Patient is kept under observation for an hour and vitals monitored. Patient is noted for post-surgical bleeding. The patient is started on intravenous antibiotic (Cefotaxime 1 g and Metrogyl 500 mg), intravenous glucocorticosteroid (Dexamethasone 8 mg) tapered after 2 days and intramuscular NSAID (Diclofenac 75 mg) administered for a period of five days. The patient is advised to avoid pressure over the cheek on the operated side and to sleep in supine position for a month. A soft diet is recommended for the same duration. Synthetic non resorbable sutures are removed on the seventh post-operative day. The patient was advised to come for follow-up on a regular basis.

Figure 23: REDUCTION IN FRONTOZYGOMATIC REGION

Figure 24: FIXATION IN FRONTOZYGOMATIC SUTURE REGION

Figure 25: REDUCTION AT INFRAORBITAL REGION

Figure 26: FIXATION AT INFRA ORBITAL REGION

Figure 27: REDUCTION AT ZYGOMATIC BUTTRESS REGION

Figure 28: FIXATION AT ZYGOMATIC BUTTRESS REGION

CASE REPORT 1

NAME : Mrs. Velankanni

AGE/SEX : 29 years/ Female

ADDRESS : Washermanpet, Chennai

CHIEF COMPLAINT : 1) Pain in the left side of the face

2) Limitation of mouth opening

HISTORY OF PRESENTING ILLNESS : Self fall from two-wheeler

PAST MEDICAL HISTORY : Non contributory

PAST SURGICAL HISTORY : Non contributory

PAST DENTAL HISTORY : Non contributory

GENERAL EXAMINATION : 1) Patient is moderately built and nourished

2) Patient is conscious, alert, oriented

3) No signs of pallor, icterus, cyanosis, clubbing, edema and regional lymphadenopathy.

LOCAL EXAMINATION

EXTRA-ORAL EXAMINATION : 1) Left subconjunctival hemorrhage and circumorbital ecchymosis

2) Step deformity in left fronto-zygomatic suture region

INTRA-ORAL EXAMINATION	**:** 1) Mouth opening 23.77 mm 2) Occlusion stable

<u>INVESTIGATION</u>

DIGITAL PNS	**:** Left fronto-zygomatic separation
CT SCAN	**:** 1) Left fronto-zygomatic separation 2) Left spheno-zygomatic separation 3) Left zygomatic arch fracture

<u>DIAGNOSIS</u>	**:** Left Zygomatico maxillary complex fracture
<u>TREATMENT PLAN</u>	**:** Open reduction and internal fixation under local anesthesia **ONE POINT FIXATION AT** 1) Left fronto-zygomatic region

Figure 29: PRE-OPERATIVE FRONTAL VIEW

Figure 30: POST-OPERATIVEFRONTAL VIEW

Figure 31: PRE-OPERATIVE PNS VIEW

Figure 32: POST-OPERATIVE PNS VIEW

CASE REPORT 2

NAME	: Mr. Sahayanathan
AGE/SEX	: 35 years/ Male
ADDRESS	: Michaelpuram, Chennai
<u>CHIEF COMPLAINT</u>	: Pain in the left side of the face
HISTORY OF PRESENTING ILLNESS	: Assault
PAST MEDICAL HISTORY	: Non contributory
PAST SURGICAL HISTORY	: Non contributory
PAST DENTAL HISTORY	: Non contributory
<u>GENERAL EXAMINATION</u>	: 1) Patient is moderately built and nourished 2) Patient is conscious, alert, oriented 3) No signs of pallor, icterus, cyanosis, clubbing, edema and regional lymphadenopathy.

<u>LOCAL EXAMINATION</u>

EXTRA-ORAL EXAMINATION	: 1) Left circumorbital ecchymosis

2) Step deformity in left fronto-zygomatic suture region and left infra-orbital region

4) Paraesthesia along the distribution of left infra-orbital nerve

INTRA-ORAL EXAMINATION : 1) Mouth opening 34.17 mm

INVESTIGATION

DIGITAL PNS : Left fronto-zygomatic separation

CT SCAN : 1) Left fronto-zygomatic separation

2) Left infra-orbital rim fracture

DIAGNOSIS : Left Zygomatico maxillary complex fracture

TREATMENT PLAN : Open reduction and internal fixation under local anesthesia

TWO POINT FIXATION AT

1) Left fronto-zygomatic region

2) Left infra-orbital rim

Figure 33: PRE-OPERATIVE FRONTAL VIEW

Figure 34: POST-OPERATIVE FRONTAL VIEW

Figure 35: PRE-OPERATIVE PNS VIEW

Figure 36: POST-OPERATIVE PNS VIEW

CASE REPORT 3

NAME	**:** Mr. Veeramuthu
AGE/SEX	**:** 23 years/ Male
ADDRESS	**:** Thiruvannamalai,
<u>CHIEF COMPLAINT</u>	**:** Pain on the left side of the face
HISTORY OF PRESENTING ILLNESS	**:** Self fall from two-wheeler
PAST MEDICAL HISTORY	**:** Non contributory
PAST SURGICAL HISTORY	**:** Non contributory
PAST DENTAL HISTORY	**:** Non contributory
<u>GENERAL EXAMINATION</u>	**:** 1) Patient is moderately built and nourished 2) Patient is conscious, alert, oriented 3) No signs of pallor, icterus, cyanosis, clubbing, edema, regional lymphadenopathy.

<u>LOCAL EXAMINATION</u>

EXTRA-ORAL EXAMINATION	**:** 1) Left circumorbital and subconjunctival hemorrhage 2) Step deformity in left fronto-zygomatic suture region and left infra-orbital region

3) Paresthesia along the distribution of left infra-orbital nerve

INTRA-ORAL EXAMINATION : 1) Mouth opening 30.12 mm

2) Step deformity in left zygomatic buttress

<u>INVESTIGATION</u>

DIGITAL PNS : 1) Left fronto-zygomatic separation

2) Left zygomatic buttress

3) Left infra-orbital rim fracture

<u>DIAGNOSIS</u> : Left Zygomatico maxillary complex fracture

<u>TREATMENT PLAN</u> : Open reduction and internal fixation under local anesthesia

THREE POINT FIXATION AT

1) Left fronto-zygomatic region

2) Left infra-orbital rim

3) Left zygomatic buttress region

Figure 37: PRE-OPERATIVE FRONTAL VIEW

Figure 38: POST-OPERATIVE FRONTAL VIEW

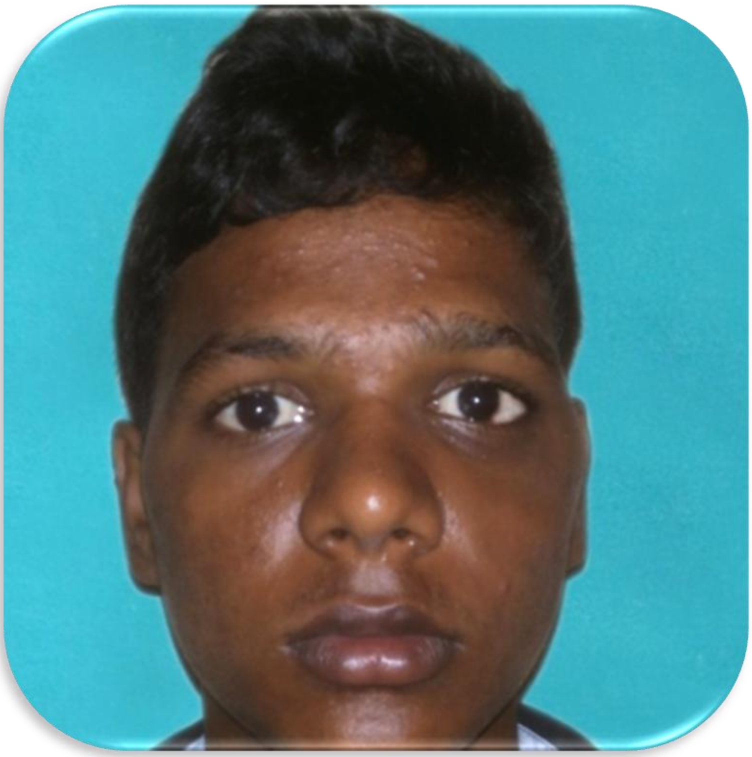


Figure 39: PRE-OPERATIVE PNS VIEW

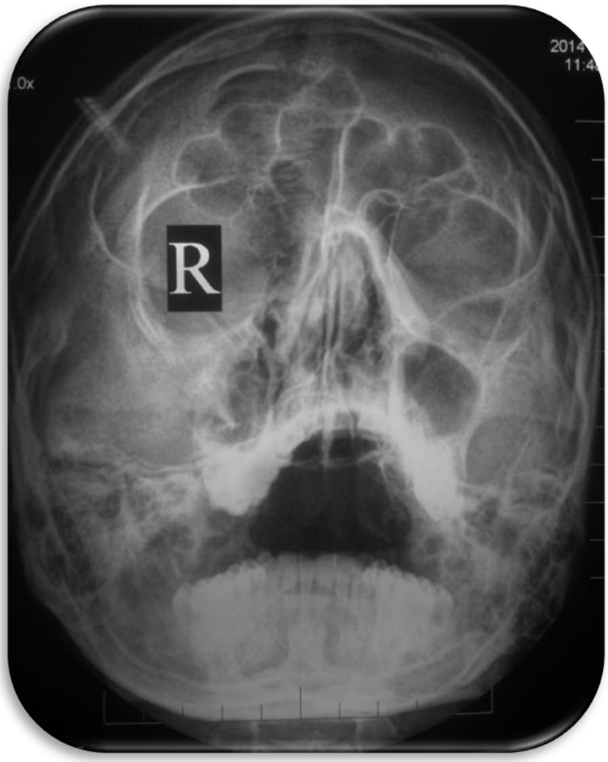
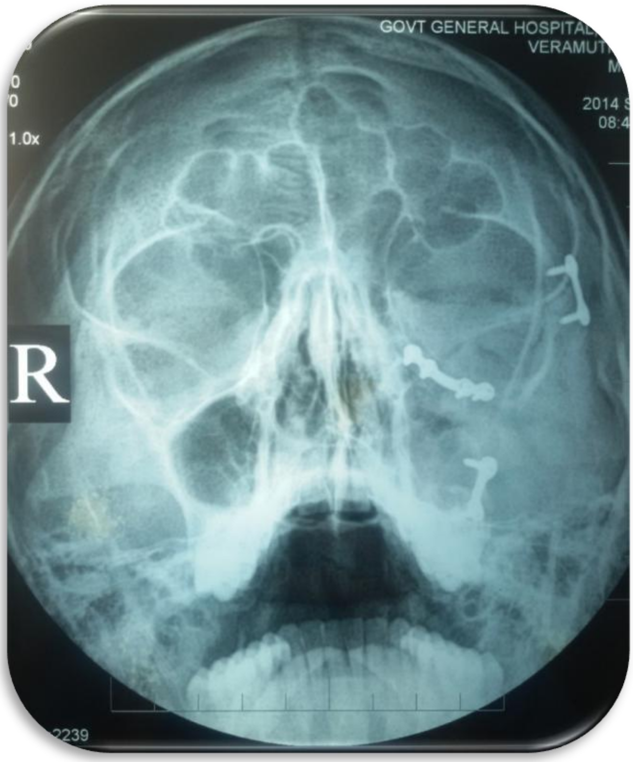


Figure 40: POST-OPERATIVE PNS VIEW



CASE REPORT 4

NAME	: Mr. Thangavel
AGE/SEX	: 40 years/ Male
ADDRESS	: Saidapet, Chennai
<u>CHIEF COMPLAINT</u>	: Pain on the right side of the face
HISTORY OF PRESENTING ILLNESS	: Self fall from two-wheeler
PAST MEDICAL HISTORY	: Non contributory
PAST SURGICAL HISTORY	: Non contributory
PAST DENTAL HISTORY	: Non contributory
<u>GENERAL EXAMINATION</u>	: 1) Patient is well built and nourished 2) Patient is conscious, alert, oriented 3) No signs of pallor, icterus, cyanosis, clubbing, edema and regional lymphadenopathy.

<u>LOCAL EXAMINATION</u>

EXTRA-ORAL EXAMINATION	: 1) Right circumorbital ecchymosis

2) Step deformity in right fronto-zygomatic suture region

INTRA-ORAL EXAMINATION **:** 1) Mouth opening 26.02 mm

2) Step deformity in right zygomatic buttress

INVESTIGATION

DIGITAL PNS **:** 1) Right fronto-zygomatic separation

2) Right zygomatic buttress

DIAGNOSIS **:** Right Zygomatico maxillary complex fracture

TREATMENT PLAN **:** Open reduction and internal fixation under local anesthesia

TWO POINT FIXATION AT

1) Right fronto-zygomatic region

2) Right zygomatic buttress region

Figure 41: PRE-OPERATIVE FRONTAL VIEW

Figure 42: POST-OPERATIVE FRONTAL VIEW

Figure 43: PRE-OPERATIVE PNS VIEW

Figure 44: POST-OPERATIVE PNS VIEW

OBSERVATION AND RESULTS

The study included 20 patients with Zygomatico maxillary complex fracture (Group I) and 20 healthy adults who were assigned to the control group (Group II). The study was conducted from March 2014 – November 2014. The demographic data of the patients included in the study has been tabulated in Table 1.

Out of the 20 fractures, 9 of them were diagnosed with right sided ZMC fractures and 11 with left sided ZMC fractures. The etiology was found to be road traffic accidents (70%), assaults (10%) and physical aggression (20%) and this has been graphically presented in Chart 1. All the fractures were classified under Group B (Larsen and Thomsen 1968) where there was displacement of fracture site requiring open reduction and internal fixation based on Digital Paranasal Sinus view radiograph.

20 patients in Group I were treated with Open Reduction and Internal Fixation under Local Anaesthesia. All patients were evaluated with a pre-operative Occipitomental view (Paranasal sinus) radiograph. Most of the patients were treated within 7 days from the day of injury. The mean delay from diagnosis to surgery was 2 days.

All the patients were evaluated pre-operatively for bite force, electromyography and mandibular movements. Most of the patients found measurement of these parameters acceptable. All the patients had complaints of pain when biting on the bite force transducer and on the bite blocks. Hence the patients were asked to rest between the procedures to minimize fatigue. The average time taken to measure each of the parameter is given in the Table 2

Table 1: Demographic data of the patients included in the study

	AGE	GENDER	
		MALE	FEMALE
GROUP I	20 – 40 years Avg: 30 years	16 (80%)	4 (20%)
GROUP II (Control)	18-41 years Avg: 28.6 years	15 (75%)	5 (25%)

Table 2: Time taken for measurement of the parameters

PARAMETERS	TIME TAKEN (MEAN IN MINUTES)
BITE FORCE	30
EMG	30
MANDIBULAR MOVEMENTS	15

Fixation was performed based on clinical and intra-operative assessment of displaced fracture segments***:***

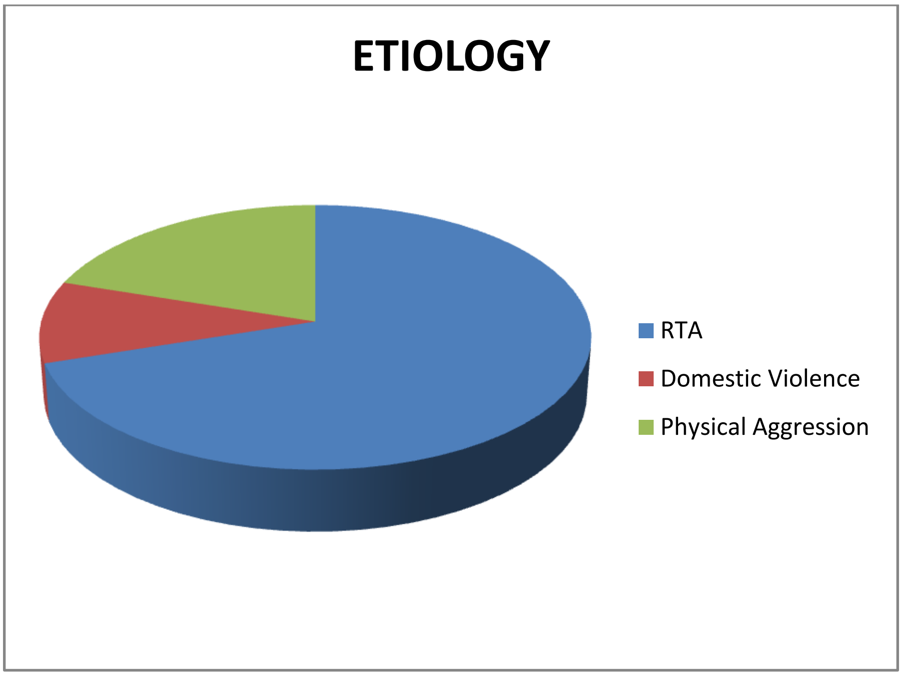
I. One point fixation at Zygomatico Frontal region

II. Two point fixation at both Zygomatico Frontal region and Zygomaticomaxillary buttress/ Infraorbital rim

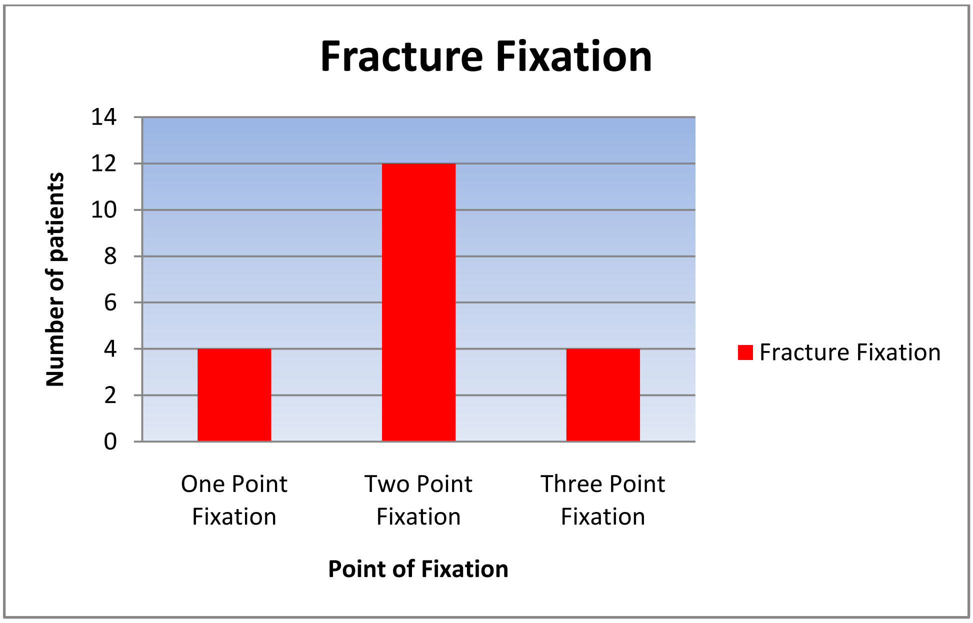
III. Three point fixation at Zygomatico Frontal region, Zygomatico maxillary buttress and Infra orbital rim

In the present study, 4 patients needed fixation at three points, 12 patients required fixation at two points and 4 patients required fixation at one point (Graph 1). The number of fixation points did not significantly affect the outcome of the parameters addressed in the present study. In other words, there was no statistically significant difference in the bite force levels and EMG activities when comparing patients with one, two or three point fixation.

Chart 1: Distribution of the etiology in the patients included in the study



Graph 1: Distribution of number of points of fracture fixation



FOLLOW-UP

The 20 patients were followed up post-operatively on the first day, one week, one month, three months and six month interval. Occipitomental view radiograph was taken on the first post operative day to confirm acceptable reduction of the fractures. The reduction was found to be acceptable in all the 20 patients. All the patients returned for follow-up with a mean delay of two weeks.

The follow-up period was uneventful except for 2 patients who reported with intra oral wound dehiscence at the end of one week which was successfully treated with debridement, chlorhexidine mouth rinse and iodoform dressing. All the patients had post-operative swelling and tolerable pain in the operated site upto 7-10 days following the surgery. The various signs and symptoms including pain, trismus, subconjunctival and periorbital ecchymosis, malar depression, neurosensory disturbance of the ipsilateral infraorbital nerve had resolved to near normal levels in all the cases within the 6 month follow-up.

During the follow-up, the patients were evaluated for the following parameters:

1) Bite force

2) Electromyographic study and

3) Mandibular movements.

Statistical analyses were performed with SPSS (Statistical Package for Social Sciences) software 18. Repeated measures ANOVA (Analysis of Variance) test was performed. A 5% level of significance ($P \leq 0.05$) was adopted.

BITE FORCE MEASUREMENTS

The patient was asked to bit on the bite force transducer and the maximum force in kilograms was recorded. The control group used in this study presented, as an average of single measurement, the following biteforce values in the following regions: first molars on the right side, 43.54 kgf; first molars on the left side, 44.84 kgf; and incisors, 42.22 kgf. The measurements have been tabulated in Table 3.

The bite force assessment showed statistically significant differences compared with control group in all 3 regions in which bite force was recorded ($P \leq .05$).

Bite Force Measurement at Maximum Voluntary Clench (10 mm Vertical Dimension)

The maximum voluntary clench at 10 mm vertical dimension was statistically significant when compared with the control group till the first month post operatively in the right and left molar region.

In the incisor region, the maximum voluntary clench at 10 mm vertical dimension was statistically significant when compared with the control group till the sixth month post operatively. There was no statistically significant difference in the bite force values between the right molar, left molar and incisors during the post operative period.

When comparing the pre-operative MVC to the 6 month post-op, there was 59.5% increase in the right molar region, 60.1% increase in the left molar region and 68.5% increase in the incisor region.

When comparing the bite force of Group I with the control group, the bite force in the right first molar was 45.68% than in the control group increasing to 78.8% in third month post operative period. For the first left molar, these values were 38.89% and 77.29%, respectively, and the values for the incisors were 39.45% and 74.18%, respectively.

When comparing the values of the bite force in the operated side and the non-operated side of the Group I patients, it was observed that there was no statistically significance for $p \leq 0.05$.

Table 3: Bite Force at Maximum Voluntary Clench in kilogram (10 mm Vertical Dimension)

Serial No.	Group I (n=20)	Right Molar (Mean±SD)	Left molar (Mean±SD)	Incisor (Mean±SD)
1.	**Pre-Op day**	15.79 ± 8.15 *	15.57 ±7.65 *	11.22 ± 5.15 *
2.	**I Post-op day**	8.40 ± 5.14 *	8.66 ± 2.96 *	9.19 ± 4.35 *
3.	**I week Post-op**	19.89 ± 6.22 *	17.44 ± 6.55 *	16.66 ± 4.60 *
4.	**I month Post-op**	29.45 ± 6.66 *	28.78 ± 9.09*	26.15 ± 5.25 *
5.	**3 month Post op**	34.31 ± 5.23	34.66 ± 6.35	31.32 ± 4.08*
6.	**6 month Post op**	39.00 ± 4.20	39.05 ± 6.06	35.62 ± 4.16*
7.	**Group II – Control**	43.54 ± 7.52	44.84 ± 6.44	42.22 ± 3.16

*** - Significance at p≤*0.05* between Group I and Group I**

BITE FORCE AT 15 MM, 20MM, 25MM, 30 MM VERTICAL DIMENSION

The patients were asked to bite on acrylic bite block of heights 15 mm, 20 mm, 25 mm, 30 mm which was attached to the bite force transducer.

At **15 mm vertical dimension**, at the end of 3 month post-operative period, the bite force in the right first molar was 68.8% than in the control group. For the left molar and incisor, these values were 68.69% and 83.10% respectively. There was increase in bite force values throughout the post operative evaluation period. Statistically significant difference in the values between Group I and Group II was observable throughout the six month post operative period. The results are tabulated in Table 4.

At **20 mm vertical dimension**, at the end of 3 month post-operative period, the bite force in the right first molar was 74.91% than in the control group. For the left molar and incisor, these values were 81.63% and 82.06 % respectively. There was increase in bite force values throughout the post operative evaluation period. Statistically significant difference in the values between Group I and Group II was observable till the first month post operative period in left molar and incisor region and till the third post operative month in the right molar region. The results are tabulated in Table 5.

At **25 mm vertical dimension**, at the end of 3 month post-operative period, the bite force in the right first molar was 78.65% than in the control group. For the left molar and incisor, these values were 75.84% and 71.34 % respectively. There was increase in bite force values throughout the post operative evaluation period. Statistically significant difference in the values between Group I and Group II was observable till the first week post operative period. The results are tabulated in Table 6.

At **30 mm vertical dimension**, at the end of 3 month post-operative period, the bite force in the right first molar was 79.12% of the control group. For the left molar and incisor, these values were 72.23% and 82.31 % respectively. There was increase in bite force values throughout the post operative evaluation period. Statistically significant difference in the values between Group I and Group II was observable till the first week post operative period. The results are tabulated in Table 7.

The graphic representation of the bite force values of the patient and control in right molar region, left molar region and incisor region has been represented in Graph 2, Graph 3 and Graph 4.

Table 4: Bite Force at 15 mm vertical dimension in kilogram

Serial No.	Group I n=20	Right Molar (Mean±SD)	Left molar (Mean±SD)	Incisor (Mean±SD)
1.	Pre-Op	8.58 ± 4.14 *	8.52 ± 4.04 *	9.35 ± 4.82 *
2.	I Post-op day	4.42 ± 3.31 *	5.04 ± 3.28 *	6.28 ± 3.36 *
3.	I week Post-op	12.09 ± 5.02 *	12.24 ± 4.30 *	12.33 ± 4.01 *
4.	I month Post-op	21.51 ± 8.01 *	20.39 ± 7.11 *	20.95 ± 4.85 *
5.	3 month Post op	26.80 ± 6.23 *	25.80 ± 6.71 *	27.25 ± 4.65 *
6.	6 month Post op	31.34 ± 5.99*	31.36 ± 6.05*	32.27 ± 3.75*
7.	Group II - Control	38.95 ± 4.56	37.56 ± 4.55	38.83 ± 4.36

*** - Significance at $p \leq 0.05$ between Group I and Group II**

Table 5: Bite Force at 20 mm vertical dimension in kilogram

Serial No.	Group I n=20	Right Molar (Mean±SD)	Left Molar (Mean±SD)	Incisor (Mean±SD)
1.	Pre-Op	7.89 ± 4.54 *	7.64 ±4.44 *	7.98 ± 4.28 *
2.	I Post-op day	3.97 ± 2.57 *	4.30 ± 2.80 *	6.10 ± 3.49 *
3.	I week Post-op	12.26 ± 3.91 *	12.37 ± 4.33 *	12.71 ± 4.47*
4.	I month Post-op	19.77 ± 6.63 *	19.29 ± 5.45 *	21.17 ± 6.04 *
5.	3 month Post op	23.41 ± 5.47*	25.21± 4.98	25.63 ± 4.77
6.	6 month Post op	30.33 ± 4.93	30.06 ± 5.17	30.75 ± 4.30
7.	Group II - Control	31.25 ± 6.66	30.88 ± 4.98	31.25 ± 4.87

*** - Significance at $p \leq 0.05$ between Group I and Group II**

Table 6: Bite Force at 25 mm vertical dimension in kilogram

Serial No.	Group I n=20	Right Molar (Mean±SD)	Left molar (Mean±SD)	Incisor (Mean±SD)
1.	Pre-Op	4.18 ± 3.52 *	4.25 ± 3.47 *	5.05 ± 3.93 *
2.	I Post-op day	2.97 ± 1.91 *	2.95 ± 2.11 *	4.15 ± 2.47 *
3.	I week Post-op	8.92 ± 5.53 *	8.40 ± 3.91 *	8.53 ± 3.63 *
4.	I month Post-op	15.75 ±4.63	14.72 ± 3.32	13.77 ± 2.34
5.	3 month Post op	20.31 ± 3.21	18.31 ± 3.09	16.66 ± 2.31
6.	6 month Post op	25.72 ± 3.82	23.27 ± 4.43	23.89 ± 22.55
7.	Group II - Control	25.82 ± 3.06	24.14 ± 3.73	23.35 ± 2.96

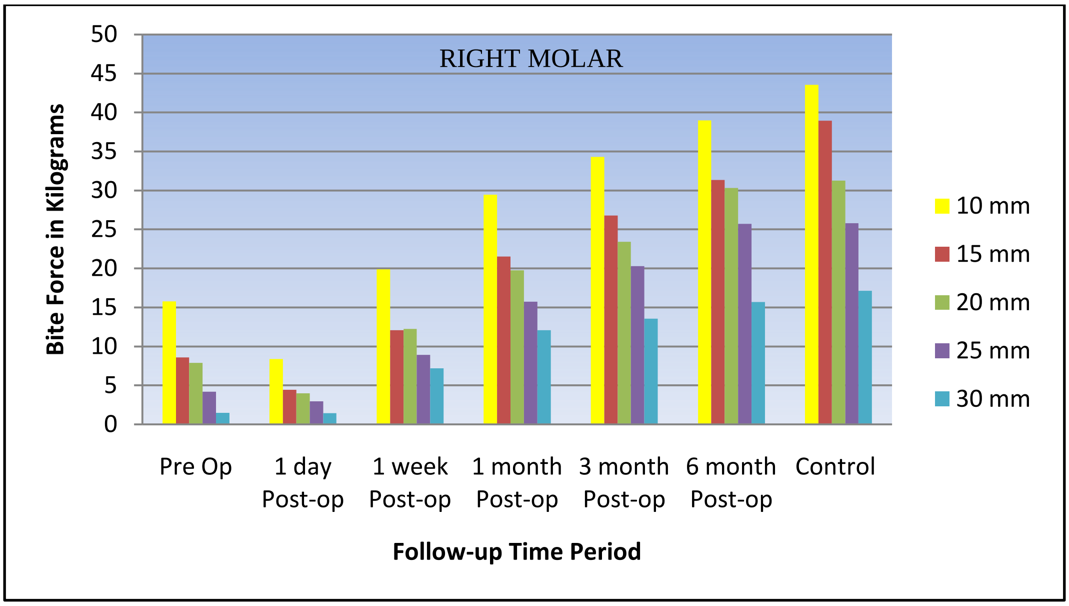
*** - Significance at p≤*0.05* between Group I and Group II**

Table 7: Bite Force at 30 mm vertical dimension in kilogram

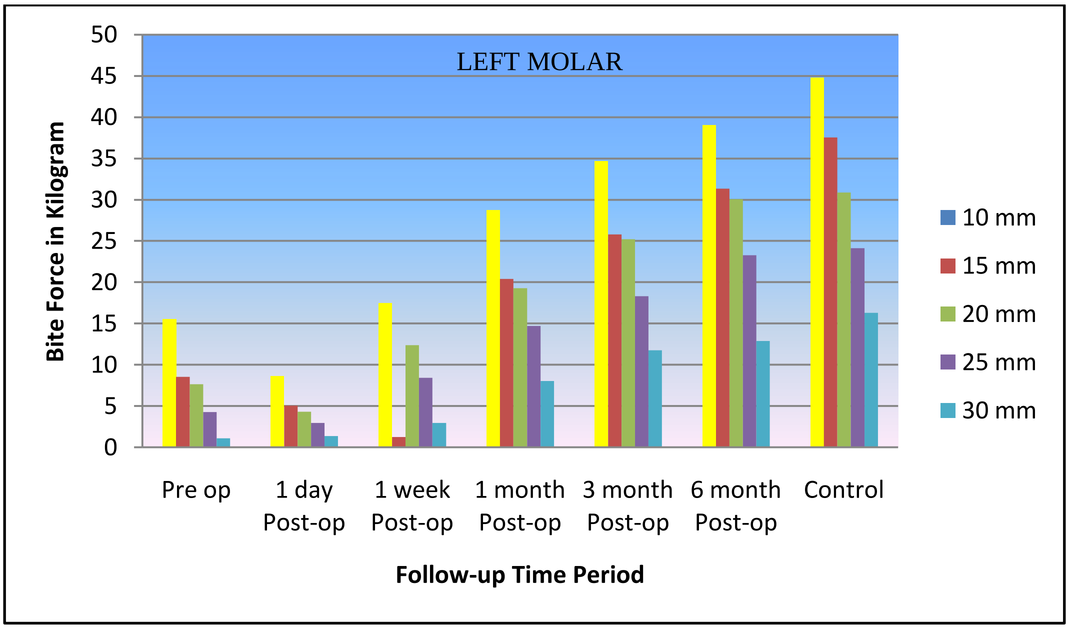
Serial No.	Group I n=20	Right Molar (Mean±SD)	Left molar (Mean±SD)	Incisor (Mean±SD)
1.	Pre-Op	1.46 ± 2.21 *	1.08 ± 1.77 *	1.38 ± 2.21 *
2.	I Post-op day	1.45 ± 1.50 *	1.34 ± 1.37 *	1.23 ± 1.52 *
3.	I week Post-op	7.18 ± 3.82 *	2.94 ± 2.40 *	5.05 ± 3.22 *
4.	I month Post-op	12.07 ± 5.06	8.04 ± 3.88	8.96 ± 4.50
5.	3 month Post-op	13.57 ± 4.24	11.76 ± 3.50	12.61 ± 4.21
6.	6 month Post-op	15.68 ± 3.83	12.87± 2.05	13.67 ± 3.08
7.	Group II - Control	17.15 ± 3.87	16.28 ± 3.05	15.32 ± 2.68

*** - Significance at p≤*0.05* between Group I and Group II**

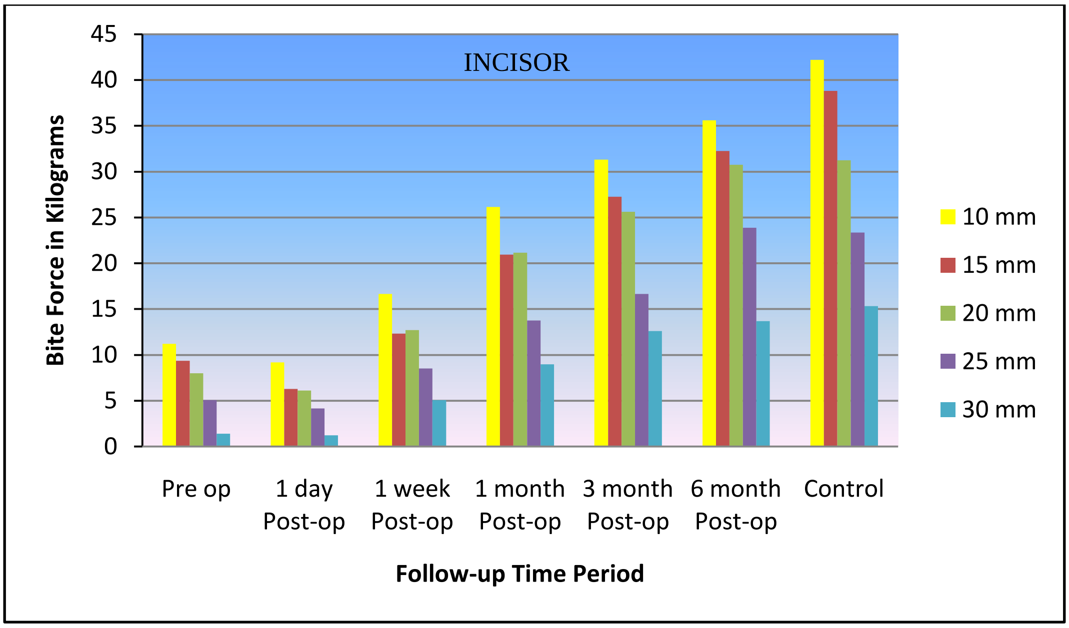
Graph 2: Bite force values of the patient and control in right molar region



Graph 3: Bite force values of the patient and control in left molar region



Graph 4: Bite force values of the patient and control in incisor region



ENDURANCE LEVEL MEASUREMENTS

The patient is asked to clench on the bite sensor of 10 mm vertical dimension and the time taken to reach and sustain the force at maximum voluntary clench is recorded.

1. Comparison of the endurance levels in the right and left molar of left sided and right sided ZMC fracture

The endurance levels in the right and left molars in left sided fracture and the right sided fracture was compared. There was no statistically significant difference in the endurance time of the right and left molars in right sided fracture and left sided fracture. The values in left sided fracture are tabulated in Table 8 and the right sided fracture in Table 9.

2. Comparison of the endurance levels in Group I patients and Group II controls

The average endurance levels in the right and left molars were compared between Group I patients and Group II controls. The difference in the endurance levels between the Group I and the control group was found to be statistically significant for $p \leq 0.05$ throughout the post-operative period of 6 months. The endurance level in the right molar was 12.91% of the control in the first week post operatively and at the end of sixth month, it was 54.63% of the control. In the left molar region, the endurance level was 14.01% of the control in the first post operative week and was 60.40% of the control in the sixth post-operative month. The values comparing the Group I and Group II are tabulated in Table 10.

Table 8: Endurance level (in seconds) in left sided ZMC fracture

Group I (n=11)		MEAN	SIGNIGICANCE
Pre-Op	**Right Molar**	24.81±18.23	**NS**
	Left Molar	25.72±16.54	
I Post-op day	**Right Molar**	14.00±9.12	**NS**
	Left Molar	13.00±5.93	
I week Post-op	**Right Molar**	28.36±13.01	**NS**
	Left Molar	31.09±11.01	
I month Post-op	**Right Molar**	52.09±15.42	**NS**
	Left Molar	53.36±17.51	
3 month Post-op	**Right Molar**	84.09±20.17	**NS**
	Left Molar	85.54±25.27	
6 month Post-op	**Right Molar**	119.91±18.11	**NS**
	Left Molar	134.00±26.66	
Group II – Control	**Right Molar**	219.65±68.99	
	Left Molar	221.85±63.14	

NS – Not Significant at p≤*0.05* between Group I and Group II

Table 9: Endurance level (in seconds) in right sided ZMC fracture

Group I (n=9)		MEAN±SD	SIGNIFICANCE
Pre-Op	**Right Molar**	19.44±9.90	**NS**
	Left Molar	32.33±18.21	
I Post-op day	**Right Molar**	8.2222±2.77	**NS**
	Left Molar	12.66±6.81	
I week Post-op	**Right Molar**	23.66±8.38	**NS**
	Left Molar	26.77±12.45	
I month Post-op	**Right Molar**	51.88±16.20	**NS**
	Left Molar	52.33±17.94	
3 month Post-op	**Right Molar**	87.77±16.58	**NS**
	Left Molar	80.66±15.14	
6 month Post-op	**Right Molar**	119.56±22.56	**NS**
	Left Molar	116.33±30.37	
Group II – Control (n=20)	**Right Molar**	219.65±68.99	
	Left Molar	221.85±63.14	

NS – Not Significant at p≤*0.05* between Group I and Group II

Table 10: Endurance level (in seconds) in Group I and Group II patients

Serial No.	Group I – Patients (n=20)	RIGHT MOLAR	LEFT MOLAR
1.	**Pre-Op**	22.40 ± 14.96 *	28.7 ± 17.17*
2.	**I Post-op day**	11.4 ± 7.46 *	12.85 ± 6.17*
3.	**I week Post-op**	26.25± 11.15 *	29.15 ± 11.57*
4.	**I month Post-op**	52.00 ± 15.35 *	52.9 ± 17.24*
5.	**III month Post-op**	85.75 ± 18.26*	83.35 ± 20.95*
6.	**6 month Post-op**	119.75 ± 19.67*	126.05 ± 29.04*
7.	**Group II – Control**	219.65 ± 68.99	221.85 ± 63.14

*** - Significance at p≤*0.05* between Group I and Group II**

3. Endurance levels at Maximum Voluntary Clench

The endurance levels in the right and left molar region was calculated at the maximum voluntary clench (10 mm vertical dimension) measured at the right and left molar region.

There was increase in endurance levels with increased values of bite force throughout the post-operative period. This increase was found to be statistically significant.

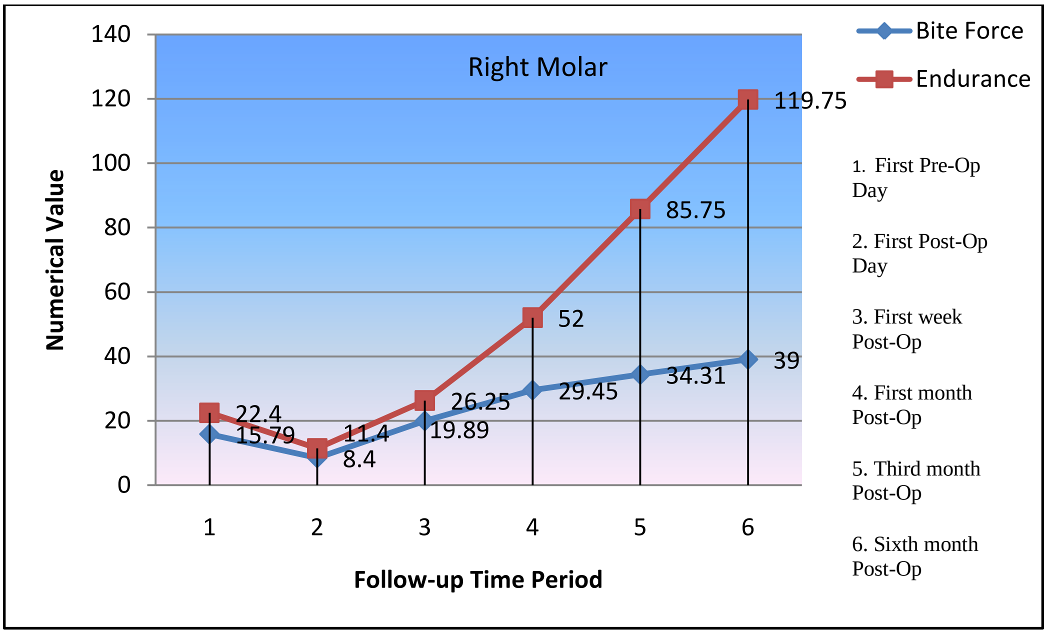
The values of bite force and their corresponding endurance level is tabulated in Table 11. The graphical representation of the bite force versus endurance levels in right and left molar is given in Graph 5 and Graph 6 respectively.

Table 11: Endurance levels at Maximum Voluntary Clench in Group I patients

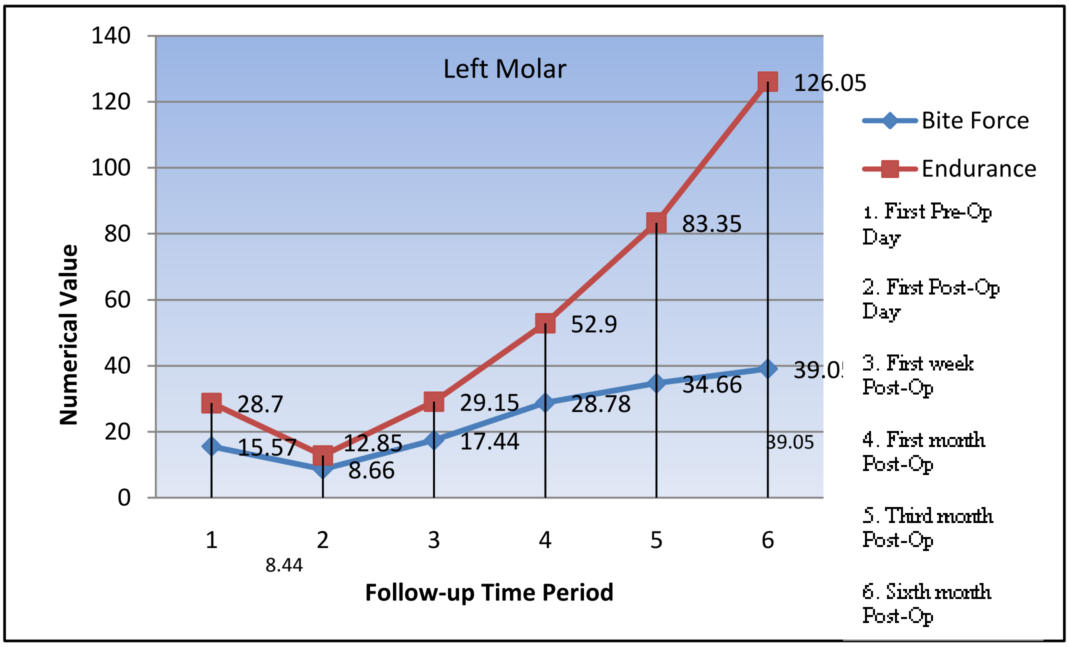
		1 Pre-Op Day 1	1 Post-Op Day 2	1 week Post-Op 3	1 month Post-Op 4	3 month Post-Op 5	6 month Post-Op 6
Right Molar	**Bite Force**	15.79	8.4	19.89*	29.45*	34.31*	39*
	Endurance	22.4	11.4	26.25*	52*	85.75*	119.75*
Left Molar	**Bite Force**	15.57*	8.66*	17.44*	28.78*	34.66*	39.05*
	Endurance	28.7*	12.85*	29.15*	52.9*	83.35*	126.05*

*** - Significance (2 tailed) at p≤*0.05* between bite force and endurance**

Graph 5: Endurance levels at Maximum Voluntary Clench in Right Molar



Graph 6: Endurance levels at Maximum Voluntary Clench in Left Molar



EMG MEASUREMENTS

EMG activity in Right and Left masseter muscle

The EMG activity was measured in right and left masseter muscle using surface electrodes. The EMG activity was recorded at rest, open position, clenching, mouth closing and lateral movements.

There was increase in the EMG activity of the masseter muscle throughout the evaluated post operative period. In clenching position, when compared with the control (Group II), there was statistically significant difference in the EMG activity throughout the evaluated post-operative period of six months.
There was no statistically significant difference noted between the right and the left masseter muscle activity.

At rest position, the values of the EMG activity of the masseter approached that of the control reflecting a normal or near normal activity of the muscles. However the difference was not statistically significant in the rest position between Group I and Group II.

There was an overall increase in the activity of masseter throughout the post-operative period in protrusion and lateral movements, but the levels did not reach that of the control.

The values of the EMG activity of the right and left masseter muscles have been tabulated in Table 12 and Table 13 respectively. The graphical representation of the data is show in Graph 7 and Graph 8.

Table 12: EMG activity (mean in millivolts) in Right masseter muscle

	Clenching Mean±SD	**Closing Mean± SD**	**Protrusion Mean±SD**	**Left Lateral Mean± SD**	**Right Lateral Mean± SD**	**Open Mean ±SD**	**Rest Mean ±SD**
Pre-Op	158.80± 34.39*	24.45± 8.82*	43.70± 13.96*	34.95± 7.12*	56.10± 26.45	53.70± 27.31*	18.00 ±4.18
I Post-op day	161.90± 17.52*	43.15± 11.21*	48.25± 14.96*	35.70± 7.27*	56.45± 22.58	54.65± 20.17*	15.45 ± 3.85
I week Post-op	184.85± 30.36*	45.95± 10.98*	57.30± 12.32*	54.90± 8.60*	70.85± 17.26	189.80 ± 105.82 *	22.65 ±2.96
I month Post-op	235.00± 37.77*	85.55± 8.63	83.50± 10.00	61.30± 9.05*	82.80± 7.93	496.90 ± 129.35	23.40 ±2.21
3 month Post-op	280.30± 34.82*	88.05± 10.74	86.15± 9.65	85.65± 7.86	89.10± 9.07	561.30 ± 111.65	23.90 ±1.77
6 month Post-op	314.10± 17.03*	98.90± 8.45	121.40 ± 13.16	95.75± 3.38	95.20± 4.66	567.75 ± 135.53	24.45 ±1.43
Group II - Control	580.00± 151.72	101.65 ± 7.36	148.25± 8.03	99.90± 9.89	97.60± 14.48	568.55 ± 115.16	24.65 ±3.99

*** - Significance at p≤*0.05* between Group I and Group II**

Graph 7: EMG activity of the Right Masseter Muscle

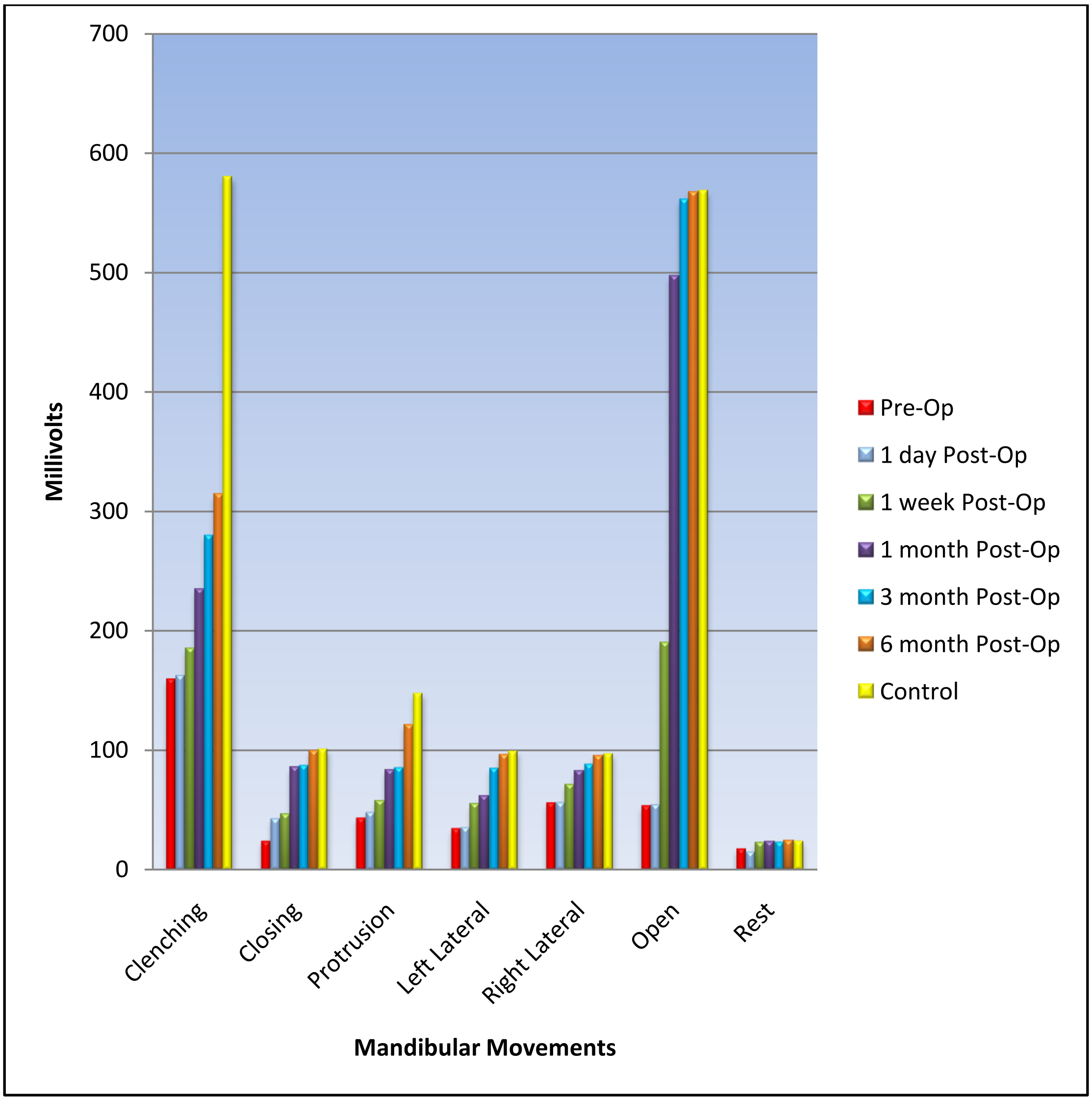
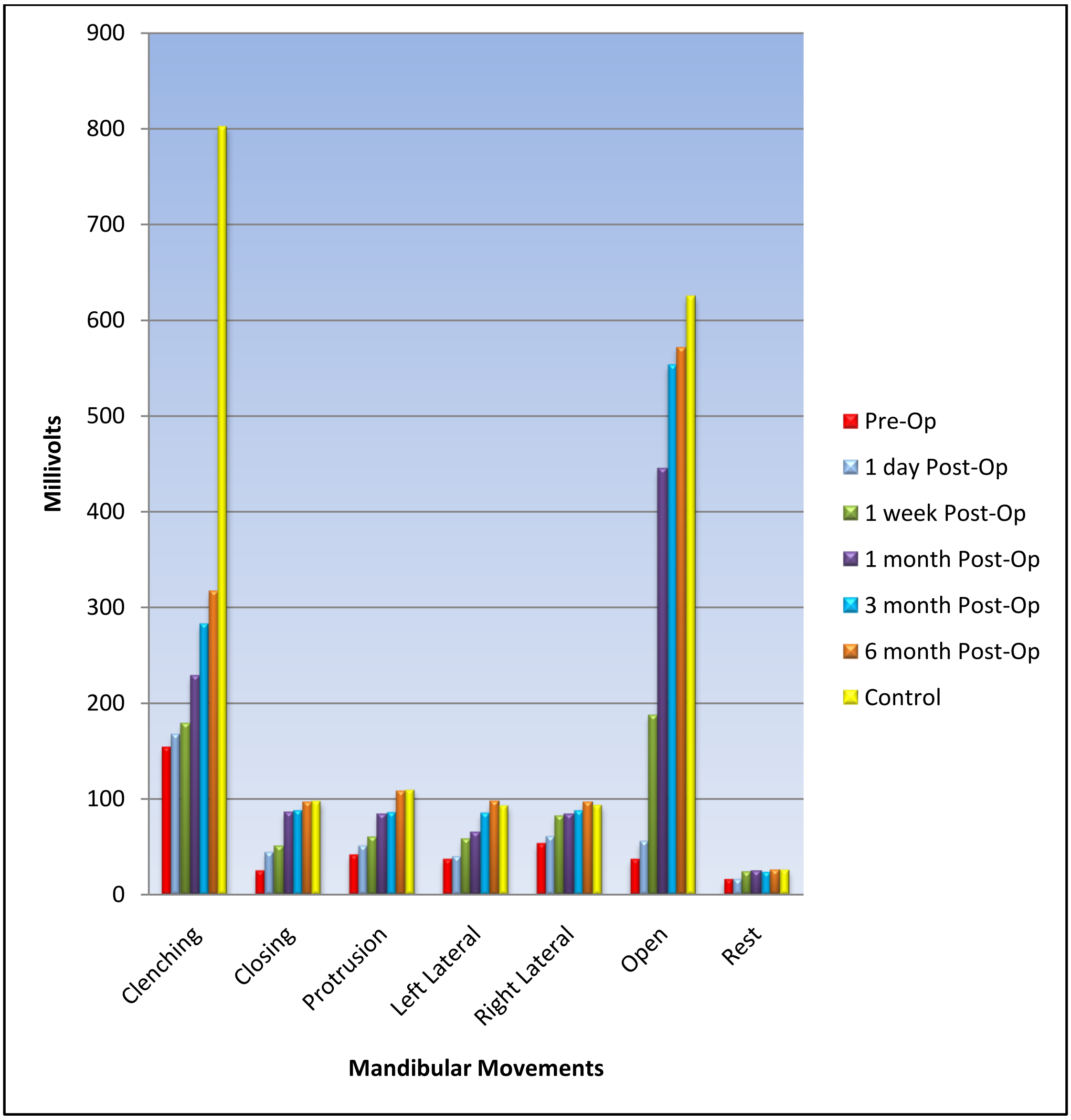


Table 13: EMG activity (mean in millivolts) in Left Masseter Muscle

	Clenching Mean±SD	Closing Mean± SD	Protrusion Mean±SD	Left Lateral Mean± SD	Right Lateral Mean± SD	Open Mean ± SD	Rest Mean ±SD
Pre-Op	153.65± 36.00*	25.10± 9.61*	41.95± 11.40*	37.35± 12.53*	53.65± 20.98*	37.35 ± 26.19*	16.30 ± 6.24
I Post-op day	166.95 ± 15.18*	44.35± 9.65*	51.20± 11.46*	40.30± 9.72*	61.10 ± 18.35*	55.85± 10.01*	16.30 ± 3.86
I week Post-op	178.40± 31.37*	50.15 ± 7.16*	59.80± 15.18*	57.35± 14.69*	82.00± 27.62	187.2± 65.50*	23.30 ± 2.57
I month Post-op	228.65± 44.89*	85.40± 8.82	83.30± 9.65	64.35± 10.78*	83.85± 7.37	444.75 ± 127.5*	24.10 ± 2.73
3 month Post-op	282.90± 34.30*	88.25± 10.17	86.10± 9.64	85.45± 7.12	88.15± 8.52	552.9± 98.37	24.05 ± 2.56
6 month Post-op	316.05± 23.77*	95.60± 6.06	107.50± 6.01	96.55± 5.79	95.85 ± 3.2	571.25 ± 65.11	24.95 ± 2.50
Group II – Control	802.10± 121.74	98.1± 9.21	109.55± 9.04	93.35± 8.34	93.80± 7.66	625.35 ± 123.69	26.15 ± 17.11

*** - Significance at p≤*0.05* between Group I and Group II**

Graph 8: EMG activity of the Left Masseter Muscle



EMG activity of Right and Left Temporalis Muscles

The EMG activity was measured in right and left temporalis muscle using surface electrodes. The EMG activity was recorded at rest, open position, clenching, mouth closing and lateral movements.

There was increase in the EMG activity of the temporalis muscle throughout the evaluated post operative period. When compared with the control (Group II), there was statistically significant difference in the temporalis muscle activity in clenching, open, lateral and protrusive positions throughout the evaluated post-operative period of six months.

There was no statistically significant difference noted between the right and the left temporalis muscle activity.

At rest position, the values of the EMG activity of the right and left temporalis were more than that of the control. This difference was statistically significant throughout the evaluated post-operative period of six months indicative of muscle activity.

The values of the EMG activity of the right and left temporalis muscles have been tabulated in Table 14 and Table 15 respectively. The graphical representation of the data is show in Graph 9 and Graph 10.

Table 14: EMG Activity (mean in millivolts) of Right Temporalis Muscle

	Clenching Mean± SD	Closing Mean± SD	Protrusion Mean± SD	Left Lateral Mean± SD	Right Lateral Mean± SD	Open Mean± SD	Rest Mean± SD
Pre-Op	155.80± 26.28*	24.70 ± 10.48*	46.35± 18.54*	52.35± 13.17	50.50± 18.65	54.45±16. 42*	22.00 ±3.88
I Post-op day	162.80± 19.43*	43.60± 9.79*	56.45± 12.07*	75.35± 11.84*	51.50± 10.66	59.25± 10.76*	20.85± 3.93
I week Post-op	179.40± 20.78*	50.55± 6.57*	68.80± 17.80*	81.35± 12.26*	60.95± 13.73	90.00± 13.44*	24.00± 2.44*
I month Post-op	194.30 ± 39.10*	84.85± 8.29*	83.95± 7.82*	83.95± 7.89*	86.75± 8.07	128.10± 37.45*	23.45± 2.06*
3 month Post-op	265.70± 28.44*	89.20± 10.37*	85.10± 8.30*	84.75± 10.27*	85.70± 8.78*	173.20± 42.18*	23.65± 2.41*
6 month Post-op	296.30± 20.33*	95.00± 4.25*	99.10± 4.41*	95.00± 4.49*	96.15± 3.57*	218.65± 32.69*	23.55± 2.25*
Group II - Control	521.45± 142.87	263.00 ±99.56	349.60± 118.00	60.20± 8.76	60.20± 9.45	523.80± 79.09	18.05± 4.9

*** - Significance at p≤*0.05* between Group I and Group II**

Graph 9: EMG activity of the Right Temporalis muscle

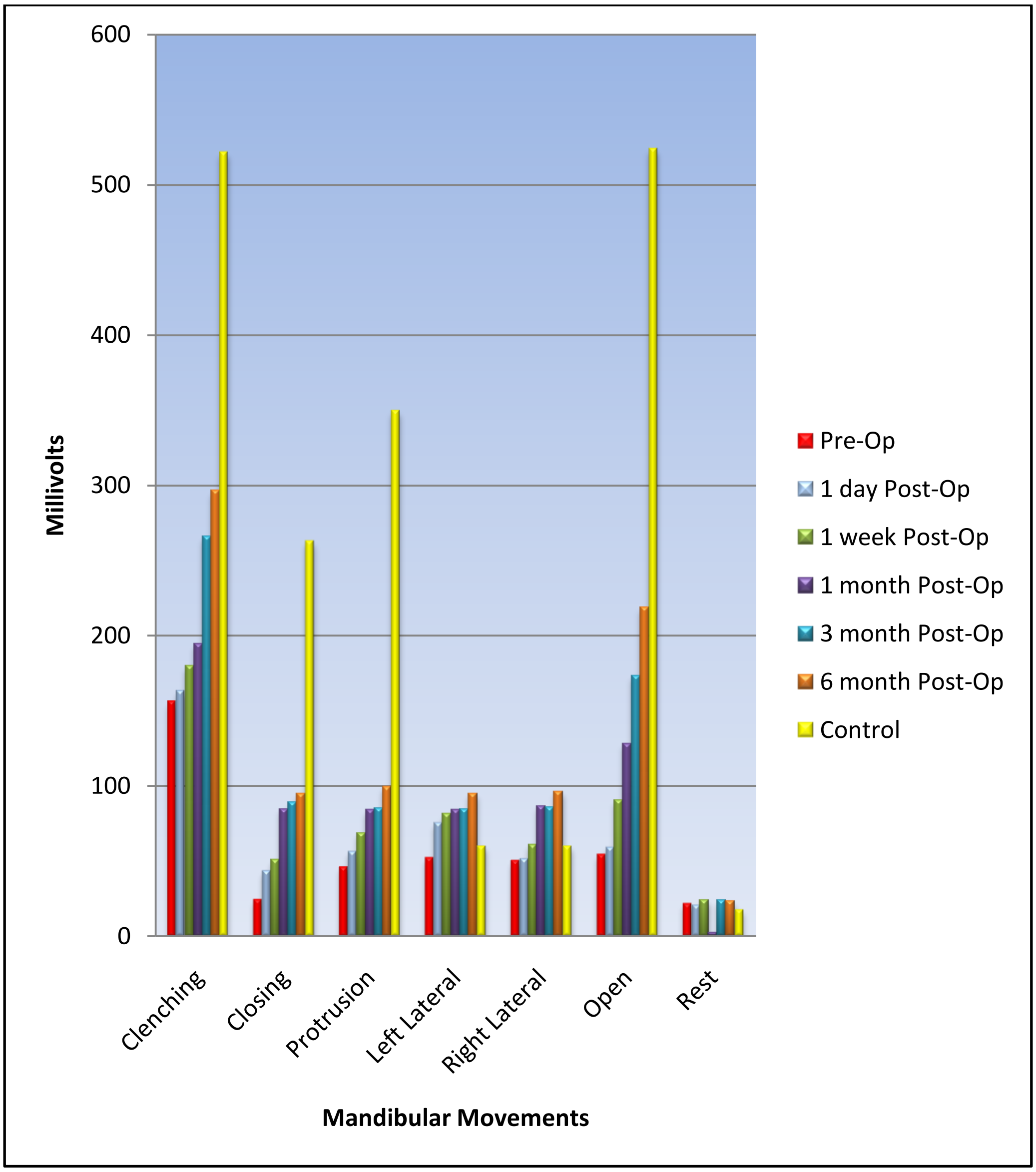
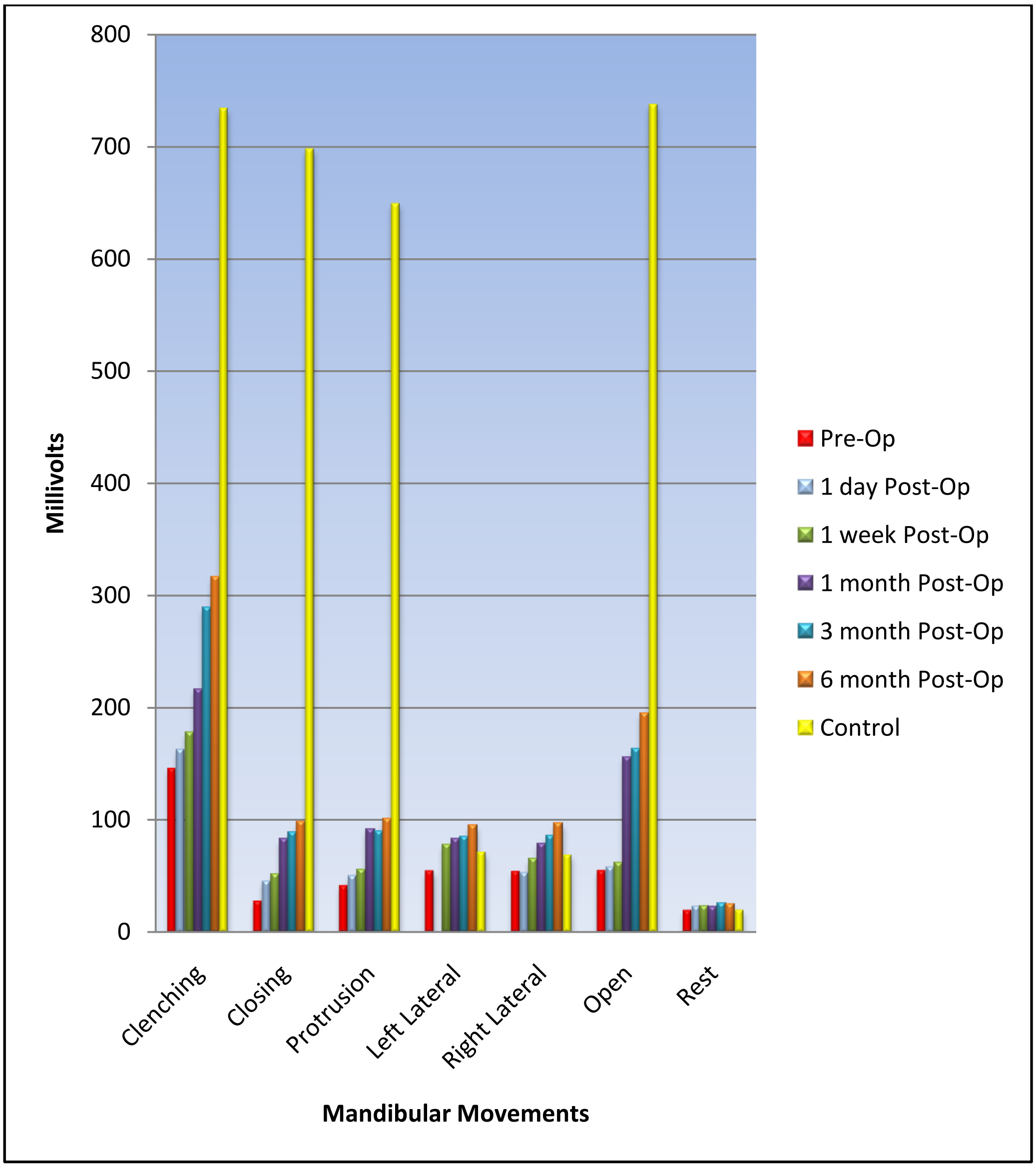


Table 15: EMG Activity (mean in millivolts) of Left Temporalis Muscle

	Clenching Mean± SD	Closing Mean± SD	Protrusion Mean± SD	Left Lateral Mean± SD	Right Lateral Mean± SD	Open Mean ± SD	Rest Mean ± SD
Pre-Op	145.65± 25.20*	28.11± 9.36 *	41.80± 7.32*	54.95± 11.49*	54.45± 15.23*	55.25± 20.64*	18.55± 5.22
I Post-op day	162.80± 20.71*	45.95± 10.93*	50.60± 4.63*	50.30± 6.66*	53.35± 14.90*	58.35± 12.39*	21.75± 4.05*
I week Post-op	178.05± 25.32*	51.47± 7.12*	55.40± 5.81*	77.65± 12.22	64.60± 15.62	61.10± 15.72*	24.6± 4.5*
I month Post-op	216.40± 43.30*	82.95± 6.67*	91.80± 10.71*	82.95± 11.43	78.95± 10.80	155.55 ± 16.24*	23.5± 1.93*
3 month Post-op	288.70± 20.74*	89.21± 9.61*	89.40± 8.67*	84.80± 7.51	85.50± 7.55	163.15 ± 30.66*	23.85± 2.39*
6 month Post-op	316.20± 20.60*	97.95± 4.98*	100.40± 6.02*	94.55± 2.89	96.30± 6.12	194.90 ± 31.29*	26.05± 3.08*
Group II - Control	733.90± 73.86	697.84 ± 141.46	649.00± 97.92	71.70± 12.70	69.80± 5.58	737.50 ± 37.65	16.25± 3.89

*** - Significance at $p \leq 0.05$ between Group I and Group II**

Graph 10: EMG activity of the Left Temporalis muscle



MANDIBULAR MOVEMENTS

The mandibular movements were measured in mouth opening, right lateral, left lateral and protrusive positions. In the mandibular movements, the mouth opening increased with time throughout the post-operative period. When compared with Group II control, there was statistical significance in the values till the first month post – operative time period.

Right and left lateral movement and protrusive movement increased throughout the post-operative evaluated period of 6 months. When compared to Group II controls, there was statistical significance till the first post-operative month for lateral movements and till first post-operative week for protrusive movements.

However the mandibular movements returned to near normal levels after the first month post-operative period.

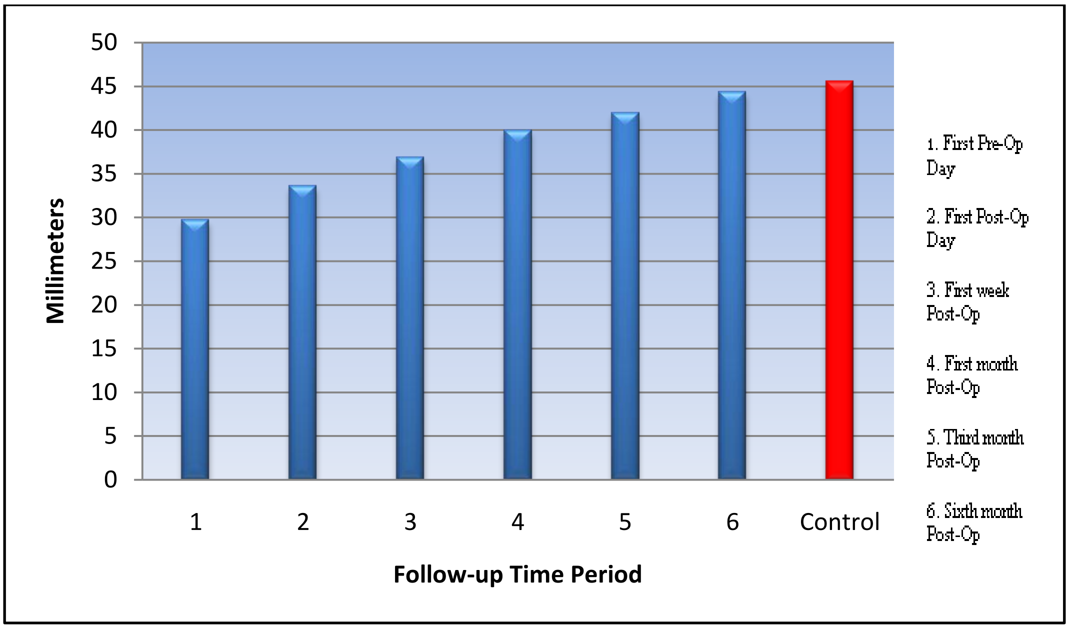
The values are tabulated in Table 16 and graphically represented in Graph 11, Graph12, Graph 13, Graph 14

Table 16: Mandibular Movements

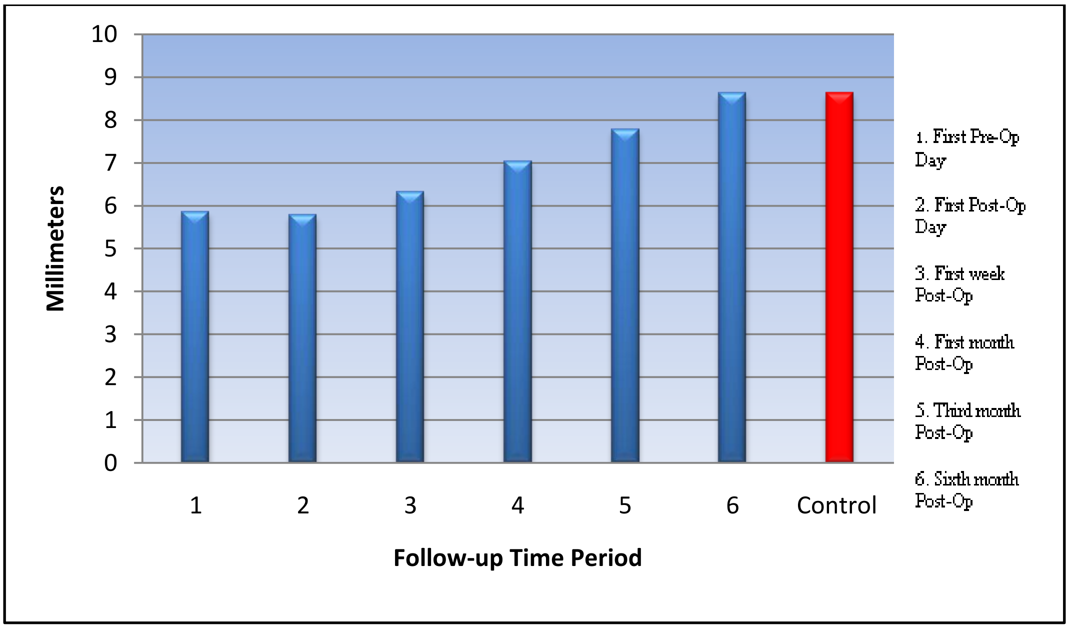
N=20	Mouth Opening Mean± SD	Right Lateral Movement Mean± SD	Left Lateral Movement Mean± SD	Protrusion Mean± SD
Pre-Op	29.68±5.05*	5.86±1.53*	5.95±1.78*	2.54±1.00*
I Post-op day	33.50±6.82*	5.79±1.47*	5.60±1.40*	2.68±0.84*
I week Post-op	36.84±5.51*	6.31±1.32*	6.28±1.46*	3.00±0.82*
I month Post-op	39.92±4.47*	7.04±1.14*	6.88±1.30*	3.32±0.73
3 month Post-op	41.92±3.58	7.78±0.96	7.51±0.96	3.54±0.72
6 month Post-op	44.28±2.53	8.62±0.9	8.37±0.84	3.96±0.43
Group II – Control	45.56±3.18	8.63±1.34	8.61±1.51	4.00±1.12

*** - Significance at p≤*0.05* between Group I and Group II**

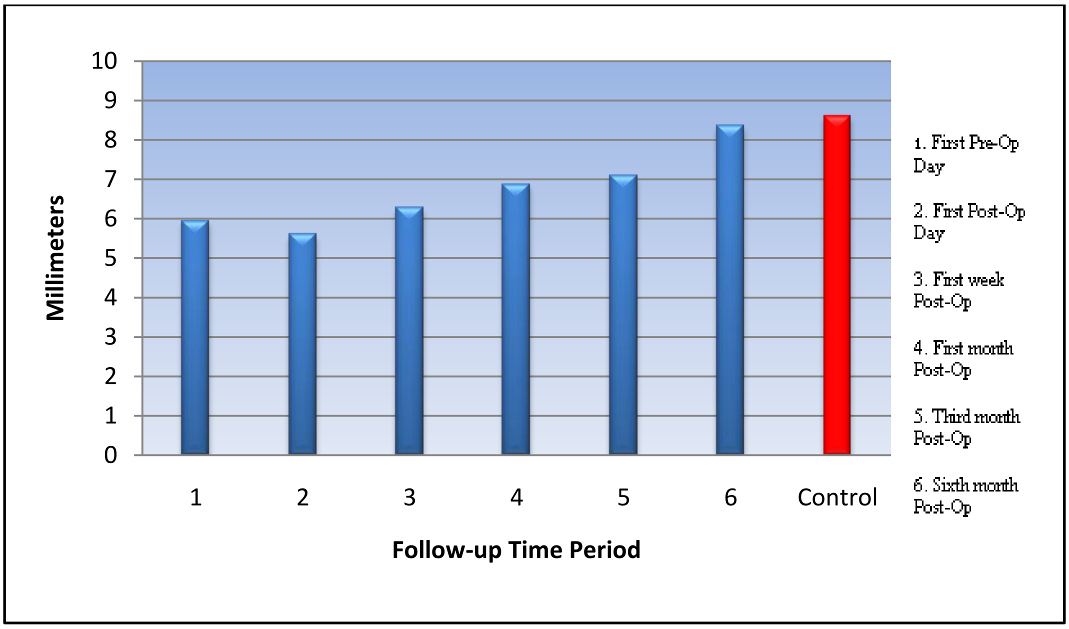
Graph 11: Measurement of Mouth Opening



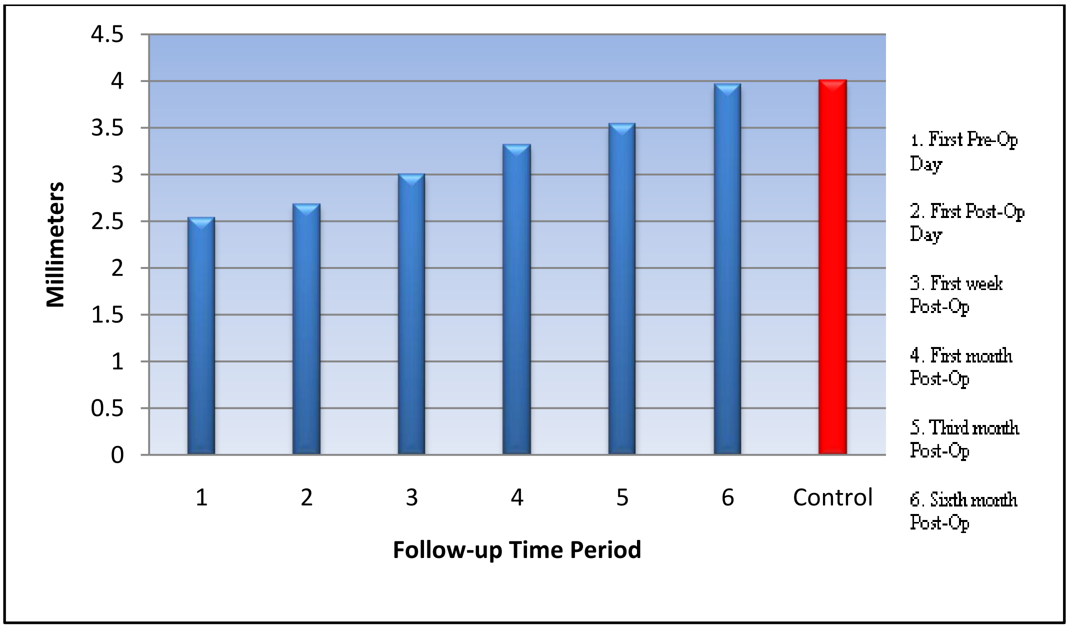
Graph 12: Measurement of Right Lateral Movements of the jaw



Graph 13: Measurement of Left Lateral Movements of the jaw



Graph 14: Measurement of Protrusive Movements of the jaw



DISCUSSION

Zygomatico maxillary complex fractures are one of the most common maxillofacial injuries. A patient with this type of facial injury usually presents with a clinical picture of gross facial edema, periorbital ecchymosis, sub conjunctival hemorrhage, bleeding from the nostril, paraesthesia of infra orbital nerve, flattening of the ipsilateral malar prominence, limitation in mouth opening. Clinical examination augmented with radiological investigation gives an accurate picture of the extent of these injuries.

The rise in motorized population and the general disregard to the traffic rules and safety regulations has resulted in a mercurial rise in RTA being a significant etiological factor for maxillofacial injuries. In the present study, ZMC fracture was due to RTA in 14 patients (70%), domestic violence in 2 patients (10%) and physical aggression/assault in 4 patients (20%). The left side of the face was involved in 55% of the patients while right side of the face was involved in 45% of the patients.

Different characteristics accompany ZMC fractures. Periorbital ecchymosis and subconjunctival hemorrhage was the most common clinical feature in this study. Another important symptom is the paraesthesia of the infraorbital nerve which is found in about 50-90% of ZMC injuries[64]. In this study, most of the patients (80%) had impaired neurosensory deficit of the ipsilateral infraorbital nerve which returned to near normal levels in six month post operative period. A striking feature of ZMC fracture is flattening of the cheek which happens when FZ suture is involved and there is medial rotation of the complex. According to Larson et al[2] and Ellis E et al[4], 70-86 % of the cases have flattening of the cheek. In this study, all the patients had flattening of cheek in varying degrees of asymmetry. Trismus is another important feature of ZMC fracture which occurs due to impingment of the coronoid process of the mandible on the displaced zygoma or due to temporalis muscle spasm. Trismus is present in 33-45% of the ZMC fractures[28]. In the present study, all the patients had trismus with varying degrees of severity ranging from 20-35 mm of mouth opening.

The four most salient considerations in treating ZMC fractures are proper reduction, adequate stabilization, adequate orbital reconstruction (when necessary) and adequate handling/positioning of periorbital soft tissues[28]. The most important principle in treating these fractures is the adequacy of reduction because if their position is not correct, the stabilization is weak.

There has been a paradigm shift in the management of zygomatic complex fractures from conservative to surgical in the last few decades. Recommendations for the treatment of ZMC fractures range from non-intervention, also called conservative treatment[12, 17], to fracture observation through open reduction and internal fixation. In all the suggested methods, the aim was to adequately restore the loss of anatomical configuration, restoring the habitual function, preventing the late visual disorders and cosmetic deformities[63].

Zingg et al[17] reviewed 946 ZMC fractures treated by a variety of means, including 164 treated by closed reduction, found a 13% incidence of malar asymmetry. Hence, the need for aggressive surgical procedures of ZMC fracture treatment through open reduction with 3 to 4 points exposure[22, 66] have been put forward for accurate reduction and there are reports discussing the need or not for requirement of fracture fixation[7, 22]. According to Fain et al[63] and Manson et al[67] fixation is essential to prevent rotation of the zygomatic bone, and the stability can be achieved both with plates and screws, in one or two points, with no need for fixing it in three or four points, other than in cases of comminuted fractures.

Some studies show that the instability of ZMC fracture is directly due to the masseter muscles action, and indirectly the temporal muscles[24]. Hence stability of the fracture should be assessed after reduction and unstable fractures should undergo fixation.

Ellis & Kittidumkerng[28] evaluated 22 patients clinically and radiographically after ZMC fracture surgeries and showed that the existence of ill-positioned zygomatic bone was probably because these fractures were not adequately reduced during surgery and was not related to masseter muscle action. In the present study, the intraoperative assessment of the stability of the repositioned ZMC was determined using digital pressure after reduction to determine the need for applying fixation devices[17]. Hence the need for fixation and the number of fixation was determined clinically during surgery[17, 28, 68]. The present study is in agreement with by Dal Santo et al[7] wherein there was no further worsening of the facial asymmetry in the post operative period i.e., the modicum of symmetry achieved intraoperatively sustained throughout the post operative period of six months. The patients did not report dissatisfaction or worsening of esthetics.

In the present study, the differences in the values of the bite force and electromyographic activities in the operated side and the non-operated side of the Group I patients were not statistically significant for $p \leq 0.05$. Also, the stability obtained by fixation (one, two or three point fixation) showed no statistically significant intra group variance ($p \leq 0.05$). This is consistent with the findings of

Ellis and Kittidumkerng[28] where regardless of the number of fixation devices applied, there was no radiologic evidence of post reduction displacement.

The results of Dal Santo et al[7] show similar findings. The study compared masseter muscle force in 10 male controls with 10 male patients who had sustained unilateral ZMC fractures. Calculation of muscle force was based on measured bite force, electromyogram, and radiographic determination of muscle vectors. It was found that the masseter muscle developed significantly less force in patients with a ZMC fracture than in controls. After fracture, the masseter force slowly increases, but at 4 weeks after surgery, most patients were still well below control levels. In the present study, the bite force in the molar region was less in patients with ZMC fracture and was 36.26% of the control group. Four weeks after fracture, the values were less than that of control (45.68%). This difference was statistical significant till the third postoperative month. At the sixth month post operative period, the bite force was 89.57% of the control. These results are in agreement with the findings of Ribeiro et al[10] in which bite force in the region of first molars were close to 70% of the control group values.

Fatiguability of the masseter muscle was measured by the endurance time (in seconds) of maximum voluntary clench on bite force transducer. The results show that there was no statistically significant difference in values between the right and left molars in right and left sided fracture. Comparison with the controls showed that at three months post surgery, the endurance time was only 23.9% of the control. Though there was statistically significant increase in the values throughout the evaluated post operative period, the values remained less than that of the control group.

According to these results, it is safe to deduce that the masseter does not seem to play a major role in displacement of the fracture segments as seen from the less bite force values in fracture group and the less endurance time in the fracture group when compared to the controls.

In the present study mandibular movements were not significantly incapacitated except for maximum mouth opening which returned to normal level within the first month post operative period. Lateral movements and protrusion were not affected in these fractures. This is consistent with the findings of Ribeiro et al[10].

EMG data in the present study showed that at one week post operative period, the masseter muscles presented an 8% increase in EMG activity compared with control in the right masseter and 10.8% increase in left masseter activity. In the temporal muscles, there was 32.96% increase in EMG activity in right temporalis and 16.70 % increase in left temporalis muscle activity than the controls. This is in contrast to the study by Ribeiro et al[10] where the EMG data during rest for the group with a fractured ZOC, the masseter muscles presented a 30% increase in EMG activity compared with the control for the right masseter, and a 2.1% increase for the left masseter and the temporal muscles, showed a 31.7% higher activation for the right temporal muscle and 38.3% for the left. In general, the present study showed that the EMG activity for functional movements in Group I was found to be less throughout the post operative period when compared to the control group. But there was increase in the EMG activity in the Group I throughout the evaluated post operative period. This was consistent with the findings of Dal Santo et al[7] and Ribeiro et al[10].

In the present study, the increase in the EMG activity of the temporalis muscle more than that of the control may be indicative of stomatogathic system dysfunction[47]. This is in accordance to the study by Oyen and Tsay[29] that there is transmission of greater forces to the region of the frontal process of the zygoma, with these forces being twofold greater on the working side compared with the balance side during mandible lateral movements. Also, Stassen et al[30] concluded that functional forces exerted by the temporalis muscle may cause delayed postoperative distraction at the frontozygomatic suture. Hence it can be safely assumed that there is more muscle activity at the frontozygomatic area and therefore it requires fixation to prevent post reduction displacement.

The need for fixation at the frontozygomatic area has been advocated in many studies. Champy et al[69] used a single bone plate at the frontozygomatic area in 342 isolated ZMC fractures and found that only 6 (1.8%) had an unsatisfactory result. Covington et al[12] were able to stabilize 30% to 40% of ZMC fractures by one-point fixation. Ellis and Kittidumkerng[28] used one point fixation in 31% of ZMC fractures. Similarly, Choung and Kaban[70] showed that rotational tendency after reduction necessitates at least 1 point of fixation, usually at the zygomaticofrontal suture, and in the study of Zachariades et al[71], only in certain cases was the fixation used in the zygomaticomaxillary buttress, with a fixation protocol in the lateral and infraorbital rim. This is in line with the philosophy popularized by Manson et al[2] that the zygomaticofrontal suture is the best fixation point but it cannot be used as a single reference guide for alignment. Even in the present study, we used a single bone plate at frontozygomatic area in all our cases.

However, one must keep in mind that zygomaticomaxillary buttress provides a great mechanical advantage for fixation as it can prevent medial rotation of the ZMC into the maxillary sinus provided it is not severely comminuted. It acts as a direct antagonist to the action of traction provoked by the masseter muscle[72]. Zingg et al[17] described that fixation of the zygomaticomaxillary buttress may be indicated to give the proper anterior projection of the ZMC in cases of unstable or complex ZMC fracture. As per Manson et al[2], zygomaticomaxillary buttress is a good place for zygoma alignment. After them, the infraorbital rim and the lateral wall of the orbit can be used for the same objective. The results of Zingg et al[17] and Markowitz and Manson[2] showed that the greater wing of the sphenoid is a key area in determining the final result for alignment. Undetected axial rotation of the zygoma at the greater wing of the sphenoid is often the culprit in an unsatisfactory outcome. Hence for fixation procedure, the best place is obtained in the zygomaticofrontal suture, the zygomaticomaxillary buttress, the zygomatic arch, and the infraorbital rim.

In the present study, we have used frontozygomatic suture site for rigid fixation and zygomatomaxillary buttress as a reference point to align the fractured segments. Second fixation was performed in the zygomatic buttress as per Manson's principle of vertical buttress reconstruction. Infra orbital rim fixation was undertaken as a second or third fixation point in cases of gross fractures involving orbital rim and the floor of the orbit. This is in line with the 'minimization concept'[31] in current clinical practice wherein three dimensional stability in a quadripod zygomatic fracture can be satisfactorily obtained with two point fixation or one point fixation provided there is no gross comminution or displacement wherein two/one point will not provide adequate stability.

However, there are limitations to the aforementioned methods of functional evaluation of the muscle activity. The bite force measurements are difficult and the reliability of the result depends on a number of factors such as presence of pain, pre existing TMJ disorders, gender, age, craniofacial morphology, occlusal factors and the type of recording device and technique. Of these, pain is a very significant limiting factor often affecting the reproducibility of the measure because the bite force decreases due to pain at subsequent measurements during the same sitting.

Similar difficulties can be encountered in EMG studies. The distance between the surface electrodes and the placement of the surface electrodes varies according to the individual's craniofacial morphology and can cause variations in readings taken at the same time. The surface electrodes may record activities from several muscle units at the same time causing "cross talk" and may move relative to these muscles when the subject performs a task (eg: mouth opening, lateral excursions). Hence surface EMG is susceptible to artifacts resulting in variations in the data acquisition.

Nevertheless, bite force measurements and EMG activity predict the functional behaviour of the muscles and gives a picture of when these muscle activities return to normal/ near normal limits. This provides a rationale for the location of the fixation points that will best maintain the position of the reduced fractures during the healing period.

However, further studies with larger samples, standardized treatment protocol, utilization of minimum variables and standardized radiological protocol for outcome assessment are recommended to verify and confirm the pattern of recovery of the masticatory muscle evaluated in this study

SUMMARY AND CONCLUSION

Management of fractures of the zygoma by open reduction and fixation is now preferred owing to the rigid fixation systems that are low profile and not palpable in the midface region. This paradigm shift is also based on evidences which support internal fixation of all fractures of the zygomatic complex, even those that are considered clinically stable, if permanent flattening of the cheekbone is to be avoided.

The decision on the number of fixation points is mostly based on features like fracture displacement and stability after reduction. However, questions have been raised as to the necessity of three point or four point fixation requiring extensive or multiple incisions for a better access. Can these fractures be addressed by using minimum incisions and fixation at strategic points designated to counter the muscle forces which are considered as the primary cause for displacement of fracture segment? The answer to this lies in evaluating the behaviour of the masticatory musculature in fractures of the zygoma quantitatively.

Assessment of the biting force (maximum voluntary clench) is a direct measure of the function of masseter attached to the zygoma and to a certain extent, the measure of the strain that indirectly develops in the temporalis muscle due to this action. EMG activities measured during various functional movements (mouth opening, closing, lateral excursions, protrusion) assess the capacity of the muscle to reinforce motor units for facilitating these functions. Following a fracture, the muscles lose their anatomical relation with the facial skeleton and can undergo spasm even at rest position which is in contrast to uninjured muscle (non-fractured) where there are no spasms at rest. This can be assessed using the EMG.

The present study supports the concept of minimization of fixation after assessing Bite force, EMG activity and Mandibular movements, the prime parameters defining the possible role of masticator muscles exerting displacing forces in a fractured zygoma.

1) Regardless of the number of fixation devices applied the degree of facial symmetry obtained intraoperatively (by one or two point fixation) remained the same throughout the post operative period.

2) Even though there was a significant increase in the bite force during the post-operative period till the first month, the values were much less than that of the control group. This suggests that the muscle activity returns to near normal levels after the first post operative month. A similar pattern was observed in the endurance levels as well.

3) The EMG activity during functional movements was found to be less throughout the post operative period. At rest position the EMG activity for masseter was less than that of the control group throughout the post operative period.

4) However, there was increase in the EMG activity of the temporalis muscle at rest position when compared with the control in the pre-operative and throughout the post-operative period indicative of increased muscle activity of the temporalis muscle.

5) The mandibular movements were not significantly affected and the values approached normal levels within the first month post operative period.

To conclude, the important derivations obtained from this study include

1) The number of fixation points did not significantly affect the outcome of the parameters.
2) The activity of the masticatory muscle (masseter and temporalis) returned to near normal levels only after the first post-operative month.
3) The increased activity of temporalis muscle as rest suggests that application of fixation at the fronto-zygomatic area would be more appropriate to counteract these muscle forces and resist displacement of the zygomatic complex during healing period.

Hence the present study is in accord with the current clinical concepts which advocate the need for minimized fixation in zygomatic fractures to provide maximum stability and efficient masticatory functions.

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CASE REPORT FORM

FUNCTIONAL EVALUATION OF THE BEHAVIOUR OF MASTICATORY MUSCLES IN ZYGOMATICOMAXILLARY COMPLEX FRACTURE

Patient's Name : ____________________________

Age/ Sex : ____________________________

Patient's Identification No : ____________________________

Contact Address : ____________________________

____

____

Contact No : ____________________________

Institution : 1. TN Govt. Dental College & Hospital,
Chennai - 600 003.

2. Rajiv Gandhi Govt. General Hospital,
Chennai 600003

Centre : 1. Dept. of Oral & Maxillofacial Surgery,
TN. Govt. Dental College and Hospital,
Chennai - 600 003

2. Institute of Physiology
Rajiv Gandhi Govt. General Hospital,
Chennai 600003

Patient's Identification/ OP No: ______________ Date: ____________

DETAILS OF SURGERY

Procedure followed : Open reduction and internal fixation

Any other information :

Details of Drug therapy :

POST-OPERATIVE ASSESSMENT:

Parameters assessed:

1. Bite force measurement

2. Electromyographic studies

3. Mandibular movements (mouth opening, lateral movements, protrusion)

Name of the Investigator :

Signature of Investigator :

CASE SHEET PROFORMA

FUNCTIONAL EVALUATION OF THE BEHAVIOUR OF MASTICATORY MUSCLES IN ZYGOMATICOMAXILLARY COMPLEX FRACTURE

PATIENT'S NAME : ______________________________

AGE/ SEX : ______________________________

PATIENT'S

IDENTIFICATION NO : ______________________________

CONTACT ADDRESS : ______________________________

____

CONTACT No : ______________________________

INSTITUTION : 1. TN Govt. Dental College & Hospital,
Chennai - 600 003.

2. Rajiv Gandhi Govt. General Hospital,
Chennai

CENTRE : 1.Dept. of Oral & Maxillofacial Surgery,
TN. Govt. Dental College and Hospital,
Chennai - 600 003

2. Institute of Physiology
Rajiv Gandhi Govt. General Hospital,
Chennai 600003

CHIEF COMPLAINT:

HISTORY OF THE PRESENTING ILLNESS:

CLINICAL FINDINGS:

INVESTIGATIONS:

TREATMENT:

Procedure followed : Open reduction and internal fixation

FOLLOW UP

1. Bite force measurement.
2. Electromyographic study
3. Mandibular movements

NAME OF THE INVESTIGATOR :

SIGNATURE OF INVESTIGATOR :

INFORMED CONSENT

FUNCTIONAL EVALUATION OF THE BEHAVIOUR OF MASTICATORY MUSCLES IN ZYGOMATICOMAXILLARY COMPLEX FRACTURE

Patient's Identification No: ____________ Patient's Name: ________________

Patient's DOB: ________________ ____________ ____________________

dd mm yyyy

I confirm that I have read and understood the Information Sheet for the above study. I have had the opportunity to ask questions and all my questions and doubts have been answered to my complete satisfaction.

I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected.

I understand that the Clinical study personnel, the Ethics Committee and the Regulatory Authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the study. I understand d that my identity will not be revealed in any information released to the third parties or published, unless as required under the law. I agree not to restrict the use of any data or results that arise from this study.

I agree not to withhold any information about my health from the investigator and will convey the same truthfully.

I agree to take part in the above study and to comply with the instructions given during the study and to faithfully co-operate with the study team and to immediately inform the study staff if I suffer from any deterioration in my health or wellbeing or any unexpected or unusual symptoms.

I am aware that my facial fracture can be treated by using plates and screws. I was explained about the surgical methods (under local or general anesthesia) of treatment and the methods to be employed to record the progress of my treatment during the follow-up period. These include measuring the bite force, measuring the muscle activity and measuring the movements of my jaw. I was also informed about the side effects of this surgical procedure and I hereby consent to participate in this study.

I consent to give my medical history, undergo complete physical examination and diagnostic tests including hematological, biochemical and urine examination etc.

Signature / Thumb Impression: _______ Place.________Date.________

Patient's Name & Address: ____

Signature of the Investigator: ____________Place________ Date_____

Study Investigator's Name: _______________________

Institution: _______________________________________

* Signature of the Witness: _______________Place_______ Date______

* Name & Address of the Witness _________________________________

____

*Mandatory for uneducated patients (Where thumb impression has been provided above).

சுய ஒப்புதல் படிவம்.

ஆய்வு செய்யப்படும் தலைப்பு.

கன்ன எலும்பு – மேல்தாடைக் கூட்டு முறிவின் காரணமாக, கடிக்கும் திறன், தசைநார்களது செயல்பாட்டுத் திறன், கீழ்த்தாடையை அசைக்கும் திறன் ஆகியவற்றில் ஏற்படும் விளைவுகளை ஆய்வு செய்தல்

ஆராய்ச்சி நிலையம் : அரசு பல் மருத்துவக் கல்லூரி. சென்னை 600 003

பங்கு பெறுபவரின் பெயர் :

பங்கு பெறுபவரின் எண் :

பங்கு பெறுபவரின் பிறந்த தேதி : --------- / ---------- / -------------

தேதி மாதம் வருடம்

அறுவைச் சிகிச்சை சம்பந்தமாக நான் மேல் கூறப்பட்ட தகவல் படிவத்தை முழுமையாகப் படித்துப் பார்த்தேன் என்று உறுதி கூறுகிறேன்.

நான் இது தொடர்பான அனைத்துக் கேள்விகளுக்கும் நிறைவான பதில்கள் பெறப்பட்டேன்.

இந்த ஆய்வில் எனது பங்கு தன்னிச்சையானது என்றும், எந்த நேரத்திலும் இந்த ஆய்விலிருந்து சட்ட உரிமைகள் பாதிக்கப்படாமல் விலகிக் கொள்ளவும் சம்மதிக்கிறேன்.

மருத்துவ ஆய்வு அதிகாரிகள், எனது சிகிச்சை தொடர்பான பதிவேடுகளைப் பார்வையிடவும், எந்த நேரத்திலும் ஆய்விலிருந்து நான் விலகினாலும் பார்வையிடவும் சம்மதிக்கிறேன். எனது அடையாளக் குறிப்புகள் மூன்றாவது நபருக்குத் தெரிவிக்கப்படமாட்டாது என்று புரிந்து கொண்டேன்.

இந்த ஆய்வு அறிக்கைகளைப் பயன்படுத்தவும், வெளியிடவும், நான் சம்மதிக்கிறேன். ஆய்வாளர் எனது மருத்துவக் குறிப்புகளை வெளியிடத் தடையாக இருக்க மாட்டேன் என உண்மையாக சம்மதிக்கிறேன்.

நான் இந்த ஆய்வுக்கு முன்னர் கூறிய மருத்துவக் குறிப்புகளின்படியும் உண்மையாக சம்மதிக்கிறேன். மேலும் எனக்கு உடல் நிலை சரியில்லாத பட்சத்தில் ஆய்வாளர்களுக்குத் தெரியப்படுத்த சம்ம்திக்கிறேன்.

பொது மயக்க மருத்துவ முறையில் கன்ன எலும்பு- மேல்தாடைக் கூட்டு முறிவுக்கு அறுவைச் சிகிச்சை அளிக்கப்படுகிறது என்பதை நான் அறிந்து கொண்டேன். இந்த அறுவைச் சிகிச்சையின் பலனைத் தெரிந்துக் கொள்ள மூன்று விதமான ஆய்வு சோதனைகளான கடிக்கும் திறன், தசை நார்கள் செயல்பாட்டுத்திறன், கீழ்த்தாடை அசைக்கும் திறன் ஆகியவற்றை மேற்கொள்ள நான் சம்மதிக்கிறேன்

நான் எனது மருத்துவக் குறிப்புகளைத் தரவும், மேலும் முழு உடல் பரிசோதனைக்கும் இரத்தம், சிறுநீர் மற்றும் வேதியல் நோய் அறிதல் சோதனைகளுக்கும் முழு ஒப்புதல் அளிக்கிறேன்.

பங்கேற்பவரின் கையொப்பம் ………………இடம்…………………தேதி……

கட்டை விரல் ரேகை

பங்கேற்பவரின் பெயர் மற்றும் விலாசம்……………………………………………………

ஆய்வாளரின் கையொப்பம்………………………………இடம் ………………தேதி………

ஆய்வாளரின் பெயர்………………………………………………………………..