UNIVERSITY of the WESTERN CAPE

THE PREVALENCE AND PATTERN OF MID FACIAL FRACTURES AT TYGERBERG ORAL HEALTH CENTRE

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Submitted in partial fulfilment of the requirements for the degree M.Sc. Maxillofacial Radiology in the Department of Diagnostics and Radiology, Faculty of Dentistry, University of the Western Cape

The prevalence and pattern of mid facial fractures at Tygerberg Oral Health Centre

KEY WORDS

Maxillofacial trauma

Mid face fractures

Imaging

CBCT

CT

Prevalence

Pattern

Radiographs

ABSTRACT

<u>The prevalence and pattern of mid facial fractures at Tygerberg Oral Health Centre</u>

Background: Changing trends have been observed in the prevalence, etiology, imaging practice and pattern of presentation of mid facial fractures in different geographical regions. Conventional (plain) radiographs remain the most common initial investigative tool for general appraisal of suspected fractures, while advanced imaging is currently the most common final investigation. This study explored the clinico-radiologic patterns of mid facial fractures with main focus on demographic characteristics, etiology, fracture patterns and imaging practice.

Aim: To determine the Prevalence, Clinical and Radiologic patterns of mid-facial fractures at Tygerberg Oral Health Centre, Faculty of Dentistry, University of the Western Cape

Methodology: A retrospective cross sectional quantitative descriptive study of mid facial fractures was conducted at The University of the Western Cape's Faculty of Dentistry based at the Tygerberg Oral Health Centre (TOHC). The study population comprised 239 patients who presented with mid facial fractures over 2 years, from January 2015 to December 2016. The data captured included demographic details, etiology, fracture site(s) and radiological investigations performed.

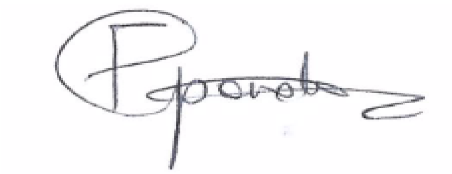
Results: A vast male predominance was observed (M: F=5.3:1). The age range was 7-76 years (mean 31.94; SD 13.13). The most affected age category was 21 to 30 years (39.7%) while the least affected groups were children aged 0 to 10 years and patients above 70 years old. A total of 285 individual fractures were identified among the 239 patients (mean of 1.2 fractures per patient). The most common pattern of fracture was zygomatic complex (24.9%) while Le Fort fractures were the least common (5.3%). 20.1% of patients had concomitant fractures of other bones of the face and skull. There was no association between gender and site of fracture ($p = 0.812$). Panoramic radiography was the most common initial investigation. A panoramic radiograph in combination with various conventional extraoral views were sufficient for diagnosis in 18.8% of the patients. However, majority (53.6%) had all the three types of imaging performed (panoramic radiograph, conventional extra oral views and advanced imaging). The most common etiological factor was assault (73.6%). There was no association between gender and aetiology of fracture ($p = 0.537$)

Conclusion: Mid facial fractures constitute a significant proportion of cranio-facial injury. The epidemiological trends observed in this study were generally comparable to other regional studies, except for a much higher prevalence of assault related fractures. Fractures of the mid facial region commonly present with concomitant injury to neighboring anatomical structures, hence interdisciplinary cooperation is valuable in-patient management. Although advanced imaging is eventually performed for most patients with mid facial fractures, conventional radiographs still have a role in the initial appraisal of a proportion of patients. The findings of the present study may serve as a reference for developing clinical and research protocol, legislation and formulating intervention measures.

DECLARATION

I declare that **'The Prevalence and Pattern of Mid Facial Fractures at Tygerberg Oral Health Centre"** is my own work, that it has not been submitted for any degree or examination in any other university, and that all sources I have used or quoted have been indicated and acknowledged by complete references.

Florence Opondo



Signed ……2nd August 2019………………...

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DEDICATION

This thesis is dedicated to:

My beloved husband Herman and my sons Jesse, Azel and Eden. You are my support pillars. You all made my journey possible and worthwhile.

My friends in South Africa, you made this my home away from home.

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LIST OF ABBREVIATIONS

TOHC Tygerberg Oral Health Centre

CT Computed Tomography

CBCT Cone Beam Computed Tomography

ZMC Zygomatico-maxillary complex

NOE Naso-orbito-ethmoidal

SN Sino-nasal

3D Three dimensional

ALARA As Low As Reasonably Achievable

MRI Magnetic Resonance Imaging

CHAPTER 1: INTRODUCTION

The incidence, etiology and pattern of presentation of facial fractures has been dynamic in various parts of the world. Both developed and developing countries report varying trends, which have been found to partly depend on demographic characteristics, etiological factors , socio-economic trends and the influence of alcohol and drug abuse (Shayyab et al., 2012; Khan et al., 2015a; Kumar et al., 2015; Gupta et al., 2018). Studies suggest that etiological factors have an influence on the resultant patterns of maxillofacial injuries seen in different settings. With the development of high-speed means of travel, increasing participation in sports across all ages and genders, and the increase in violent crime, the incidence of mid facial fractures is also increasing (Vrinceanu & Banica, 2014).

The diagnosis of mid facial fractures is based on correlation of clinical and radiologic findings. This can be challenging especially in patients presenting with multiple and complex fractures. Misdiagnosis results in poor treatment outcomes and patients may suffer long term consequences such as disfiguring scars, bony malformations, loss of vision and adverse psychological impact.

For the optimal use of ionizing radiation and time, clinicians need adequate knowledge regarding the imaging procedures that provide the greatest diagnostic information in the shortest amount of time and at the lowest radiation dose. (David et al., 2017).

The role of conventional radiographs in mid facial trauma evaluation has been questioned, with some studies suggesting that conventional radiography is no longer relevant in mid facial fracture diagnosis. Although most patients with mid facial fractures initially undergo conventional radiography and eventually end up having advanced imaging in the form of Computed Tomography (CT) or Cone Beam Computed Tomography (CBCT), Dreizin *et al.*, (2018) reported that the role of multidetector CT is key yet not singular.

Changing trends necessitate continuous research to describe and document the patterns that are unique to each setting. This study explored the clinico-radiologic patterns of mid facial fractures with key interest in demographic characteristics, etiology, fracture patterns and imaging practice. The study findings may be a basis for preventive legislation as well as contribute to a clinical and research protocol in mid facial trauma evaluation.

CHAPTER 2: LITERATURE REVIEW

2.1 Anatomy of the mid-face

The mid facial region is a complex part of the craniofacial anatomy. It comprises multiple separate bony units that inter-relate with each other hence diagnosis and management of fractures of this region can be challenging. It also includes some of the most prominent facial bones and thus contributes greatly to an individual's appearance. Its strategic location makes it the main focus of our gaze in face to face communication, therefore deformities of this region are generally perceived to be more disfiguring compared to those of the lower part of the face (Marciani, 1993).

Apart from its structural properties, the mid-face has functional roles pertaining to respiration, speech, swallowing, mastication, olfaction and vision hence it deserves particular attention with regard to evaluation and management.

The mid-face or middle third of the face comprises the central part of the facial skeleton that includes the nose, maxillary sinus and related neighboring bony structures (Figure 1). The superior boundary of the mid-face is a line that runs across the skull from the right zygomatico-frontal suture, through the fronto-nasal and fronto-maxillary sutures to the left zygomatico-frontal suture. The inferior boundary is the occlusal plane of the maxillary teeth in dentate patients or the maxillary alveolar ridge in edentulous patients. The lateral boundary is the temporal bone while the posterior boundary is the frontal bone superiorly and the sphenoid inferiorly. Thin bone segments of the mid-face are supported by a rigid frame of buttresses. The canines, zygomatic and pterygoid buttresses form the structural pillars of the mid-face (Thapliyal & Rajan, 2014). The bony components of the midface include two maxillae, zygomatic bones, zygomatic processes of the temporal bones, lacrimal, palatine and nasal bones, the vomer bone, the ethmoid including its attached conchae, two inferior conchae and the pterygoid plates of the sphenoid bone (Salzmann, 1978).

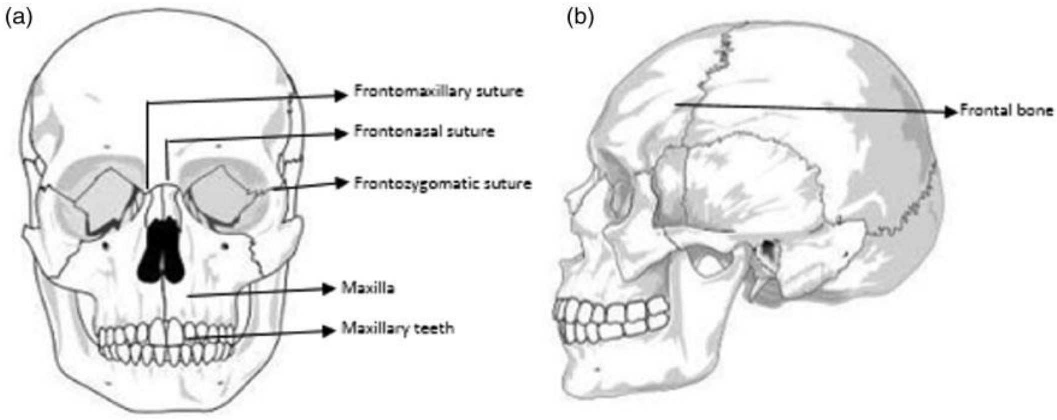


Figure 1. Anatomy of the mid face (David et al., 2017)

Fractures of the middle third of the face commonly occur in a complex fashion and rarely involve single bones. The sphenoid bone may be fractured in high energy mid facial trauma. The traumatic force is commonly dissipated through the pterygoid processes (Ernesto et al., 2013; Güneş, Aktürk & Güldoğan, 2018a).

2.2 Classification of mid-face fractures

The mid facial bones articulate in a complex manner; thus, most fractures involve injury to more than one bone. The classification of fractures of the mid-face has evolved over time from simple to more complex systems. Khan *et al*., (2015a) suggested that the complexity of mid facial injury may have also increased with the modernization of roads and the resultant high speed of traffic. As illustrated by Alves *et al*., (2014), mid facial fractures have traditionally been classified into Maxillary (Le Fort), Naso-orbito-ethmoidal (NOE), Zygomatico-maxillary complex (ZMC) and Orbital fractures. Currently, there are many classification systems for facial fractures. One of the most inclusive is the Duke classification (Figure 2) which is hierarchical and hence is practical for complex facial fractures (Follmar et al., 2007). Single bone fractures of the midfacial region may also occur.

Order 1	LeFort I
Order 2	LeFort II
Order 3	LeFort III Zygomaticomaxillary complex
Order 4	Naso-orbital-ethmoid
Order 5	All simple fractures

Figure 2. Duke classification system of facial fractures (Follmar et al., 2007)

2.2.1 Le Fort fractures

These fractures were described in the early 20th century by the French scientist Rene le Fort, cited in Bagheri *et al.*, (2005). His cadaveric study that was based on low impact traumatic force established typical fracture locations and formed a simple basis for describing maxillary fractures as Le fort I, II and III. Rene used plain radiographs to classify maxillary fractures based on major lines of disruption of the structural framework of the face. The fractures occurred bilaterally and symmetrically. Le Fort fractures involve the maxilla and surrounding structures in either a horizontal, pyramidal or transverse direction (Figure 3).

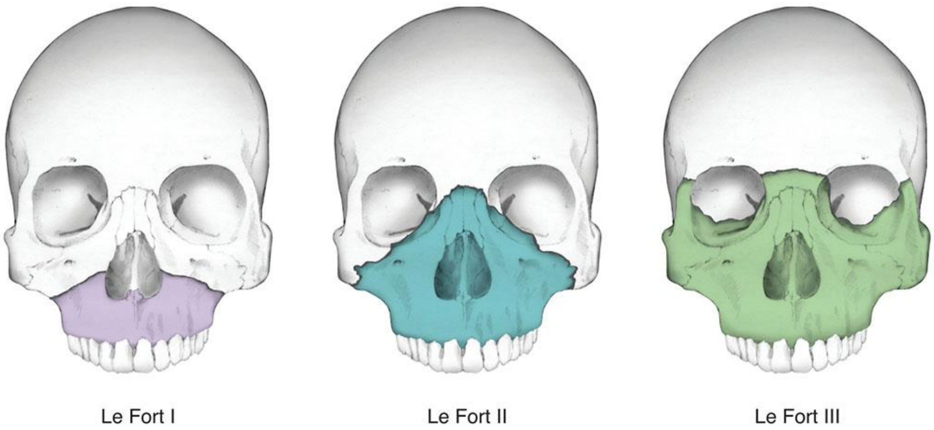


Figure 3. Le Fort fracture lines (Rogers & Allen, 2012)

The Le Fort I (horizontal) fracture separates the teeth from the upper face. The fracture extends through the alveolar ridge, lateral aspects of the nose and the inferior wall of maxillary sinus. They may be caused by an anterior force that is directed to the maxillary alveolar rim.

The Le Fort II (pyramidal) fracture extends through the posterior alveolar ridge, lateral walls of maxillary sinuses, inferior orbital rim and the nasal bones. Clinically, the entire maxilla separates from the face hence the maxilla moves freely in relation to the skull base.

The Le Fort III (transverse) fracture, also described as craniofacial disjunction, involves complete detachment of the face from the cranium. The fracture line extends through the naso-frontal suture, maxillo-frontal suture, orbital wall, zygomatico-frontal suture and zygomatic arches. All the three types of Le Fort fractures involve the pterygoid plates.

The Le Fort classification has been found to underestimate the complexity of mid-face fractures as seen on 3D imaging, thus reducing its practical application. Fractures seen in modern practice often deviate from the traditional bilateral and symmetrical Le fort presentation

(Dreizin et al., 2018). In a recent South African study by Magagula and Hardcastle, (2016) that involved retrospective review of CT scans of 52 patients with facial fractures, only 1 patient had true Le Fort type fractures. Other authors have since formulated other classifications to further describe more complex fracture patterns now detectable on CT (Osuagwu et al., 2013; Dreizin et al., 2018). The addition of Le Fort IV type of fractures has been suggested by some authors, in order to accommodate those Le Fort fractures that extend to the orbital apex (with frontal sinus fracture). Pre-operative identification of orbital apex involvement is of clinical relevance because significant force is generally applied to reduce Le Fort fractures. If fracture of orbital apex is missed, disimpaction and reduction of Le Fort fractures can pose substantial risk of inadvertent injury to surrounding vital structures including the internal carotid artery.

2.2.2 Nasal fractures

Naso-septal fractures

The nose is reported as one of the most frequently fractured facial bones (Kwang Seog Kim1 et al., 2018). The pair of nasal bones articulate with the frontal process of the maxilla and the frontal bone at the nasomaxillary and frontonasal sutures respectively. Although isolated nasal fractures may be perceived as minor, they may cause permanent disfigurement. The nasal septum maintains facial symmetry and airway patency

Naso-orbito-ethmoidal (NOE) fractures involve injury to the nasal, orbital and ethmoid bones and occur along five fracture lines. These include 1) the lateral nose encompassing the piriform aperture; 2) fractures crossing the nasomaxillary buttress and 3) extending to inferior orbital rim or floor; and 4) fractures of the medial orbital wall, 5) which extend back to the lateral nose through the frontomaxillary suture (Figure 4).

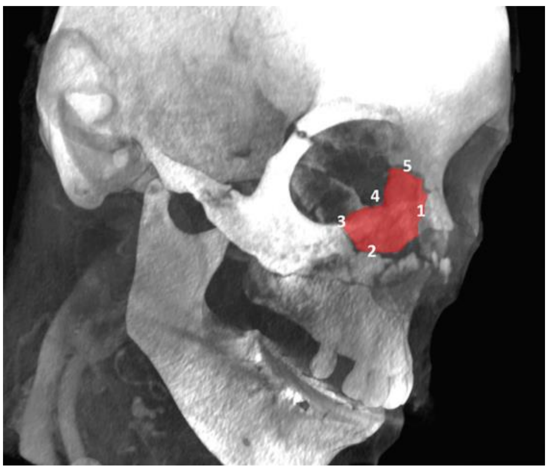


Figure 4. Preoperative volume-rendered CT image of NOE fracture (Dreizin et al., 2018)

The clinical signs include reduction of nasal prominence and increased intercanthal distance. Radiologically, a description of the nature and severity of comminution of the medial vertical maxillary buttress and ethmoid sinus would be valuable to the surgeon. Markowitz *et al.*, (1991) further classified NOE fractures based on the degree of injury to the medial canthal attachment as type I, II and III. In type I, the medial canthal insertion is intact while in type II the buttress is communited hence the canthus is only held by a fragmented bone. In type III the medial canthus is completely detached from bone. In a different study, Osuagwu *et al.*, (2013) described fractures involving the nasal bones, maxillary, ethmoid and frontal sinuses as Sino-nasal (SN) fractures.

2.2.3 Zygomatic fractures

Subsequent to the initial classification of zygomatic fractures by Zingg *et al.*, (1992), there have been additional classifications, but a uniform one is yet to be adopted.

Zygomatico-maxillary complex (ZMC) fractures involve injury to the zygomatic bone, zygomatic arch, orbital and maxillary bones. In a true ZMC fracture, the zygoma is fractured at the temporal, maxillary, sphenoid and frontal articulations (Figure 5). The four main fracture points include 1) the zygomaticomaxillary buttress from the inferior aspect of the crest to the infraorbital rim 2) the zygomaticosphenoid suture along the lateral wall of the orbit 3) the frontozygomatic suture and 4) the zygomaticotemporal suture. (Moreira Marinho & Freire-Maia, 2013).

Zygomatic arch fractures

Fractures of the zygomatic arch can occur in isolation or as part of Le Fort and ZMC fractures. Similarly, disruption of the zygomaticofrontal suture can also occur as part of a complex Le Fort fracture.

Figure 5. Three-dimensional reconstruction of ZMC fracture (Louis et al., 2017)

2.2.4 Orbital fractures involve fracture of the medial and lateral walls, roof and floor of the orbit (Osuagwu, et al., 2013). They rarely occur in isolation, but more commonly in association with ZMC fractures, Le Fort fractures and NOE fractures.

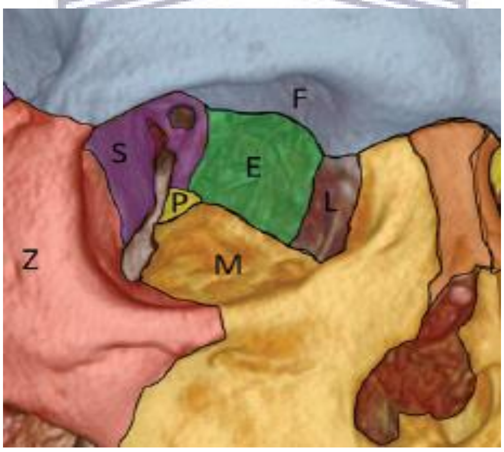


Figure 6. Three dimensional (3D) volume-rendered CT of the bony orbit: orbital surface of maxilla (M), ethmoid bone (E), orbital plate of the frontal bone (F), lacrimal bone (L), lesser and greater wings of the sphenoid (S), orbital surface of the zygomatic bone (Z), and orbital process of the palatine bone (P) (Dreizin et al., 2018)

Isolated fractures of the pterygoid processes are extremely rare. The pterygoid plates of the sphenoid bone are involved in all Le Fort type fractures. They may also occur in relation to other mid facial bone fractures (Surya et al., 2017; Güneş, Aktürk & Güldoğan, 2018b). In a study of 209 patients by Garg *et al.*, (2015)**,** 63% of pterygoid plate fractures were part of Le Fort Fractures while the other 37% were associated with spheno-temporal buttress fractures, zygomatic complex fractures, temporal bone fractures and complex mandibular fractures.

2.3 Clinical and demographic patterns

The clinical pattern and complexity of fractures is influenced by various factors, including the patient's age, type of force, degree of impact and the physical properties of the particular bone. In addition, many studies have reported that young people, especially men, generally suffer more maxillofacial trauma (Adebayo, Ajike & Adekeye, 2003; Septa et al., 2014; Thapliyal & Rajan, 2014; Khan et al., 2015a). A multicenter study on the pattern of maxillofacial injury in India by Naveen Shankar *et al.*, (2012) revealed that the highest incidence of facial fractures occurred among young patients aged 21-30. In a systematic review by Shayyab *et al.*, (2012), it was established that most of the patients with facial fractures in different countries across the world were young adults with a mean age of 24.4. The studies above also revealed a male preponderance in the epidemiology of facial fractures.

There have been many large studies on maxillofacial trauma while only few have concentrated on the epidemiology of mid facial trauma. Zaleckas *et al.*, (2015) reported that the mean age of patients with mid-face fractures was 33.1 years, with a male predominance (4.4:1). This finding was close to Septa *et al.*, (2014) study of mid facial fractures, whereby the mean age was 29.6 years and a male predilection of 76% was seen. From the studies reviewed, it generally appears that mid facial fractures occur in an older age group compared to mandibular fractures.

Generally, studies on facial trauma previously reported a higher prevalence of mandibular fractures compared to the mid-face. However, different trends are emerging. In a retrospective analysis of maxillofacial fractures of 1284 patients in Seoul, Korea, the incidence of mid facial fractures was much higher than mandibular fractures (6.4:1). The overall incidence of mid facial fractures was 86%, which is the highest incidence reported among the studies reviewed (Park et al., 2015). In a study by Naveen Shankar *et al.*, (2012), 44% of the patients had mid facial trauma. Notably, patients with fractures extending to the skull base were not included in this study. Their inclusion would have possibly resulted in a higher incidence of mid facial fractures.

Many studies have reported that the nasal bone is the most commonly fractured bone in mid facial trauma (Kühnel & Reichert, 2015; Park et al., 2015; Kwang Seog Kim1 et al., 2018). On the contrary, a large Lithuanian study of 799 patients with mid facial trauma reported that the ZMC was the most frequently fractured region (Zaleckas et al., 2015). Two other large studies of maxillofacial trauma also found that the ZMC was the most common fracture site, more so in the age group of 21-30 years (Septa et al., 2014; Mezitis et al., 2015). However, in a large study in Portugal by Alves *et al.*, (2014) the most affected region was the NOE complex (67.5%) followed by the maxilla (57.4%). In a study by Van As *et al.*, (2006) on facial trauma among pediatric South African children, the leading fracture site among pediatric patients was the orbit, followed by the frontal bone and maxilla. However, Wong *et al.*, (2016a) found that the mandible was more frequently fractured in pediatric patients when he studied pediatric facial fractures at the same hospital eight years later.

Mid facial fractures commonly present with concomitant injuries of the head and cervical spine. Mithani *et al.*, (2009) suggested that concomitant injuries should be explored closely with various forms of facial fractures. According to Zhou *et al.*, (2015), head injuries occur in significant association with etiology, age and site of fractures. Osuagwu *et al.*, (2013) found a significant association between head injury and mid-facial fractures in a Nigerian study, whereby 33% of the patients with acute head injury had mid facial fractures. In a different study, Septa *et al.*, (2014) found that 85% of patients with midfacial fractures had associated ocular injuries. According to Tatar *et al.*, (2016), mandibular fractures are the most commonly occurring concomitant fractures and in general, orthopaedic injuries are the most common among associated systemic complications.

2.4 Etiology of midfacial fractures

Facial bone fractures generally result from motor vehicle accidents, interpersonal violence, falls, occupational accidents, sports related accidents and other miscellaneous causes such as pathological fractures or gun shots. A systematic review by Shayyab *et al.*, (2012) revealed that road traffic accident related facial trauma had decreased in developed countries and increased in developing countries. On the contrary, assault related facial trauma had increased in developed countries and reduced in developing countries.

In many studies where motor vehicle accidents were the leading etiology, the mandible was reported as the most frequently fractured bone (Adebayo, Ajike & Adekeye, 2003; Motamedi, 2003; Shayyab et al., 2012). However, in a retrospective analysis of maxillofacial fracture patterns in the metropolitan region of Seoul, Korea, by Park *et al.*, (2015) the most common etiologies were falls (32.5%) and assault (26%) and one third of the fractures were related to alcohol use.

Studies reveal that interpersonal violence and motor vehicle accidents are the leading cause of mid facial fractures in many developed and developing countries (Van As et al., 2006; Dibaie, Raissian & Ghafarzadeh, 2009; Naveen Shankar et al., 2012; Osuagwu et al., 2013; Septa et al., 2014; Zaleckas et al., 2015; Louis et al., 2017). In addition, most fractures of the nasal complex are due to assault (Kühnel & Reichert, 2015).

In an Iranian study of facial injuries by Dibaie, Raissian and Ghafarzadeh, (2009) whereby nasal bone fractures were the majority, the leading cause of facial fractures was assault. This may possibly demonstrate a link between etiology and fracture pattern because in interpersonal violence, the nose is an easy target due to its prominence and weak nature.

Most pterygoid plate fractures occur in association with other mid facial bone fractures. However, isolated fractures of the pterygoid plates are commonly caused by penetrating injuries. Surya *et al.*, (2017) reported a rare incident of an isolated lateral pterygoid plate fracture that was caused by a penetrating foreign body.

There are few published studies on etiology of facial fractures in South Africa and none on mid facial fractures. In a study of adult patients in Kwa Zulu Natal by Magagula and Hardcastle, (2016), 96% of facial fractures were caused by motor vehicle accidents while the remaining 4% were caused by assault. The etiology of facial fractures differs between adult and pediatric groups (Tatar et al., 2016). There are only two published studies on facial fractures among pediatric patients in Cape Town, South Africa and in both studies, motor vehicle accidents were also the leading etiological factor (Van As et al., 2006; Wong et al., 2016b). Since various etiological factors have been found to influence the incidence and subsequent fracture patterns observed (Thapliyal & Rajan, 2014; Khan et al., 2015b), correlation of etiology and resultant fracture patterns would be an important aspect of data analysis.

2.5 Imaging of the mid-face

Due to the complexity of the mid facial skeleton, thorough clinico-radiologic evaluation is essential for accurate diagnosis and effective management. The choice of imaging modalities is steered by the overall condition of the patient, imaging options available, cost effectiveness and specific clinical needs of the patient (David et al., 2017). During the clinical examination of a patient with suspected mid facial fractures, palpating bony landmarks like the orbital rims, malar bones, zygomatic arches and nasal bones for irregularities is vital as it guides the imaging modality to be performed and provides focal points for the area of interest. Paresthesia in the area distributed by a particular nerve may be suggestive of injury and this can also guide the imaging modality. A high index of suspicion for intracranial and ocular injuries must be maintained, especially in complex mid facial fractures with comminution (Thapliyal & Rajan, 2014; Khan et al., 2015a).

Conventional (two dimensional) radiographs are still the most common initial investigation performed in the evaluation of mid facial fractures due to availability, affordability and low radiation exposure (David et al., 2017). The relevance of conventional radiography has however been questioned due to low diagnostic accuracy in evaluation of facial skull injury (Bogusiak & Arkuszewski, 2010). Conventional radiographs, though widely used, do not allow accurate assessment of the extent and severity of mid facial injuries. This was demonstrated in a study by Van As *et al.*, (2006), whereby patients with maxillofacial fractures had both CT scans and plain radiographs ordered. Sixty-five percent of the fractures missed on plain radiographs were revealed in the CT scans of the same patients. The fractures frequently missed on plain radiographs were those of the maxilla, zygoma and orbit.

The utilization of 3D imaging (CT, CBCT, Magnetic Resonance Imaging (MRI) and sonography) in evaluation of mid facial trauma has increased recently (David et al., 2017). CT is currently the final and most common investigation carried out for definitive diagnosis of most mid facial fractures and is regarded as the gold standard (Van As et al., 2006; Osuagwu et al., 2013; Dreizin et al., 2018). High definition scanners enable visualization of very small fractures of the facial skeleton (Sohns et al., 2013; Ansari et al., 2015). Osuagwu *et al.*, (2013) reported that CT is the imaging modality of choice in evaluating mid facial trauma when head injury is suspected.

The positioning of patients with complex and multiple fractures is challenging and potentially dangerous particularly when there is injury to the cervical spine. Current Multi Detector CT Scanners (MDCT) allow fast, sensitive assessment of both bone and soft tissue injuries in patients with extensive trauma. Their good spatial resolution and ability to produce multiplanar reformations and 3D reconstruction aids diagnosis and treatment planning hence they are the imaging of choice in maxillofacial trauma when extensive assessment is needed (Ansari et al., 2015). The use of CBCT has also increased lately in various clinical applications in maxillofacial surgery. Its popularity is based on its compact designs, lower set up cost, good hard tissue contrast and lower radiation dose compared to multi slice computed tomography, especially when smaller fields of view are needed. However, a systematic review by (De Vos, Casselman & Swennen, 2009) reported that there was iadequate evidence based data to support dose reduction by CBCT when large fields of view are used for assessment as seen during evaluation of extensive trauma. A different CBCT study by Roman *et al.*, (2016) revealed that the orbital floor is involved in most cases of mid facial trauma and oblique sections from the 3D volume are highly accurate in detecting orbital floor fractures. The use of ultrasound as a complementary diagnostic procedure to augment CT in the assessment of patients with mid-facial fracture has also been suggested (Shah, 2014). Access to advanced imaging modalities has influenced the imaging practice in many centres, leading to enhanced diagnostic yield regarding extent and severity of fractures (Dreizin et al., 2018).

2.6 Summary of literature review

Mid facial fractures constitute a significant proportion of craniofacial injury. The studies reviewed have demonstrated changing trends in the prevalence, etiology, imaging practice and pattern of presentation of mid facial fractures regionally and across the world. It is also clear that the vast majority of traumatic lesions of the mid face present with concomitant injury to neighboring structures such as the cervical spine, skull base and orbit hence require interdisciplinary cooperation. A wide range of imaging techniques can be utilized in mid facial fracture evaluation. The choice of imaging technique(s) is eventually guided by the principle of As Low As Reasonably Achievable (ALARA). Most of the large studies reviewed here have been retrospective cross-sectional studies, an approach which has enabled easier sample selection and access to patient data.

There is little information about the epidemiology of mid facial trauma in South Africa. The findings of a descriptive study of mid facial fractures may be a useful reference for developing clinical and research protocol, legislation and evaluating preventive measures. The resultant database may also contribute to a larger multicenter study in future.

CHAPTER 3: AIMS AND OBJECTIVES

3.1 Aim

To determine the prevalence, clinical and radiologic patterns of mid-facial fractures at Tygerberg Oral Health Centre.

3.2 Objectives

- To determine the prevalence of mid facial fractures.
- To describe the demographic characteristics of the study population.
- To describe the patterns of mid facial fractures.
- To describe the imaging modalities commonly used in evaluation of mid facial fractures.
- To describe the reported etiology of mid facial fractures.

CHAPTER 4: MATERIALS AND METHODS

4.1 Study area

The study was conducted at The University of the Western Cape's Faculty of Dentistry based at the Tygerberg Oral Health Centre (TOHC). This is a public teaching and referral dental hospital that serves a wide catchment area within the Western Cape Province. The folders of all the patients seen at TOHC are kept in a centralized registry. Patients who present with facial fractures are seen at the maxillofacial surgery clinic, whereby the demographic details and folder numbers of all the patients seen are recorded in daily registers and stored chronologically. The TOHC has a comprehensive radiology department where conventional radiographs, digital imaging and advanced imaging techniques (CBCT) are carried out. Other advanced imaging other than CBCT are performed at the Tygerberg hospital and viewed at the TOHC through the PACS system.

4.2 Study design

This was a retrospective cross sectional quantitative descriptive study of mid facial fractures using secondary data over a two-year period, from January 2015 to December 2016.

4.3 Study population

This comprised all the patients who presented with mid facial fractures at TOHC over a period of 2 years, from January 2015 to December 2016.

Inclusion criteria

All the patients with mid facial fractures from January 2015 to December 2016

Patients whose clinical findings and radiological diagnosis were clearly outlined

Exclusion criteria

Patients without mid facial fractures, even if they had fractures of other facial bones

Patients with incomplete clinical records

Patients with unclear or inconclusive diagnosis

4.4 Sample size and sampling methods

A convenience sampling method was applied whereby all patients with mid facial fractures over the study period who met the inclusion criteria were included in the study. At the onset, the sum total of patients who presented with facial fractures over the two-year period was 781. Out of these, 278 patients were found to have presented with mid facial fractures. Among the 278 patients with mid-face fractures, 39 patients were eliminated due to inadequate records such as incomplete clinical notes, unclear diagnosis and missing folders. Eventually, the final sample of patients studied was 239.

4.5 Data collection

Two pre-designed Microsoft excel 2017 spreadsheets were used to capture the data (Appendix). The initial step in data acquisition was to access the trauma patients' register at the out-patient maxillofacial and oral surgery clinic and identify all the patients who presented with maxillo-facial fractures from January 2015 to December 2016. Their folder number and fracture site were recorded on Data chart 1. From the first data chart, patients with mid facial fractures were identified and their folders retrieved for additional information with regard to age, gender, type of imaging performed, and fracture patterns observed. This information was recorded on data chart 2.

4.6 Data processing

Each subject was given a record number that corresponded to the folder number. This guaranteed confidentiality and additionally ensured a cross-reference for the researcher. Subjects with missing data within Data chart 2 were identified and eliminated. There were 14 missing folders while another 25 subjects were eliminated due to missing or inconclusive clinical and radiological information.

4.6.1 Imaging

The extraoral imaging procedures performed on the subjects preoperatively were recorded. Intra oral radiographs were not considered. It was noted that a wide range of radiological examinations were performed on different subjects as follows: Occipitomental projections (standard views and waters views); Panoramic radiographs; Lateral skull projections; Postero-anterior radiographs; Reverse towne's radiographs; Submento-vertex radiographs; Lateral oblique radiographs; CBCT and CT scans. For purposes of this study, the radiological examinations performed were eventually grouped into four main categories as follows.

- Panoramic radiograph (PAN) only
- PAN + additional conventional extra-oral views
- PAN + additional conventional extra-oral views + Advanced imaging (CBCT & CT)
- Advanced imaging only (CBCT & CT)

4.6.2 Fracture patterns

While recording the fracture sites, a variety of fracture patterns were observed as follows: Le Fort (I, II, III); Isolated fractures of the zygoma and/or zygomatic arch; ZMC; NOE; Isolated nasal; Orbital rim and/or floor; Dento-alveolar; Maxillary buttress and fractures of the maxillary tuberosity. For purposes of this study, the fracture patterns observed were grouped into the following main categories.

- Le Fort (I, II, III)
- Maxillary occlusion bearing segment (dento alveolar and tuberosity)
- Zygoma (isolated)
- ZMC
- Nasal
- NOE
- Orbit (isolated)
- Concomitant fractures of skull and facial bones

4.7 Analysis

The data was analyzed using StataCorp. 2017 (Stata statistical software: Release 15. College Station, TX: StataCorp LLC). The relative frequency of the fracture patterns and imaging modalities was determined, and the prevalence of mid facial fractures was determined for the two years. Statistical tests of significance were computed and applied where applicable.

4.8 Ethical Considerations

A research proposal was initially submitted to the Dental Faculty and Senate Research Ethics Committee of the University Western Cape and permission to conduct the study was granted (Appendix). In addition, permission to access medical records at TOHC was granted by the Dean of Faculty (Appendix).

Since secondary data was used in this study, there was no direct interaction with patients. Patients' names and other personal identification details were not captured during data collection. Anonymity was preserved by using a record number that was linked to the patient folder number. Patients' folders were analyzed within the institution and none left the Centre.

CHAPTER 5: RESULTS

5.1 Prevalence of mid facial fractures

Based on the patient register at the Department of Maxillofacial and Oral Surgery at TOHC, a total of 781 patients presented with facial fractures from 1st January 2015 to 31st December 2016. Out of these, 278 patients (35.6%) were found to have presented with mid facial fractures**.** 39 out of the 278 patients were eliminated due to incomplete clinical records and missing folders. Eventually, 239 patients (30.6%) with mid facial fractures met the inclusion criteria and were studied.

5.2 Demographic characteristics

201 males (84.1%) and 38 females (15.9%) were studied (Table 1). The male to female ratio was 5.3:1. The overall age range at the time of diagnosis was 7 to 76 years with a mean age of 31.94 (SD 13.13). The most affected overall age category was 21 to 30 years (39.7%) while the least affected groups were children aged 0 to 10 years and patients above 70 years old (2.1% and 1.3% respectively).

Table 1. Distribution of patients with midfacial fractures according to age and gender (N=239)

Age	Female (n)	Female (%)	Male (n)	Male (%)	Grand Total	Grand Total (%)
0-10	0	0.0%	5	2.5%	5	2.1%
11-20	3	7.9%	31	15.4%	34	14.2%
21-30	10	26.3%	85	42.3%	95	39.7%
31-40	9	23.7%	39	19.4%	48	20.1%
41-50	6	15.8%	26	12.9%	32	13.4%
51-60	7	18.4%	8	4.0%	15	6.3%
61-70	2	5.3%	5	2.5%	7	2.9%
70+	1	2.6%	2	1.0%	3	1.3%

Mean age 31.94 (SD 13.13)

5.3 Pattern of mid facial fractures

A total of 285 individual fractures were identified among the 239 patients. This represents a mean of 1.2 fractures per patient. Overall, seven fracture patterns were observed at the 285 fracture sites. These included Le Fort fractures (I, II, III), isolated fractures of the zygomatic bone (including isolated arch fractures), ZMC fractures, isolated nasal fractures, NOE fractures, isolated orbital fractures and fractures of the occlusion bearing segment of the maxilla (dento-alveolar and tuberosity).

The most common pattern of fracture was ZMC (24.9%) followed by isolated orbital fractures (22.1%) while the least common fracture pattern was Le Fort fractures (Table 2).

Table 2. Frequency of fracture patterns

	LE FORT	ZYGOMA	ZMC	NASAL	NOE	ORBIT	MAXILLA	TOTAL
n	15	33	71	41	12	63	50	N=285
%	5.3%	11.6%	24.9%	14.4%	4.2%	22.1%	17.5%	100%

15 patients presented with Le Fort fractures, as follows: Le Fort I (n=7), Le Fort II (n=3), Le Fort III (n=2), while 3 patients had a combination of various Le Fort fractures. Dento alveolar and tuberosity fractures were both categorized as fractures of the maxilla. In this category, 92% were dentoalveolar fractures while fractures of the maxillary tuberosity were only 8%.

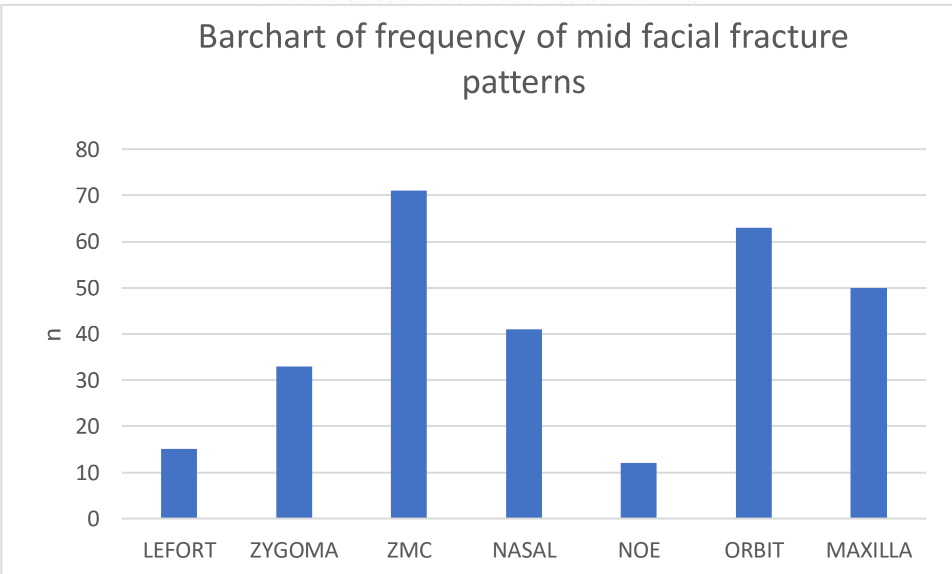


Figure 7. Frequency of mid facial fracture patterns

Regarding distribution of fractures among different ages, isolated nasal fractures and fractures of the maxilla (dento alveolar) were seen across all the age categories. ZMC fractures were also seen across all ages except in the pediatric group aged 0 to 10 years. The majority of mid facial fractures were seen among patients aged 21 to 30 years (39.7%), with ZMC fractures being the most frequent fracture pattern in this group. Forty-three percent of the ZMC fractures occurred among the 21 to 30 years age category. It is also notable that isolated orbital fractures were the most common among the youngest age group (0 to 10) and the oldest group (70+). Figure 8 and Table 3 illustrate the distribution of fracture patterns according to age category.

Table 3. Distribution of fractures according to age category (N=285)

Age	Le Fort (n)	Le Fort (%)	Zygoma (n)	Zygoma (%)	ZMC (n)	ZMC (%)	Nasal (n)	Nasal (%)	NOE (n)	NOE (%)	Orbit (n)	Orbit (%)	Maxilla (n)	Maxilla (%)
0-10	0	0.0%	0	0.0%	0	0.0%	1	2.4%	0	0.0%	3	4.8%	1	2.0%
11-20	2	13.3%	1	3.0%	10	14.1%	4	9.8%	2	16.7%	9	14.3%	11	22.0%
21-30	4	26.7%	11	33.3%	30	42.3%	14	34.1%	5	41.7%	24	38.1%	24	48.0%
31-40	4	26.7%	6	18.2%	14	19.7%	6	14.6%	3	25.0%	16	25.4%	7	14.0%
41-50	3	20.0%	9	27.3%	10	14.1%	10	24.4%	2	16.7%	6	9.5%	4	8.0%
51-60	1	6.7%	6	18.2%	2	2.8%	4	9.8%	0	0.0%	3	4.8%	1	2.0%
61-70	0	0.0%	0	0.0%	5	7.0%	1	2.4%	0	0.0%	0	0.0%	1	2.0%
70+	1	6.7%	0	0.0%	0	0.0%	1	2.4%	0	0.0%	2	3.2%	1	2.0%
N=285	15		33		71		41		12		63		50	

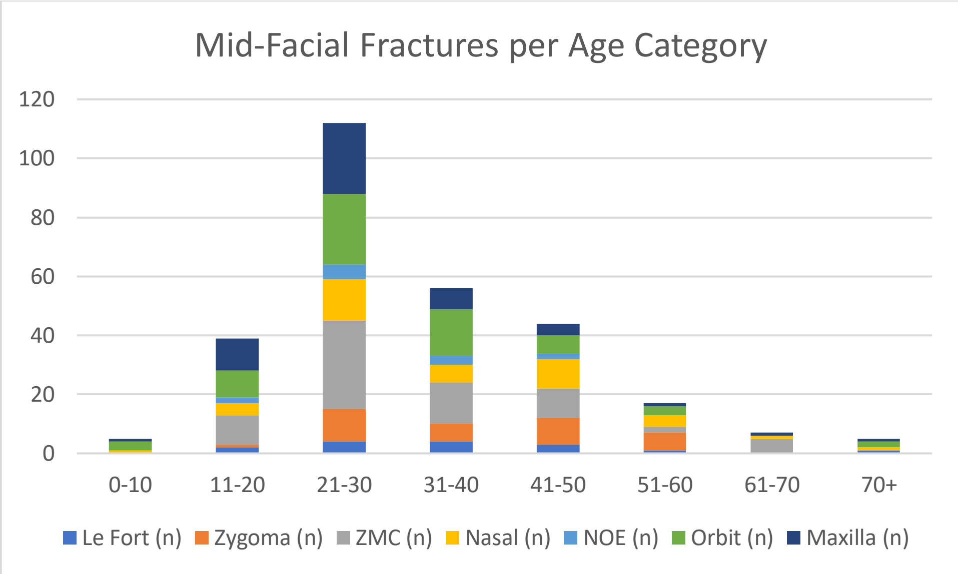


Figure 8. Graph illustrating distribution of fracture patterns according to age category.

All the fracture patterns were more prevalent among the male patients (Figure 9). The most common fracture pattern in males was ZMC while isolated orbital fractures were the most common in the female patients. It was also notable that no female presented with NOE fracture during the study period. The assumptions for a Chi square test (expected value must be >5) were not fulfilled and hence the Fisher's exact test was utilised to test the relationship between gender and site of fracture. There was no association between gender and site of fracture according to the Fisher's exact test ($p = 0.812$; which is >0.05).

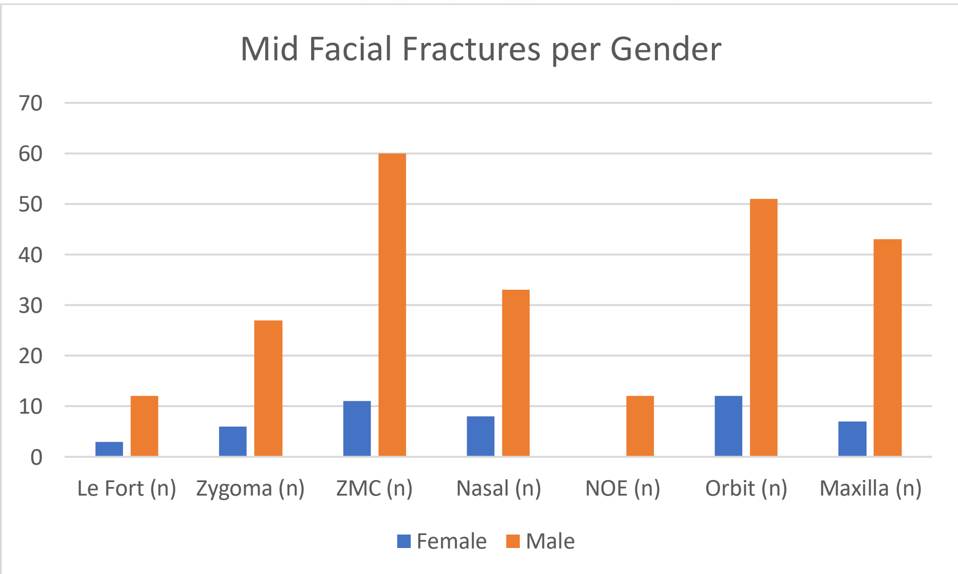


Figure 9. Bar graph showing distribution of fracture patterns according to gender.

Concomitant fractures of the face and skull were observed in 20.1% of the patients (N=48) with mid facial fractures (Figure 10). Twenty-three patients had concomitant mandibular fractures while 18 patients had frontal bone fractures. The distribution of concomitant fractures among the other patients was as follows: Fracture of both frontal and parietal bone (n=1), fracture of both mandible and frontal bone (n=1), pterygoid fracture (n=1), skull base fracture (n=1), unspecified skull fracture (n=1) and temporal bone fracture (n=2).

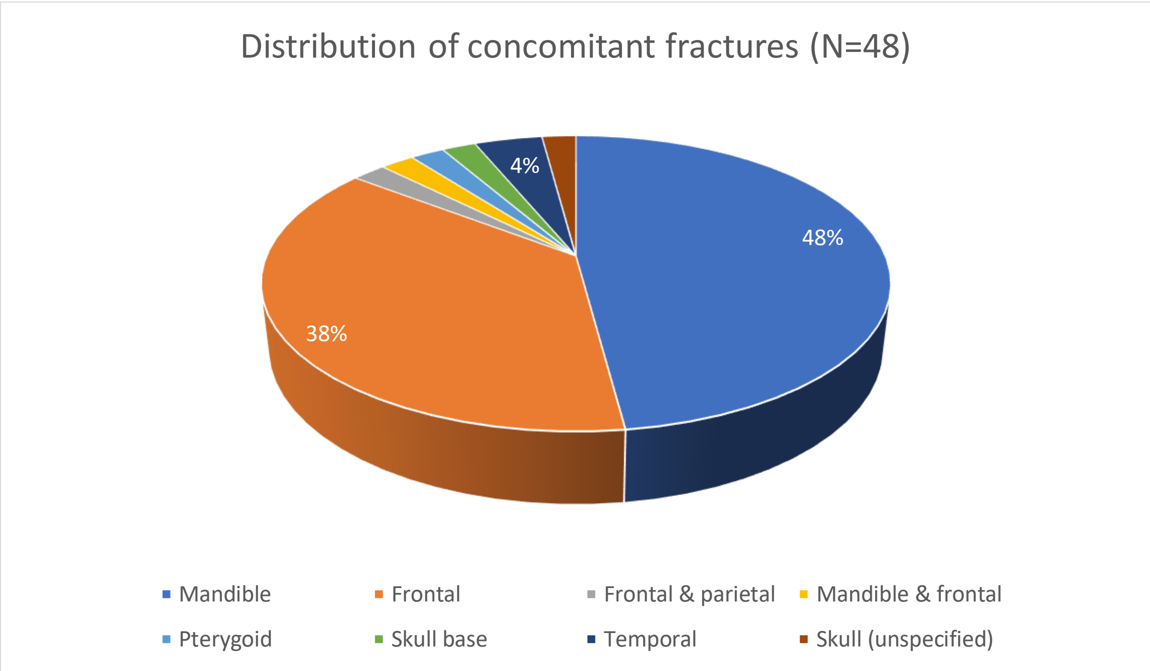


Figure 10. Distribution of concomitant fractures (N=48).

5.4 Imaging modalities

The extra-oral imaging modalities utilized during the pre-treatment evaluation of patients with mid facial fractures were appraised. For the diagnostic imaging of individual patients (N=239), the panoramic radiograph was the most common initial investigation, as it was performed in 196 patients (82%). A panoramic radiograph in combination with various two-dimensional extraoral views were found to be sufficient for diagnosis in 18.8% (n=45) of the patients. However, majority of the patients (53.6%) had all the three types of imaging performed (panoramic radiograph, conventional extra oral views and advanced imaging). Only 18% of the patients (n=43) had advanced imaging as the only investigation (Table 4).

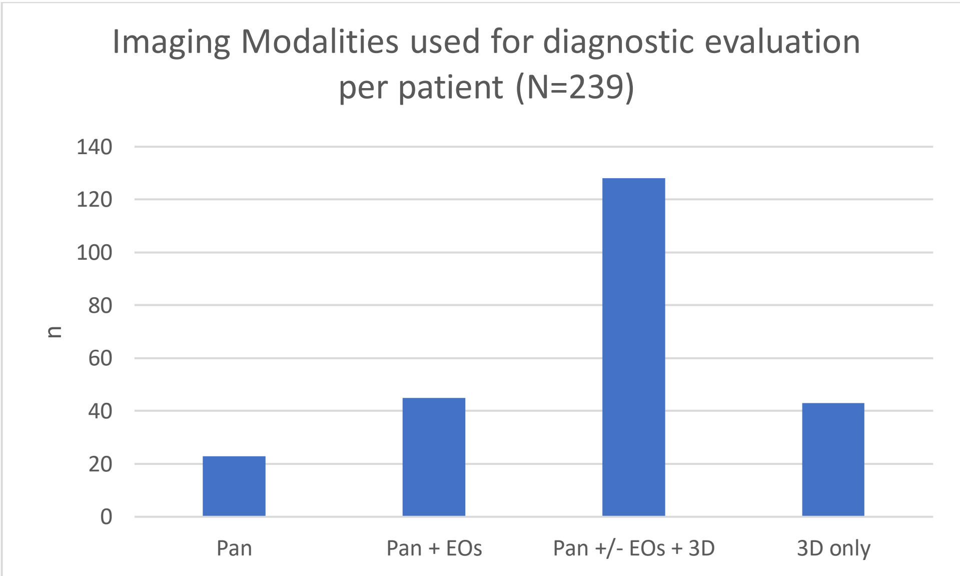


Figure 11. Imaging modalities used for diagnostic evaluation per patient (N=239)

Regarding the diagnostic evaluation of specific fracture sites (N=285), the panoramic radiograph was once again the most commonly used imaging modality, as it was utilized in the evaluation of 80.4% of the fractures, either alone or in combination with other radiological examinations. Only 8.1% of mid facial fractures were diagnosed using panoramic radiographs alone while 16.8% were diagnosed using a combination of panoramic radiograph and additional conventional extraoral views. Majority of the fractures (55.4%) were diagnosed using a combination of panoramic radiograph, conventional extraoral views and advanced (3D) imaging while 19.7% were diagnosed using advanced (3D) imaging alone (Table 4 and Figure 12).

It is notable that advanced imaging was incorporated in the diagnostic evaluation of all the NOE fractures. However, two-dimensional imaging alone was found to be sufficient for the diagnosis of most dento alveolar and tuberosity fractures (60%).

Table 4. Imaging modalities utilized during pre-treatment evaluation of specific fracture sites (N=285).

	Le Fort (n)	Le Fort (%)	Zygoma (n)	Zygoma (%)	ZMC (n)	ZMC (%)	Nasal (n)	Nasal (%)	NOE (n)	NOE (%)	Orbit (n)	Orbit (%)	Maxilla (n)	Maxilla (%)	
Pan	0	0.0%	2	6.1%	2	2.8%	3	7.3%	0	0.0%	0	0.0%	16	32.0%	23
Pan + EOs	1	6.7%	9	27.3%	9	12.7%	7	17.1%	0	0.0%	8	12.7%	14	28.0%	48
Pan +/- EOs + 3D	12	80.0%	15	45.5%	48	67.6%	16	39.0%	10	83.3%	41	65.1%	16	32.0%	158
3D only	2	13.3%	7	21.2%	12	16.9%	15	36.6%	2	16.7%	14	22.2%	4	8.0%	56

(Pan: Panoramic radiograph; EO: Extra-oral radiograph)

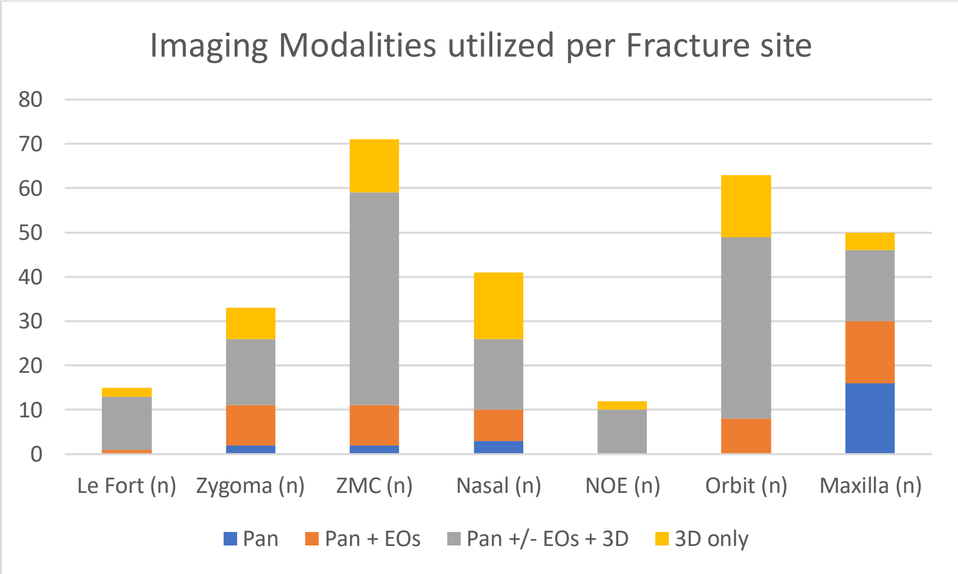


Figure 12. Graph of imaging modalities utilized during pre-treatment evaluation of specific fracture sites (N=285)

20.1% of the patients with mid facial fractures (N=48) presented with concomitant fractures of the skull and facial bones. The imaging modalities employed in the diagnosis of concomitant fractures were recorded. It was notable that advanced imaging was incorporated in the diagnostic evaluation of 42 out of 48 patients with concomitant fractures. In 6 patients with concomitant mandibular fractures, no advanced imaging was utilized. Thirty-seven out of 48 patients (77.1%) with concomitant fractures were evaluated using a combination of panoramic radiograph, conventional extraoral views and advanced (3D) imaging while only 5 patients underwent advanced imaging alone (Table 5).

Table 5. Imaging modalities utilized in diagnosis of concomitant fractures of the skull and facial bones (N=48)

	Frontal	Frontal & Parietal	Mandible	Mandible & Frontal	Pterygoid	Skull	Skull Base	Temporal
	n	n	n	n	n	n	n	n
Pan	-	-	1	-	-	-	-	-
Pan + EOs	-	-	5	-	-	-	-	-
Pan +/- EOs + 3D	15	1	17	1	-	1	1	1
3D only	3	-	-	-	1	-	-	1
(Pan: Panoramic radiograph; EO: Extra-oral radiograph)								

5.5 Etiology of mid facial fractures

A total of 176 out of 239 patients (73.6%) sustained mid facial fractures as a result of assault while 12.6% sustained fractures following motor vehicle accidents. Pedestrian vehicle accidents (pedestrian hit) were responsible in 4.6% of patients. The least common etiological factors were sports injuries (2.1%), occupational (0.4%) and iatrogenic injuries (1.7%). In terms of the different age categories, assault was by far the leading etiological factor except in patients under 10 years, whereby fractures were mainly caused by motor vehicle accidents or personal injuries (falls). Table 6 illustrates the etiological factors in relation to age.

The assumptions for a Chi square test (expected value must be >5) were not fulfilled and hence the Fisher's exact test was utilised to test the association between gender and etiology of fracture. The association between gender and etiology of fracture was not significant according to the Fisher's exact test ($p = 0.537$; which is >0.05).

Table 6. Etiological factors in relation to age category (N=239)

Age	MVA	Assault	Sport	Personal	Occup.	PVA	Iatrog.	Total
<10	**2**	**1**	**0**	**2**	**0**	**0**	**0**	**5**
11-20	**6**	**22**	**2**	**1**	**0**	**3**	**0**	**34**
21-30	**7**	**81**	**2**	**0**	**0**	**2**	**3**	**95**
31-40	**5**	**36**	**1**	**4**	**1**	**1**	**0**	**48**
41-50	**6**	**21**	**0**	**2**	**0**	**3**	**0**	**32**
51-60	**2**	**11**	**0**	**2**	**0**	**0**	**0**	**15**
61-70	**2**	**3**	**0**	**1**	**0**	**2**	**1**	**9**
71-80	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**
Total	**30**	**176**	**5**	**12**	**1**	**11**	**4**	**239**

CHAPTER 6: DISCUSSION

The bones of the mid facial region have a complex anatomical relationship, hence diagnosis of fractures of this region can be challenging to both the clinician and radiologist. A variety of possible fracture patterns have been described to date. Conventional radiography remains the most common initial investigative tool for general appraisal of suspected fractures. In modern practice, the use of advanced imaging has immensely enhanced diagnostic accuracy with resultant improvement in post treatment outcomes.

This study analysed the clinico-radiologic features of mid facial fractures in 239 patients seen at Tygerberg Oral Health Centre with key emphasis on epidemiology, etiology, pattern of presentation and imaging practice. This is one of the rare studies on mid facial fractures conducted among the South African population. Many similarities and some differences have been highlighted by comparison of the findings of this study with other population-based studies.

6.1 Prevalence of mid facial fractures

The prevalence of mid facial fractures differs widely between various geographical regions. Despite the fact that most studies report mandibular fractures as more common than mid facial fractures, there is universal agreement on the overall rising prevalence of mid facial fractures as a result of multiple factors. The highest prevalence of mid facial fractures (86%) was reported by Park *et al.*, (2015) in a retrospective Korean study of 1284 patients with maxillofacial fractures. A different multicenter study of facial trauma in Karnataka, India reported a prevalence of 29.7% (Naveen Shankar et al., 2012). A lower prevalence of 21.2% was reported in a comprehensive 7 year study by Bali *et al.*, (2013), while the lowest prevalence of mid face fractures (11.7%) was seen in a study of facial injuries in children aged 0-16 years by Ashrafullah, Pandey and Mishra, (2018). Few published studies describe the epidemiology of maxillofacial fractures in South Africa, but none focusses on mid facial fractures. The overall prevalence of mid facial fractures in this study was 35.6%. This compares closely to the study by Naveen Shankar *et al.*, (2012) in Karnataka, India.

6.2 Demographic characteristics

The outcome of this study concurs with most current literature that there is a vast male preponderance with regard to facial fractures in general. A Lithuanian study of 799 patients with mid facial fractures reported that 82% of the participants were male (Zaleckas et al., 2015).

This compares closely to the present study, as 201 (84.1%) were males while only 38 (15.9%) were females. The male to female ratio was 5.3:1. The male patients were predominant in all the age categories, while notably, there was actually no female in the age category of 0 to 10 years. A total of 155 out of the 201 male patients (77.1%) were aged between 11 to 40 years old. This supports the notion by Shayyab *et al.*, (2012) that facial fractures mainly occur in young males. The overall age range for the patients studied was 7 to 76 years with a mean age of 31.94 (SD 13.13). This is close to the findings of two studies performed in Lithuania and Indore whereby the mean age for mid facial fractures was 33.1 and 29.6 years respectively (Septa et al., 2014; Zaleckas et al., 2015). In the current study, the most affected overall age category was 21 to 30 years, as 39.7% of all the fractures were observed in this category. The least affected groups were children aged 0 to 10 years and patients above 70 years old (2.1% and 1.3% respectively). These findings are comparable to numerous studies that reported a low prevalence of mid facial fractures in children under 10 years and adults over 70 years (Naveen Shankar et al., 2012; Shayyab et al., 2012; Septa et al., 2014; Thapliyal & Rajan, 2014)

6.3 Pattern of mid facial fractures

The clinical pattern and complexity of fractures may vary depending on the patient's age, type of force, degree of impact and the physical properties of the particular bone (Khan et al., 2015a). Due to the complex articulation of mid facial bones, most fractures involve more than one bone. Single bone fractures also occur, though to a lesser extent, as was the case in this particular study.

In general, mid facial fractures have traditionally been classified into Maxillary (Le Fort), Naso-orbito-ethmoidal (NOE), Zygomatico maxillary complex (ZMC) and Orbital fractures (Alves et al., 2014). Currently, there are many classification systems for facial fractures in the literature. In the present study, a broad range of fracture patterns were observed, namely: Le Fort (I,II,III); Isolated fractures of the zygoma and/or zygomatic arch; ZMC; NOE; Isolated nasal; Orbital rim and/or floor; Dento-alveolar; Maxillary buttress and fractures of the maxillary tuberosity. For purposes of this study, the mid facial fractures observed were categorized into seven overall patterns of presentation. These included Le Fort fractures, isolated fractures of the zygomatic bone (including isolated arch fractures), ZMC fractures, isolated nasal fractures, NOE fractures, isolated orbital fractures and fractures of the maxilla (dento-alveolar and tuberosity). Concomitant fractures of other bones of the skull and face were also noted.

A total of 285 individual mid facial fractures were identified among the 239 patients. This represents a mean of 1.2 fractures per patient. This finding supports other studies which reported that a proportion of patients with mid facial fractures had multiple fracture sites (Septa et al., 2014; Vrinceanu & Banica, 2014; Mezitis et al., 2015). In a study by Bali *et al.*, (2013), an average of 1.4 fractures per patient was reported while Sohns *et al.*, (2013) reported a mean of 1.5 fractures per patient.

In the present study, the most prevalent pattern of fracture was ZMC (24.9%) followed by isolated orbital fractures (22.1%) while the least common fracture pattern was Le Fort fractures (5.3%). Comparably, ZMC fractures were the most prevalent in some large studies with demographic characteristics that were similar to the present study (Septa et al., 2014; Mezitis et al., 2015; Zaleckas et al., 2015). A large study in Greece by Mezitis *et al.*, (2015) reported a significant increase in ZMC fractures over the past three decades. However, many more studies reported that the majority of mid facial fractures involved the nasal bone, either in isolation or as part of the NOE complex (Alves et al., 2014; Kühnel & Reichert, 2015; Park et al., 2015; Dreizin et al., 2018; Kim et al., 2018). It is also worth noting that only 15 out of the 239 patients studied (6.3%) had Le Fort fractures. The low prevalence of Le Fort fractures is supported by current literature which reveals that fractures seen in modern practice often deviate from the traditional bilateral and symmetrical Le fort presentation (Dreizin et al., 2018). The practical application of the Le Fort classification has reduced in clinical practice, as it underestimates the complexity of mid-face fractures as seen on 3D imaging. A recent South African study by Magagula and Hardcastle, (2016) involving retrospective review of CT scans also supported this notion, since only 1 patient had a true Le Fort type of fracture. In the present study, dento alveolar and tuberosity fractures were categorized as fractures of the maxilla. 46 out of 285 fractures (16.2%) were dento alveolar while tuberosity fractures were only 4 out of 285 fractures (1.4%). Bali *et al.*, (2013) found that dento alveolar fractures comprised 28% of all mid facial fractures. All in all, majority of the literature reviewed did not consider maxillary dento alveolar and tuberosity fractures as autonomous entities.

Regarding distribution of fracture patterns across different ages, isolated nasal fractures and maxillary dento alveolar fractures were observed across all the age categories. The susceptibility of patients across all age categories to nasal and maxillary dento-alveolar fractures could be explained by the prominent location of the nose and maxillary dento-alveolar bone, making them a vulnerable site in mid facial trauma. The nasal bones are also structurally weaker than other mid facial bones that are supported by a strong framework of buttresses.

ZMC fractures were by far the most common fracture pattern, particularly in the age category of 21-30 years old. Notably, ZMC fractures were also observed across all ages except in the pediatric group aged 0 to 10 years. Isolated orbital fractures were the most common among the youngest age group (0 to 10 years). Comparatively, in a study of South African children aged 2 months to 12 years, Van As et al., (2006) reported that the orbit was the leading fracture site. On the contrary, Wong et al., (2016a) found that the mandible was more frequently fractured in pediatric patients when he studied pediatric facial fractures at the same hospital eight years later.

All the fracture patterns were more prevalent among the male patients. This could partly be explained by the overall male predominance in the study. The most common fracture pattern observed in males was ZMC while isolated orbital fractures were the most common in the female patients. Septa *et al.*, (2014) found that ZMC fractures were the most common among both males and females. In the present study, it was notable that no female presented with NOE fracture during the study period. Since the assumptions for a Chi square test were not fulfilled, the Fisher's exact test (which is non-parametric) was used to test the relationship between gender and site of fracture. The association between gender and site of fracture was not significant ($p = 0.812$, which is >0.05).

Trauma to the cranio-maxillofacial region is often accompanied by occult concomitant head and cervical spine injuries (Mithani et al., 2009). It is of paramount importance to rule out concomitant fractures when evaluating mid facial trauma. The present study observed concomitant fractures of the skull and facial bones in 20.1% (N=48) of the patients with mid facial fractures. The most commonly occurring concomitant fractures were mandibular fractures (n=23) followed by fractures of the frontal bone (n=18). Tatar *et al.*, (2016) also found that mandibular fractures were the most commonly occurring concomitant fractures in relation to mid facial trauma. An interesting observation in the present study was that one patient with a ZMC fracture had a concomitant fracture of the pterygoid plate. Isolated fractures of the pterygoid processes are extremely rare. Pterygoid plate fractures are commonly part of Le Fort fractures and less frequently associated with other mid facial bone fractures (Surya et al., 2017; Güneş, Aktürk & Güldoğan, 2018b). The other concomitant fractures observed included fracture of both frontal and parietal bone (n=1), fracture of both mandible and frontal bone (n=1), skull base fracture (n=1), unspecified skull fracture (n=1) and temporal bone fracture (n=2).

6.4 Imaging modalities

Imaging is an indispensable tool in the evaluation of a trauma patient. Detailed and systematic clinico-radiologic evaluation is essential for diagnostic accuracy and effective management of mid facial fractures. Radiological protocol should include the imaging procedures that provide the greatest diagnostic information in the shortest amount of time and at the lowest radiation dose. The choice of imaging modalities is steered by the general state of the patient, imaging options available, cost effectiveness and specific clinical needs of the patient (David et al., 2017). The principle of ALARA must be applied in answering each clinical question (Shah, 2014).

A general appraisal of the extraoral imaging modalities utilized during the pre-treatment evaluation of patients with mid facial fractures was done. During the diagnostic evaluation of individual patients (N=239), the panoramic radiograph was the most common initial investigation, as it was performed in 82% (n=196) of the patients. Bali et al., (2013) had a similar observation in Haryana, India, whereby 72% of the patients had a panoramic radiograph as the initial investigation. An important finding in the present study was that a panoramic radiograph in combination with various two-dimensional extraoral views (Occipitomental views, Lateral view of face, Postero-anterior, Reverse towne's, Submento-vertex and Lateral oblique) were sufficient for establishing the final diagnosis in 45 (18.8%) of the patients. In the study by Bali et al., (2013) two dimensional imaging modalities were even more extensively utilized, as 98% of the patients initially had conventional radiographs comprising panoramic views, occipito-mental views, submento-vertex views, postero-anterior views and intra-oral periapicals.

Majority of the patients in the present study (53.6%) had a combination of all the three types of imaging performed (panoramic radiograph, conventional extra oral views and advanced imaging). These findings confirm that conventional (two dimensional) radiographs are still the most common initial investigation performed in the evaluation of mid facial fractures due to availability, affordability and low radiation exposure (David et al., 2017).

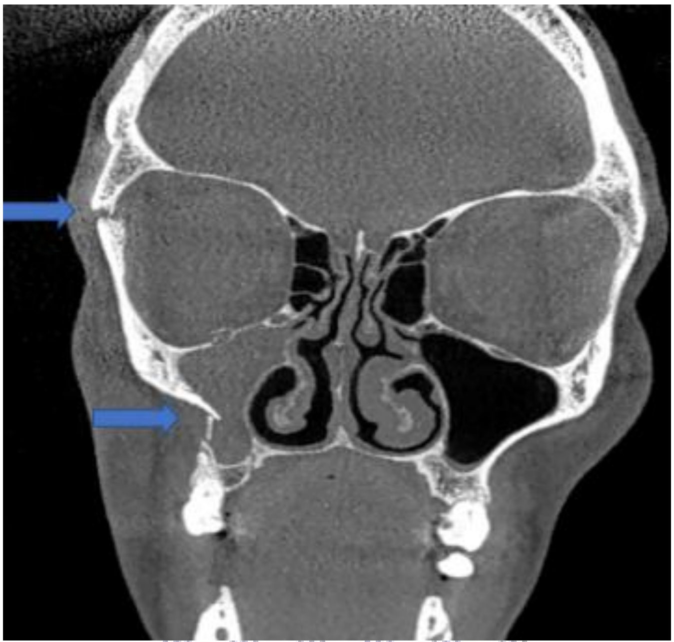
Only 43 patients (18%) had advanced imaging (CBCT and CT) as the only pre-treatment investigation. On overall appraisal of the utilization of advanced imaging modalities, the utilization of CT far exceeded the utilization of CBCT in the evaluation of individual patients. An overall total of 18 CBCT scans were performed compared to 158 CT scans (CBCT: CT=1:8.8). This could partly be attributed to the fact that a number of patients were initially seen at the emergency department of the Tygerberg hospital and hence CT examinations were performed prior to their presentation at the TOHC. In addition, most clinicians primarily asked for CT for mid facial trauma evaluation. In a study by Roman et al., (2016) on the use of reformatted CBCT images in evaluating mid-facial fractures with an emphasis on orbital fractures, the CBCT oblique sections offered good quality images comparable with bone window sections on medical CT. The high resolution reformatted CBCT images were sufficient in evaluating uncomplicated orbital floor fractures. However, most orbital fractures are accompanied by soft tissue injury, presence of foreign bodies, rupture of the globe, lens subluxation and haemorrhage, thus CT is indicated in evaluation of orbital trauma (David et al., 2017).

Regarding the diagnostic evaluation of specific fracture sites (N=285), the panoramic radiograph was once again the most frequently used imaging modality, as it was utilized in the initial evaluation of 80.4% of the fractures, either alone or in combination with other radiological examinations. Only 8.1% (n=23) of the mid facial fractures were diagnosed using panoramic radiographs alone while 16.8% were diagnosed using a combination of panoramic radiograph and additional conventional extraoral views. Two-dimensional imaging alone was found to be sufficient for the diagnosis of most dento alveolar and tuberosity fractures. Panoramic radiography alone is often not sufficient for the accurate diagnosis of most fractures outside the dento-alveolar segment of the maxilla (David et al., 2017).

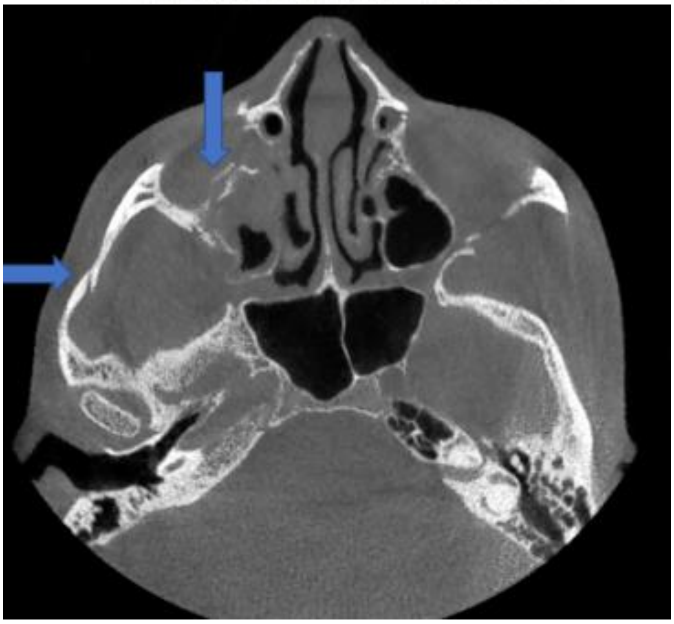
A combination of panoramic radiograph, conventional extraoral views and advanced (3D) imaging was utilized in the diagnosis of 55.4% of the mid facial fractures. This pattern of imaging supports the notion that two dimensional imaging may be sufficient for initial appraisal, but advanced imaging is thereafter incorporated in many cases when there are signs of underlying fractures and displacements (David et al., 2017). Only 19.7% of the fractures were diagnosed using advanced (3D) imaging alone. This was especially done when patients had multiple fracture sites. Notably, advanced imaging was incorporated in the diagnostic evaluation of all the NOE fractures. Ansari *et al*., (2015) compared the diagnostic efficacy of CT and conventional radiographs for mid face fractures and found that CT was statistically more significant in detecting fractures, displaying comminution and degree of displacement. Some studies have suggested the use of ultrasonography and MRI as alternatives for mid facial trauma evaluation (Shah, 2014). In as much as both have the benefit of being non ionizing, sonography is inaccurate in detecting non displaced fractures while MRI is less sensitive than

CT for bone disruption (David et al., 2017). In the present study, sonography and MRI were not utilized in the diagnosis of mid facial fractures.

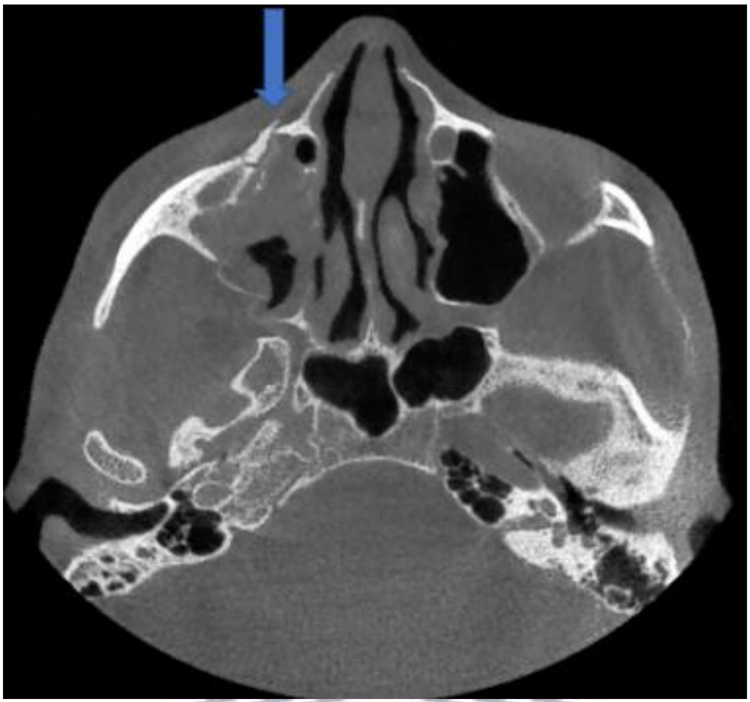
Figure 13: (A-E) CBCT images of a 27-year-old female patient with ZMC (quadripod) fracture whose complete imaging profile comprised occipitomental views (0^0,15^0,30^0), panoramic radiograph, CBCT and CT.



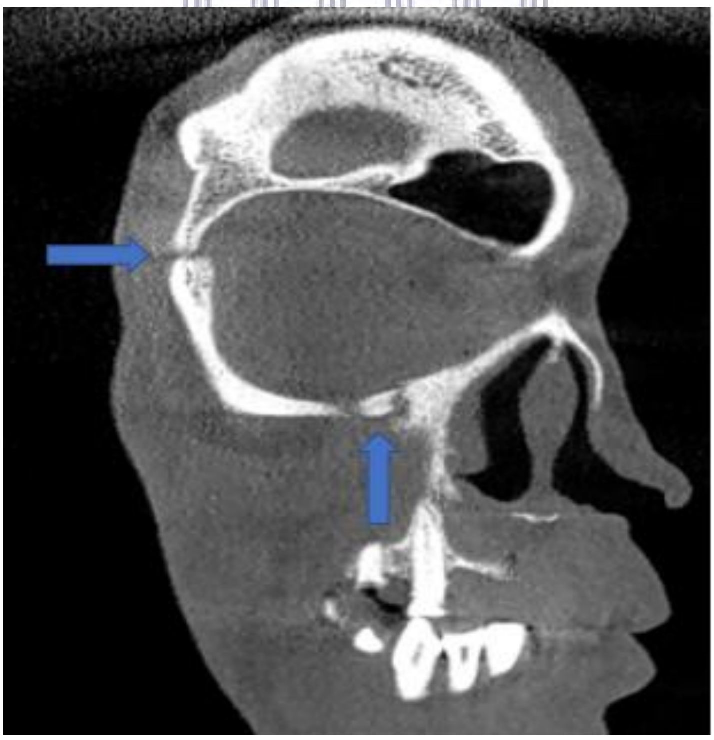
A: CBCT coronal slice; arrows illustrate fracture of lateral wall of right orbit and maxillary sinus and opacification of the right maxillary sinus



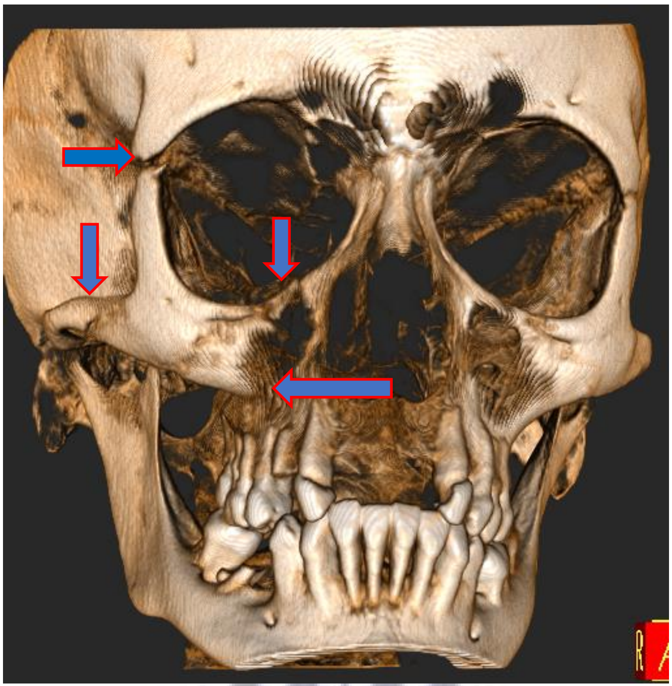
B: CBCT axial slice showing fracture of right zygomatic arch and floor of right orbit



C: CBCT axial slice showing orbital floor fracture in the same patient



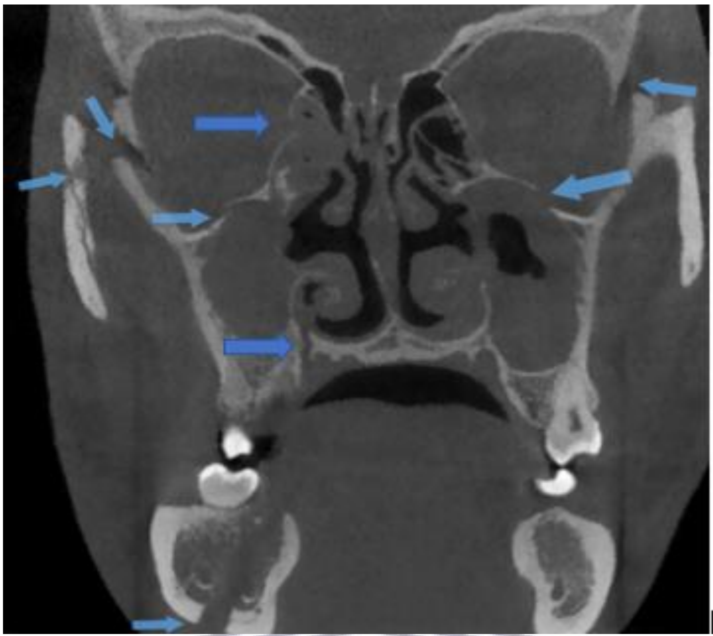
D: CBCT coronal oblique of same patient showing fracture of right lateral wall and floor of orbit



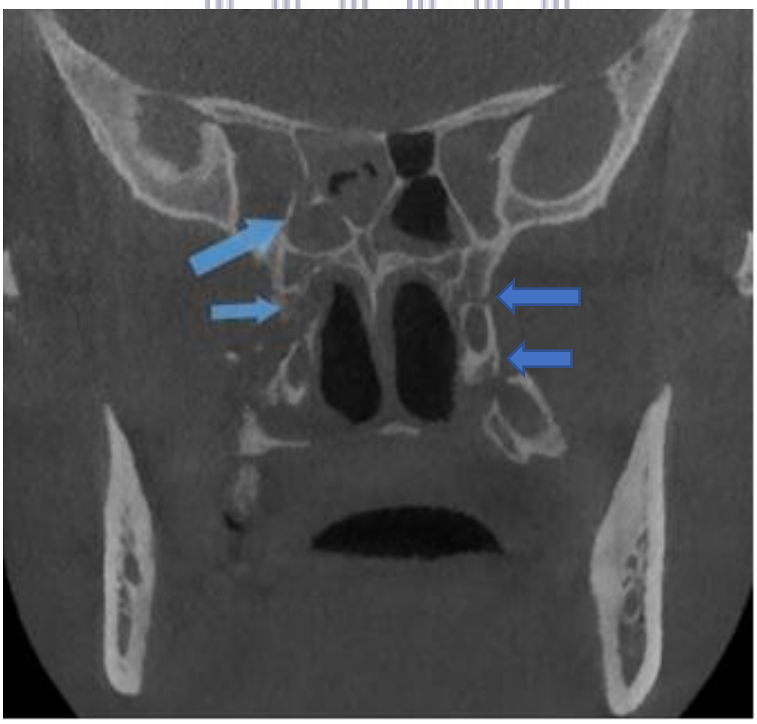
E: CBCT 3D reconstruction of same patient illustrating the ZMC (quadripod) fracture

In terms of associated injuries, 20.1% (N=48) of the patients with mid facial fractures had concomitant fractures of the skull and facial bones. The type of imaging modalities employed in the diagnosis of concomitant fractures were recorded. It was notable that advanced imaging was utilized in the diagnostic evaluation of 88% (n=42) of patients with concomitant fractures. This confirms that most clinicians rely on advanced imaging for the final diagnosis of associated injuries. Seventy-seven percent (n=37) of patients with concomitant fractures were evaluated using a combination of panoramic radiograph, conventional extraoral views and advanced imaging while only 5 patients underwent advanced imaging alone**.** For 6 patients with concomitant mandibular fractures, no advanced imaging was utilized. When Ansari et al., (2015) compared the diagnostic efficacy of CT and conventional radiographs for mandibular fractures, they concluded that there was no statistical difference between plain radiographs and CT for detection of fractures of the mandible.

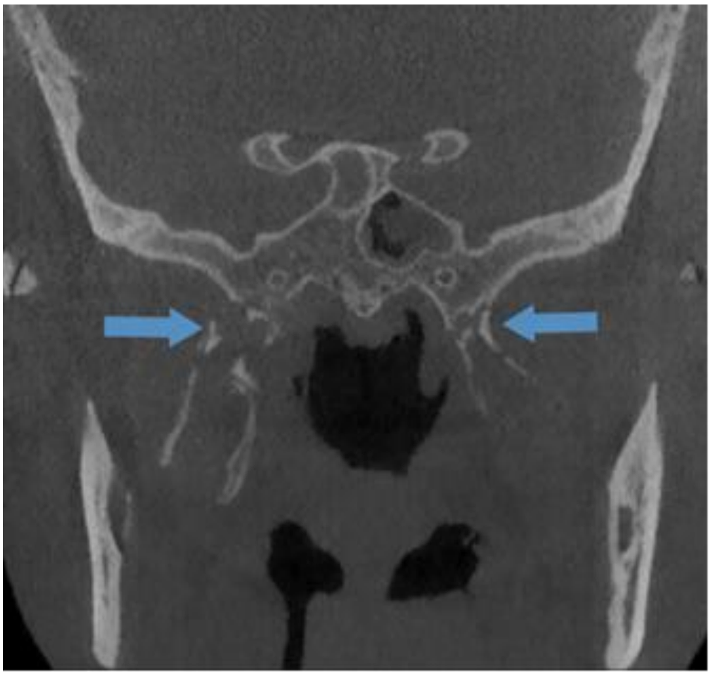
Figure 14: (A-D) CBCT images of a 22-year-old male patient with Le Fort III fracture and a concomitant mandibular fracture. His complete imaging profile comprised panoramic radiograph, postero-anterior view, CBCT and CT.



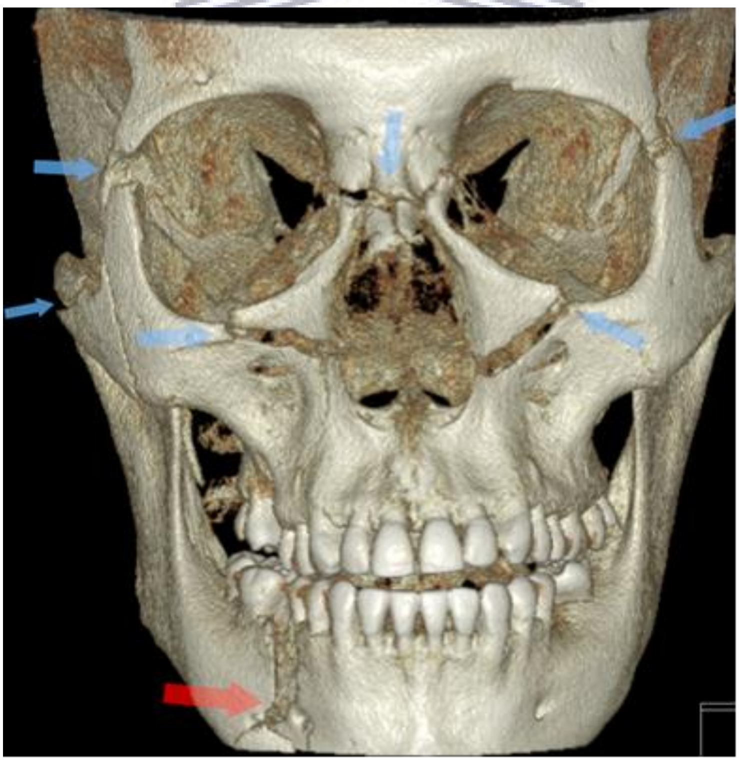
A: CBCT coronal slice; arrows indicate various fracture points. Opacification of right ethmoid and both maxillary sinuses is seen. Note the concomitant fracture of right body of mandible



B: CBCT coronal slice; arrows indicate various fracture points of sphenoid bone and pterygoid plates. Note opacification of sphenoid sinus.



C: CBCT coronal slice showing bilateral pterygoid fractures



D: CBCT 3D reconstruction; arrows illustrate various fracture points in cranio-facial dysjunction. Note concomitant fracture of mandible (red arrow).

6.5 Etiology of mid facial fractures

Literature has highlighted differences and changing trends in the etiology of facial fractures in general depending on geographical location, socio-economic factors, seasonal variations, gender, among others (Shayyab et al., 2012). Various etiological factors have been found to influence the incidence and subsequent fracture patterns observed (Thapliyal & Rajan, 2014; Khan et al., 2015b). In general, maxillofacial fractures are commonly caused by motor vehicle accidents, interpersonal violence, falls, work related accidents, sports related accidents and other miscellaneous causes such as pathological fractures or gun shots. A general trend is that road accidents are responsible for most cranio-facial trauma in developing countries while interpersonal violence is reportedly the leading cause in developed countries (Shayyab et al., 2012; Septa et al., 2014). Most studies also concur that the leading etiological factors in mid facial trauma (and facial trauma in general) are motor vehicle accidents and assault. (Louis et al., 2017). There is scanty literature on the etiology of facial fractures in South Africa and no published studies on the etiology of mid facial fractures.

The present study found that 176 out of 239 patients (73.6%) sustained mid facial fractures following assault while only 12.6% sustained fractures as a result of motor vehicle accidents. Only few studies of populations with similar demographic characteristics have reported interpersonal violence as the leading cause of mid facial fractures (Dibaie, Raissian & Ghafarzadeh, 2009; Zaleckas et al., 2015). On the contrary, most of the studies reviewed overwhelmingly reported motor vehicle accidents as the leading cause of mid facial fractures, followed by interpersonal violence (Lee et al., 2007; Naveen Shankar et al., 2012; Osuagwu et al., 2013; Septa et al., 2014; Kühnel & Reichert, 2015; Mezitis et al., 2015). The present study also found that pedestrian-vehicle accidents (pedestrian hit) were responsible for the fractures of 4.6% of the patients. The least common etiological factors were sports injuries (2.1%), occupation related injuries (0.4%) and iatrogenic injuries (1.7%). A different study in New Zealand compared aetiologies in maxillofacial trauma and reported that mid facial fractures were more commonly caused by motor vehicle accidents while interpersonal violence was responsible for most mandibular fractures (Lee et al., 2007).

When etiology was related to age, assault was still the leading aetiological factor in all the age categories except in patients under 10 years. The fractures in patients under 10 years old were mainly a result of motor vehicle accidents or personal injuries (falls). This confirms the observation by Tatar that the etiology of facial fractures differs between adult and pediatric groups (Tatar et al., 2016). Currently, there are only two published studies on facial fractures among pediatric patients in Cape Town, South Africa and in both studies, motor vehicle accidents were also the leading etiological factor (Van As et al., 2006; Wong et al., 2016b).

Since the assumptions for a Chi square test were not fulfilled, the Fisher's exact test (which is non-parametric) was used to test the relationship between gender of the patient and etiology of the fracture. The association between gender and etiology was not significant according to Fisher's exact test ($p = 0.537$, which is >0.05).

6.6 Study limitations and assumptions

The study relied on consistency of record keeping and the availability and accessibility of clinical information and radiographic images. It is worth noting that 39 patients with mid facial fractures were excluded from the study due to incomplete records or ambiguous clinical information.

Being a retrospective study, the opinion and interpretation of different clinicians could not be evaluated or standardised.

Another limitation is that this study explored only the extra oral imaging modalities that were utilized during the pre-treatment evaluation of patients. During the data collection process, it was evident that additional radiological investigations were performed during the post-treatment follow up period, mainly comprising plain radiographs. The utilization of conventional radiographs in mid facial trauma evaluation may thus be higher than depicted by the study outcome since the imaging modalities utilized in post treatment evaluation were beyond the scope of this study.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

Changing trends have been demonstrated in the prevalence, etiology, imaging practice and pattern of presentation of mid facial fractures regionally and across the world. The present study confirms that mid facial fractures constitute a significant proportion of cranio-facial injury. In this retrospective study, the epidemiology and pattern of mid facial fractures was presented in relation to previous and current literature. The trends observed in this study were generally comparable to other regional studies, except for a much higher prevalence of assault related trauma.

The value of interdisciplinary cooperation in patient management has also been highlighted as fractures of the mid facial region commonly present with concomitant injury to neighboring anatomical structures.

Radiological protocol should include the imaging procedures that provide the greatest diagnostic information in the shortest amount of time and at the lowest radiation dose. In as much as advanced imaging is eventually performed for most patients with mid facial fractures, conventional radiographs still have a role in the initial appraisal of a proportion of patients.

Utilization of cone beam computed tomography (CBCT) in the initial evaluation of mid facial trauma patients should be considered, when justified clinically. CBCT provides three dimensional images of bone with good resolution, at lower radiation doses compared to conventional CT. This may provide a more accurate overall picture of the extent of injury than conventional radiographs and further guide the clinician in determining the need for any additional advanced imaging procedures.

The findings of the present study may serve as a reference for developing clinical and research protocol, legislation and formulating intervention measures.

Long-term multicenter studies, especially prospective studies of larger populations using additional parameters are essential to confirm the findings of the present study and further explore the complexity of mid facial fractures in greater detail.

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APPENDICES

9.1 Ethical approval

UNIVERSITY of the WESTERN CAPE

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03 April 2019

Dr F Opondo
Faculty of Dentistry

Ethics Reference Number: BM17/2/2

Project Title: The prevalence and pattern of mid facial fractures at Tygerberg Oral Health Centre.

Approval Period: 19 October 2018 – 19 October 2019

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

BMREC REGISTRATION NUMBER -130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

9.2 Permission to access radiographic records

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15/02/2017

Dear Sir/Madam,

RE: PERMISSION TO USE RADIOGRAPHIC RECORDS

I hereby grant permission to Dr. Florence A. Opondo (student no: 3619370) to use the records from the radiographic archives for completing her postgraduate thesis: The Incidence and Pattern of Mid Facial Fractures at the Tygerberg Oral Health Centre

....

The Dean of Dentistry
Prof. Y. Osman

Private Bag X1, Tygerberg 7505, South Africa

A place of quality, a place to grow, from hope to action through knowledge

9.3 Data collection charts

<u>Data chart 1 (N=781)</u>

J13

	A	B	C	D	E	F	G	H	I
1	Folder number	Month & year	Fracture site						
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
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14									
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16									
17									
18									
19									
20									
21									

Sheet1

Data chart 2 (N=239)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
1	Record no	Age	G	OM0	OM15	OM30	OM45	Pan	Lat.F	PA	L.Obl	SMV	R.Town	CBCT	CT	LF1	LF2	LF3	ZMC	Z.Arch	Nasal	NOE	Orb. Flr	Orb.Rim	D.Alv	Tuber.	Zygoma	Other	Aetiology(1-6)
2																													
3																													
4																													
5																													
6																													
7																													
8																													
9																													
10																													
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16																													
17																													
18																													
19																													
20																													
21																													

Sheet1 Sheet2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Rec no	Age	G	Pan	Pan + EOs	Pan +/- EOs + 3D	3D only	LEFORT	ZYGOMA	ZMC	NASAL	NOE	ORBIT	MAXILLA	Other	Etiology
2																
3																
4																
5																
6																
7																
8																
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10																
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22																

Sheet1 Sheet2