Summary and conclusions
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This thesis aims to give an overview of the incidence, aetiology and treatment modalities of patients with traumatic injuries of the midface, especially zygomatic complex fractures, and their consequences.

The incidence of midfacial fractures is influenced by contributing factors, such as geographical area, cultural differences and socioeconomic status. The pattern of midfacial fracture presentation varies, depending on the trauma aetiology. Common causes of maxillofacial fractures include road traffic collisions (e.g. motorcycle, automobile, scooter, bicycle), violence, falls, sport related accidents, industrial/work related accidents and other miscellaneous causes (e.g. gunshot injuries, pathological fractures).

As there is still no consensus on the treatment of zygomatic complex fractures, Chapter 2 investigates the incidence and aetiology of surgically treated patients with zygomatic complex fractures (period 2000-2010), as well as the department’s protocol for the treatment of zygomatic complex fractures at VU University Medical Center in Amsterdam. The study population consisted of 236 patients, mostly males (72%) with a mean age of 39.3 years (SD: ±15.6). A total of 210 zygomatic complex fractures (89%), and 26 solitary zygomatic arch fractures (11%) were identified. In accordance with the literature, the main cause of the injury was road traffic collisions, followed by interpersonal violence. An aetiological transition tendency towards a rise in aggression over traffic accidents might explain why the left side (145 patients) was more affected than the right side (91 patients). The majority of people are right-hand dominant, and therefore more likely to deliver a blow on the left zygomatic complex in the violence-related cases. Clinical features most often demonstrated, were paraesthesia of the infraorbital nerve (47.0%), malar depression (37.3%) and periorbital hematoma/ecchymosis (36.0%). All of the patients with a solitary zygomatic arch fracture (11%) were treated with closed reduction, using the Gillies approach. Thirty-three patients (14%) with zygomatic complex fractures were treated with closed reduction, using a bone hook. As plate osteosynthesis has become state of the art in the treatment of maxillofacial fractures (greater stability and fewer complications), the remaining 177 zygomatic complex fractures (75%) were treated with open reduction and internal fixation (ORIF). Most of the fractures were fixed with 1 plate on the lateral orbital rim. With regard to surgical access of the zygomatic complex, there seems to be no consensus. In contrast to what is often shown in the literature, the department’s protocol demonstrates the lateral orbital rim approach (frontozygomatic suture) as the first-choice approach. Besides the low infection risk, which makes the use of prophylactic antibiotics unnecessary, the lateral orbital
rim approach is easy accessible for plate osteosynthesis. However, the frontozygomatic area is thought to be a less clear reference point for fracture reduction.\textsuperscript{11} On the other hand, the intraoral approach would result in a more stable reduction with a lower complication rate, whereas the infraorbital rim approach seems to be associated with higher complication rates.\textsuperscript{3,9,10,12-14} As the patients’ opinion was not obtained, regarding the formation of scar tissue at the lateral orbital rim, strong recommendations regarding the best surgical approach could not be provided. Twenty-nine patients (12.3\%) presented with complications after surgical treatment, of which suboptimal fracture reduction (15 patients) was most commonly described, followed by wound infection (9 patients). In 7 patients (3\%) surgical retreatment was necessary, of whom 4 patients (1.7\%) required a secondary orbital floor reconstruction due to enophthalmos and diplopia. Although no absolute indications for surgical treatment of zygomatic complex fractures have been demonstrated in the literature so far, it is supposed that in many studies, fracture displacement is considered as an indicator for surgical treatment, unless there are profound contraindications, such as comorbidities, the patient’s refusal or the absence of functional and/or aesthetic problems.\textsuperscript{15-18}

In Chapters 3 and 4 the epidemiological, clinical and radiographic features of surgically and non-surgically treated patients with zygomatic complex fractures over the period of 2007-2012 are retrospectively evaluated. Both patient groups were compared according to age, gender, cause of the trauma, clinical features, fracture site and the degree of fracture displacement (mild, moderate or severe displacement). In this way, an attempt was made to establish guidelines whether or not to treat a zygomatic complex fracture surgically. The population included 283 patients (71\% males, 29\% females), of whom 133 patients were treated surgically and 150 patients were treated non-surgically. The mean age was 42.8 years (SD: ±19.8), which was slightly higher compared to what is demonstrated in the literature (20-30 years), as also the non-surgically treated patients were included.\textsuperscript{3-5} However, a predominance of zygomatic complex fractures (23.7\%) in the age group of 20-29 years was found. The mean age of the non-surgically treated patients was significantly higher, compared to the surgically treated patients. Furthermore, the non-surgically treated patients with fracture displacement were aged higher (51.2 years, SD: ±23.6), especially the female patients (59.5 years, SD: ±27.4), compared to the non-surgically treated patients without fracture displacement (43.4 years, SD: ±20.6). Hypothetically, the non-surgically treated patients were older, as in this group aesthetics are arguably less important and more of the patients are regarded to be medically unfit for surgical treatment. Traffic accidents were the main cause of the trauma (43.1\%), followed by fall (27.2\%) and assault (20.5\%). With regard to the male patients, traffic accidents accounted for 43.3\% of the cases, followed by assault (26.4\%) and falls (20.9\%). Concerning the female patients, both traffic accidents (42.7\%) and falls (42.7\%) were
found as the most common cause, whereas zygomatic complex fractures due to assault were not found frequently (6.1%). In many other studies, traffic related accidents and assault are the most common causes, which is in accordance with our surgically treated population, but not with the non-surgically treated population. Fall was the main cause of injury in the non-surgically treated patients group and, in particular in those with displaced zygomatic complex fractures. This higher incidence of fall-related injuries, compared to what is demonstrated in the literature, could partially be attributed to the older aged female patients, who are greater at risk of falling and have different living and/or social habits. Overall, the surgically treated patients mainly consisted of young male adults and the traffic- and assault-related cause highly contributed to this group, whereas the non-surgically treated patients consisted of a high number of elderly female patients, especially where there was displacement of the zygomatic complex. Furthermore, there was a high number of fall-related causes, which accounted significantly more for the older ages (> 60 years).

In both the surgically and non-surgically treated patients, traffic related accidents mainly consisted of bicycle and motorcycle accidents with relatively more bicycle accidents accounting for the female patients. Amsterdam is a city with a lot of cyclists, which could explain this high prevalence of bicycle accidents.

All of the severely displaced and a majority (68.6%) of the moderately displaced zygomatic complex fractures were treated surgically, whereas only 2.1% of the mildly displaced zygomatic complex fractures were treated surgically. Surgical treatment of zygomatic complex fractures was significantly associated with the presence of palpable intraoral and extraoral step defects and malar depression. As paraesthesia of the infraorbital nerve was not significantly associated with surgical management, this feature should not be mentioned as an indicator for surgical treatment, which is also reported in the literature.14,15

In contrast to maxillofacial fractures in general, less information is available concerning the incidence and aetiology of midfacial fractures. Chapter 5 comprises a retrospective descriptive study, investigating the incidence, aetiology, surgical treatment and complications arising from the treatment of midfacial fractures at VU University Medical Center in Amsterdam during the period of 2000–2010. The purpose of this study was to have a close look on midfacial fractures in a Dutch trauma population. A total of 278 patients were treated surgically for their midfacial fractures by open or closed reduction. The midfacial fractures were classified into zygomatic complex fractures, zygomatic arch fractures, orbital blowout fractures, Le Fort I, Le Fort II, Le Fort III fractures and a combination of these fractures. The mean age was 38.2 years (SD: ±16.0). In accordance with what is reported in the literature, most of the patients were male (male-female ratio of 2.6:1) and were found in the age group of 20–29 years. Most of the female patients were aged 50 years and older. Road traffic collisions were identified as the most common cause of midfacial
Chapter 8 fractures (39.5%), followed by violence for males (16.9%) and falls for females (4.3%). When comparing male with female patients, violence-related midfacial injuries proved to be significantly more common in male patients. Compared with non-alcoholic patients, in patients whose alcohol consumption was involved, violence was found as the main cause of the injury. Accordingly, several other studies demonstrate that interpersonal violence has surpassed traffic accidents as the main causative event, most likely due to an aetiological transition tendency towards a rise in, alcohol induced, aggression over traffic accidents.\textsuperscript{13,22} As in line with the literature, zygomatic complex fractures were found to be the most common midfacial fracture site\textsuperscript{4,28}, followed by zygomatic arch fractures and orbital floor fractures. Complications arising after surgical treatment of midfacial fractures consisted mainly of suboptimal fracture reduction (7.6%), followed by temporary paraesthesia of the infraorbital nerve (3.6%) and wound infection (3.2%). Complications were dealt with by either surgical retreatment, removal of the osteosynthesis material, antibiotic therapy or an expectant approach. As instrumentation, biocompatibility of osteosynthesis materials and surgical techniques have improved over the last few years, the management of maxillofacial fractures has changed, ending up with open reduction and internal fixation being used more commonly.\textsuperscript{3} Treatment with plate osteosynthesis will probably lead to better results, fewer complications, shorter operating time and faster hospital discharge.

Maxillofacial trauma is often associated with injuries to the cranium, especially following high energy trauma.\textsuperscript{22,29} Chapter 6 focuses on the incidence and aetiology of maxillofacial, especially midfacial, trauma patients with associated traumatic brain injury (TBI), requiring maxillofacial and neurosurgical intervention. TBI is defined as evidence of loss of consciousness and/or post-traumatic amnesia in a patient with a non-penetrating head injury.\textsuperscript{30} The Glasgow Coma Scale (GCS) is used to describe the level of consciousness in patients with TBI, and classifies TBI as mild (GCS 14-15), moderate (GCS 9-13) or severe (GCS 3-8).\textsuperscript{31} According to the literature, 40% of the severe TBI cases are potentially fatal, making them an important patients group to take into account.\textsuperscript{32} The extent to which midfacial fractures have an association with traumatic brain injury remains unclear. Several authors demonstrate midfacial fractures to be strongly associated with traumatic brain injury, assuming that in case of trauma to the midface, energy will be directly transmitted to the cranium, causing damage to the brain.\textsuperscript{33} Others deny an association of facial fractures with an increased risk of traumatic brain injury, theorizing that the midfacial bones act as a protective barrier against high energy trauma, thus protecting the brain from damage.\textsuperscript{34} A total of 47 patients (8.1%) were identified from a general maxillofacial trauma population of 579 patients over a period of 10 years (2000-2010) for this part of the study. Data collected included age, gender, cause of the trauma, radiographic examination, maxillofacial fracture type, neurological injury, neurological deficits and
treatment modalities. The main cause of injury was road traffic collisions (55.3%), followed by falls (25.5%). Violence (4.3%) correlated less with TBI, as only high-energy trauma to the craniofacial skeleton seems to cause injury to the brain tissue with the consequence of neurological morbidity and mortality. Most of the patients were males (89.4%) aged 20-29 years, followed by those aged 30-39 years. The mean age was 31.4 years (SD: ±12.1). The frontal sinus was the most common maxillofacial fracture site (21.9%) associated with neurosurgical input, followed by the zygomatic complex (16.2%). However, in the general maxillofacial trauma population, frontal sinus fractures were only found in 4.5% of the cases. This finding, as well as the fact that 8.1% of the surgically treated maxillofacial trauma patients also suffered from TBI indicating neurosurgical intervention, might suggest an association of midfacial trauma with TBI, which could question the barrier function of the frontal sinus.

Twenty-seven patients (57.4%) presented with severe TBI (GCS 3-8), 10 patients (21.3%) with moderate TBI (GCS 9-13) and 10 patients (21.3%) with mild TBI (GCS 14-15). For prognostication of neurological outcome, the initial CT-sans were analysed using the modified Marshall CT classification. Most of the patients (56%) were diagnosed with a Marshall CT class II, indicating diffuse cerebral injuries with a midline shift of 0–5 mm and/or lesion densities, sometimes including bone fragments and foreign bodies. Neurological deficits were classified into nerve injuries and focal neurological deficits. Focal nerve injuries (e.g. infraorbital, facial and supraorbital nerve injuries) were found most commonly (34.0%), followed by disturbed cognition (31.9%), and disturbed speech (17.0%).

Intracranial pressure (ICP) monitoring was demonstrated as the most common neurosurgical intervention (24.1%) in traumatic maxillofacial and brain injury patients. This was followed by reconstruction of craniofacial bone defects (16.1%) and hematoma evacuation (12.4%). The aim of ICP monitoring is maintenance of adequate cerebral perfusion and oxygenation and avoiding of secondary injury while the brain recovers. In our study, early stage treatment was most commonly undertaken (72.7%), as early surgical intervention seems to be associated with improved outcomes. However, sometimes a delay of surgery is preferred in TBI patients, while monitoring neurological status and stabilising intracranial and blood pressures is undertaken first.

Despite the small population in this study, it could be concluded that if male patients, in the age group of 20-39 years, present with a traumatic maxillofacial injury following a road traffic collision (especially motorcycle and scooter accidents), one should be aware of the possibility of additional TBI, requiring neurosurgical intervention. In these cases, the multidisciplinary approach of oral and maxillofacial surgeons and neurosurgeons in the treatment of traumatic maxillofacial and brain injury patients seems to be beneficial.
In chapter 7 the focus is on the rate and type of complications, as well as the treatment modalities and follow-up, occurring in the study population as described in chapter 6. The exact definition of complications and their classification remains a matter of current debate. The study population consisted of 47 traumatic maxillofacial and brain injury patients, 36 (76.6%) of whom developed complications. The high complication rate, compared to what is demonstrated in the literature (11%-30%), might be explained by definition differences. Neurological deficits were all recorded. However, it seems to be unclear whether neurological injury occurred due to surgical intervention or as a direct consequence of the trauma. In total 121 complications were found, which were classified into 10 different groups. In accordance with the literature, infection and inflammation (36.4%) were demonstrated as the most common complication, followed by neurological deficit (24%). Patients involved in road traffic collisions (26 patients) were most likely to develop complications (92.3% of the cases), followed by falls (12 patients) as the mechanism of injury (66.7% of the cases). Patients aged 20-29 years accounted for the largest group in which complications occurred (37.2%), followed by the group of 30-39 years of age (32.2%). Patients aged 60–69 years experienced the highest complication rate (5 complications), which might be due to an impaired capacity to heal and less physiological reserve, compared with younger patients. Twenty-seven patients (57.4%) were diagnosed with severe TBI, 10 patients (21.3%) with moderate TBI and 10 patients (21.3%) with mild TBI. Patients with severe TBI developed most of the complications (90 in total), whereas patients presenting with mild TBI developed few complications (5 in total) with most of them (80%) demonstrating no complications. Complications in traumatic maxillofacial and brain injury patients could be categorized as ‘early’ (e.g. airway compromise) or ‘late’ (e.g. malunion/non-union) and as ‘minor’ (e.g. wound dehiscence) or ‘major’ (e.g. vision loss). However, the most commonly encountered complication, infection, could be categorized in some cases as early and in some cases as a late complication. Furthermore, infection could be categorized as both a minor and major complication, depending on the consequences. As complications easily seem to occur (76.6%) in these extensively traumatized patients, a more unanimously accepted classification for categorizing complications could facilitate treatment and would help in future studies. A simple classification of complications, as ‘early’ or ‘late’, with further subdivision into infection, bleeding, functional and cosmetic categories, is therefore recommended.

A total of 114 interventions were performed to treat the complications, which were subdivided into 13 different treatment groups and treatment modalities. The most common treatment modality was pharmacological (non-antibiotic) treatment (24.4%), followed by antibiotic treatment (16.7%), conservative treatment (10.5%) and decompression therapy (9.6%). According to the classification of interventions, the treatment modalities described in this population could be roughly categorized into conservative, pharmacological and surgical. Consensus on this plain classification of
complications and treatment modalities could lead to faster decision-making and hence even better quality of life after trauma care in this patients group. The mean hospital stay was 28 days (range: 3 – 57 days). The follow-up of patients for the department of Oral and Maxillofacial surgery was an average 4.5 months and for the department of Neurosurgery an average 7.5 months. Patients demonstrated improved neurological status in 25% of the cases and improvement of nerve injuries in 22.2% of the cases. A total of 13 patients (36.1%) were transferred to a rehabilitation centre or a nursing home. However, 4 patients (11%) eventually died after the trauma.
References