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MANDIBULAR FRACTURE DIAGNOSTICS AND TREATMENT IN SPECIAL PATIENT GROUPS: CHILDREN AND THE ELDERLY

Leena Kannari

ACADEMIC DISSERTATION

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to my family

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ABSTRACT

BACKGROUND AND PURPOSE

Mandibular fractures are common facial fractures, especially in young adults, but they also occur in other age groups. The youngest and oldest age groups have specific characteristics, such as edentulousness, possible age-related delayed recovery, differences in bone structures, and inability to communicate, which affect the diagnostics and treatment of fractures. The aim of this study was to investigate the special characteristics of mandibular fracture patients as well as the diagnosis and treatment of mandibular fractures at both ends of life.

PATIENTS AND METHODS

This study consists of four retrospective studies (Studies I-IV). The research material comprises mandibular fracture patients treated at the Oral and Maxillofacial Emergency Unit of the Oral and Maxillofacial Surgery at Helsinki University Hospital in 2013–2018 (Studies I-III) and 2018–2021 (Study IV). In Studies I and II, the outcome variable was missed mandibular fracture during the first health care assessment and in Study III dental injury. In Study IV, the primary outcome variable was non-surgical site-related postoperative complication, and the secondary outcome variable was type of complication.

RESULTS

Mandibular fracture was often detected late. It was missed in 14.8% of 182 patients aged under 20 years and with a recent mandibular fracture and in 20.0% of 135 patients aged over 60 years during their first health care assessment. Fractures were missed significantly more often in patients under 13 years of age than in teenagers and young adults ($p<0.01$). The only significant symptom or clinical finding associated with missed fractures in previous age groups was skin wound of the jaw ($p=0.01$). In patients over 60 years of age, memory disorder ($p=0.02$) and scene of injury ($p=0.02$) were significantly associated with missed fractures. Fractures were missed more frequently in patients who were in hospital or in a nursing home at the time of injury.

Dental injuries were common in children and adolescents. Dental injuries were detected in 34.7% of 118 patients aged under 18 years, and they had on average 3.5 injured teeth. Non-complicated crown fracture (50.7%) was the most common injury type. Altogether 16.2% of the injured teeth were lost, and

avulsion was the most common cause of tooth loss (52.2%). Loss of at least one tooth was found in 10.2% of patients.

Non-surgical site-related postoperative complications occurred in 6.7% of 314 patients aged over 16 years. The most common complication type was pulmonary (36.0%). Non-surgical site-related postoperative complications were most likely to occur in elderly patients (aOR 5.55; 95% CI 1.92 to 16.21; p<0.01), patients with combined craniofacial fractures (aOR 2.92; 95% CI 1.06 to 8.03; p=0.04), and patients with alcohol or drug abuse (aOR 4.51; 95% CI 1.70 to 11.96; p<0.01). Pulmonary complications occurred more often in elderly patients, whereas urinary complications prevailed in younger patients.

CONCLUSIONS

Mandibular fractures are often missed in the primary examination at the first health care contact in both children and the elderly. Dental injuries are common in paediatric mandibular fracture patients, and they often lead to tooth loss. Non-surgical site-related postoperative complications are more common in elderly patients. The type of non-surgical site-related postoperative complication varies between age groups.

Clinical examination requires accuracy, especially in children and elderly patients. More support and training are needed for health care professionals for proper examination of facial trauma patients to identify symptoms of mandibular fractures. Careful evaluation and follow-up of dental injuries is also essential in these patients. All clinicians treating mandibular fractures should also be aware of the possibility of non-surgical site-related postoperative complications and their management.

SUOMENKIELINEN TIIVISTELMÄ (ABSTRACT IN FINNISH)

TAUSTAA

Alaleuan murtumat ovat yleisiä kasvomurtumia erityisesti nuorilla aikuisilla, mutta niitä esiintyy myös muissa ikäryhmissä. Nuorimpiin ja vanhimpiin ikäryhmiin liittyy erityispiirteitä, kuten hampaattomuutta, mahdollinen iän tuoma viivästynyt toipuminen, eroavuudet luun rakenteessa ja kyvyttömyys kommunikoida, jotka vaikuttavat murtumien tunnistamiseen ja hoitoon. Tämän tutkimuksen tarkoitus oli tarkastella alaleukamurtumapotilaiden erityispiirteitä, etenkin murtuman tunnistamista ja hoitoa, elämän ääripäissä.

MENETELMÄT

Tämä tutkimus koostuu neljästä retrospektiivisestä osatyöstä (tutkimukset I-IV). Tutkimusten aineistot sisältävät vuosina 2013–2018 (tutkimukset I-III) ja 2018–2021 (tutkimus IV) Helsingin yliopistollisen sairaalan suu- ja leukakirurgian päivystyksessä hoidettujen alaleukamurtumapotilaiden tiedot. Tutkimuksissa I ja II tulosmuuttujana oli ensimmäisessä terveydenhuollon hoitokontaktissa havaitsematta jäänyt alaleukamurtuma, ja tutkimuksessa III tulosmuuttujana oli hammasvamma. Tutkimuksessa IV ensisijainen tulosmuuttuja oli leikkauskohtaan liittymättömät murtumahoidon oheiskomplikaatiot ja toissijainen tulosmuuttuja oli oheiskomplikaation tyyppi.

TULOKSET

Alaleukamurtuma havaittiin usein viiveellä. Se jäi havaitsematta ensimmäisessä hoitokontaktissa 14,8 prosentilla 182:sta alle 20-vuotiaasta potilaasta ja 20,0 prosentilla 135:stä 60-vuotiaista ja sitä vanhemmista potilaista. Murtuma jäi havaitsematta tilastollisesti merkitsevästi useammin alle 13-vuotiailla potilailla kuin teini-ikäisillä ja nuorilla aikuisilla ($p < 0,01$). Ainoa havaitsematta jääneisiin murtumiin liittyvä tilastollisesti merkitsevä oire tai kliininen löydös edellisissä ikäryhmissä oli haava leuassa ($p < 0,01$). Yli 60-vuotiailla muistisairaus ($p = 0,02$) ja vamman tapahtumapaikka ($p = 0,02$) liittyivät tilastollisesti merkitsevästi havaitsematta jääneisiin murtumiin. Murtumat jäivät havaitsematta useammin potilailla, jotka olivat tapaturmahetkellä sairaalassa tai hoivakodissa.

Hammasvammat olivat yleisiä lapsilla ja nuorilla. Hammasvammoja havaittiin 34,7 prosentilla 118:sta alle 18-vuotiaasta potilaasta, ja heillä oli keskimäärin 3,5 vaurioitunutta hammasta. Komplisoitumaton kruunumurtuma (50,7 %) oli yleisin hammasvammatyyppi. Kaikkiaan 16,2 prosenttia vaurioituneista hampaista menetettiin ja hampaan irtirevähtäminen oli yleisin syy menetykselle (52,2 %). Kaikkiaan 10,2 % potilaista menetti vähintään yhden hampaan.

Leikkauskohtaan liittymättömiä leikkauksen oheiskomplikaatioita havaittiin 6,7 prosentilla 314:sta yli 16-vuotiaasta potilaasta. Yleisin komplikaatiotyyppi oli keuhkokomplikaatio (36,0 %). Leikkauskohtaan liittymättömiä leikkauksen oheiskomplikaatioita esiintyi useammin iäkkäillä potilailla (aOR 5,55; 95 % CI 1,92 – 16,21; $p < 0,01$), potilailla, joilla oli alaleukamurtuman lisäksi muu kasvomurtuma (aOR 2,92; 95 % CI 1,06 – 8,03; $p = 0,04$) ja päihteitä säännöllisesti käyttävillä potilailla (aOR 4,51; 95 % CI 1,70 – 11,96; $p < 0,01$). Keuhkokomplikaatioita havaittiin useimmin iäkkäillä potilailla, kun taas virtsatiekomplikaatiot olivat yleisempiä nuoremmilla.

JOHTOPÄÄTÖKSET

Alaleukamurtumat jäävät usein havaitsematta ensimmäisessä hoitokontaktissa sekä lapsilla että ikääntyneillä. Hammasvammat ovat yleisiä lasten alaleukamurtumien yhteydessä ja ne usein johtavat hampaan menetykseen. Leikkauskohtaan liittymättömät leikkauksen oheiskomplikaatiot ovat yleisempiä iäkkäillä potilailla. Leikkauksen oheiskomplikaatiotyyppien esiintyminen vaihtelee eri ikäryhmissä.

Kliininen tutkiminen edellyttää erityistä huolellisuutta erityisesti nuorilla ja iäkkäillä vammapotilailla. Terveydenhuollon ammattilaisille tarvitaan lisää tukea ja koulutusta kasvovammapotilaiden tutkimiseen alaleukamurtumien oireiden havaitsemiseksi. Alaleukamurtumapotilaiden hammasvaurioiden havaitseminen ja seuranta on myös tarpeellista. Kaikkien alaleukamurtumia hoitavien kliinikoiden tulee tunnistaa ja osata hoitaa leikkauskohtaan liittymättömät leikkauksen oheiskomplikaatiot.

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications, which are referred to in the text by their Roman numerals:

I Kannari L, Marttila E, Toivari M, Thorén H, Snäll J. Paediatric mandibular fracture – a diagnostic challenge? Int J Oral Maxillofac Surg. 2020 Nov;49(11):1439-1444.

II Kannari L, Marttila E, Thorén H, Toivari M, Snäll J. Mandibular fractures in aged patients – challenges in diagnosis. Dent Traumatol. 2022 Dec;38(6):487-494.

III Kannari L, Marttila E, Thorén H, Snäll J. Dental injuries in paediatric mandibular fracture patients. Oral Maxillofac Surg. 2022 Mar;26(1):99-104.

IV Kannari L, Marttila E, Oksa M, Furuholm J, Snäll J. Non-surgical site-related complications in mandibular fracture surgery – a problem of elderly patients? J Oral Maxillofac Surg. 2024 Jan;82(1):47-55.

ABBREVIATIONS

AI = associated injury

CBCT = cone beam computed tomography

COPD = chronic obstructive pulmonary disease

CT = computed tomography

DI = dental injury

DPR = dental panoramic tomography

IMF = intermaxillary fixation

LHOS = length of hospital stay

MVA = motor vehicle accident

ORIF = open reduction with rigid internal fixation

TMJ = temporomandibular joint

ZMC = zygomaticomaxillary complex

1 INTRODUCTION

The face consists of numerous bones, muscles, vessels, and nerves (1). Bony injuries of the facial area are often divided based on their location into upper face fractures, midface fractures, and lower face fractures (2). Sometimes, however, fractures are not limited to just one area of the face but are found in combinations comprising several areas. In panfacial fractures, the fracture involves all thirds of the face (upper, middle, and lower thirds) at the same time (3-5).

Lower face fractures include all fractures in the mandibular region, e.g. mandibular symphysis, parasymphysis, body, angle, ramus, coronoid, and condyle fractures. The mandible differs from other facial bones in that it is the only movable bone in the facial region. The mandible plays an important role in key oral behaviours like production of speech, breathing, chewing, and swallowing (6). Many previous studies have found that the mandible is one of the most frequently involved regions in facial fractures (7-11).

There are some differences in the aetiology, location, and treatments of mandibular fractures between different age groups. In young children, the most common mechanism of injury are road traffic accidents and fall (12, 13) and the most common fracture site is the condyle (12-14), while in adolescents and adults, violence (15, 16) becomes more common. In the elderly population, on the other hand, ground level fall is the predominant cause of injury (17-19) and the mandibular body the most common fracture site (17).

Most of the previous studies have evaluated mandibular fractures at the level of the whole population and found that the most fractures occur in young and adult men (20-23). However, it is common knowledge that special features can appear in the diagnosis and treatment of fractures in children and the elderly relative to the adult population. In children, developing dentition, rapid healing capacity, growth of bony structures, and incomplete cooperation may affect diagnosis and treatment decisions, while in the elderly, long-term diseases, atrophy of the mandibular bone caused by missing teeth, and impaired healing capacity must be considered in treatment decisions (24-34). Early diagnosis is important to avoid complications such as malocclusion, prolonged pain, distorted growth and functional disorders, chronic temporomandibular joint (TMJ) complications, and revision procedures (35, 36).

The purpose of this study was to examine the special features in children and the elderly in the diagnostics and treatment of mandibular fractures. In addition, the study examines the complications associated with mandibular fractures and the complications related to mandibular fracture treatment.

2 REVIEW OF THE LITERATURE

2.1 STRUCTURE AND FRACTURES OF THE UPPER AND MIDFACIAL AREA

The facial area consists of 14 bones: one mandible, two maxillary, two zygomatic, two nasal, two palatine, two inferior nasal concha, two lacrimal, and one vomer bone. In addition, the frontal bone forms the majority of the forehead and part of the orbital cavity. The orbital cavity comprises a mosaic arrangement of the previously mentioned surrounding facial bones (maxilla, zygoma, lacrimal, and palatine bones), as well as ethmoid and sphenoid bones (Figure 1).

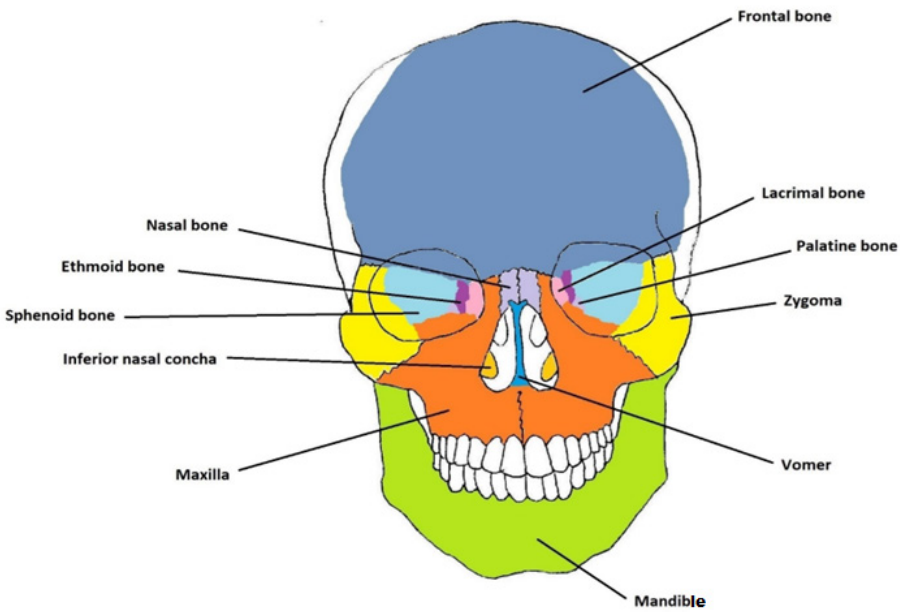

Figure 1. Facial bones (L. Kannari).

Maxillofacial fractures can be divided into upper face fractures, including the frontal bone and supraorbital rim; midface fractures, including nasal, orbital, maxillary, and zygomatic injuries as well as Le Fort fractures; and lower face fractures, including the mandible (2). The present study mainly focuses on mandibular fractures, and they are presented more specifically below. However, mandibular fractures often occur together with other facial fractures (22).

2.1.1 FRONTAL BONE FRACTURES

The frontal bone is the strongest bone in the adult face (37, 38), and thus, fractures in this area are relatively rare. According to the literature, frontal bone fractures account for 5–15% of all facial fractures (39, 40). Chrcanovic et al. (41) reported that only 2% of mandibular fracture patients with other associated facial fractures had a frontal bone fracture.

2.1.2 MIDFACIAL FRACTURES

The midface includes the nasal, orbital, maxillary, and zygomatic bones. Midfacial fractures can affect the patient's appearance, nasal function, vision, and occlusion (42). The different types of midfacial fractures are described below.

2.1.2.1 MAXILLARY FRACTURES

In addition to the mandible, the maxilla is another bone that forms basis for the dental arches. The maxilla often breaks as part of another entity, such as in Le Fort 2 and 3 fractures, as well as in zygomaticomaxillary complex (ZMC) fractures, where the fracture runs along the suture between the maxillary and zygomatic bones. Cohn et al. (43) reported the most common maxillary fracture site to be the maxillary sinus (29%), followed by the ZMC (26%), frontal process of the maxilla (20%), dentoalveolar region (16%), and Le Fort fracture (9%). Isolated lateral and/or posterior maxillary sinus fractures are encountered in 4.8% of mandibular fracture patients (44).

2.1.2.2 LE FORT FRACTURES

Le Fort classification consists of three stages: Le Fort I fractures, Le Fort II fractures, and Le Fort III fractures. In a Le Fort I fracture, the fracture occurs along a horizontal plane and detaches the hard palate or maxillary alveolus from the skull base, allowing free movement of the hard palate (3, 6, 7) (Figure 2).

Le Fort II fractures are pyramid-shaped fractures, and they go through the medial and inferior orbital rims and zygomaticomaxillary buttress. They dissociate the central midface from the rest of the skull, allowing the free movement of the nose and hard palate as one unit (2, 42, 45) (Figure 2).

Le Fort III fracture means complete midface dissociation, where the fracture line runs through the medial and lateral orbital walls, the nasofrontal region, and the zygomatic arches, allowing free movement of the entire midface (2, 42, 45) (Figure 2).

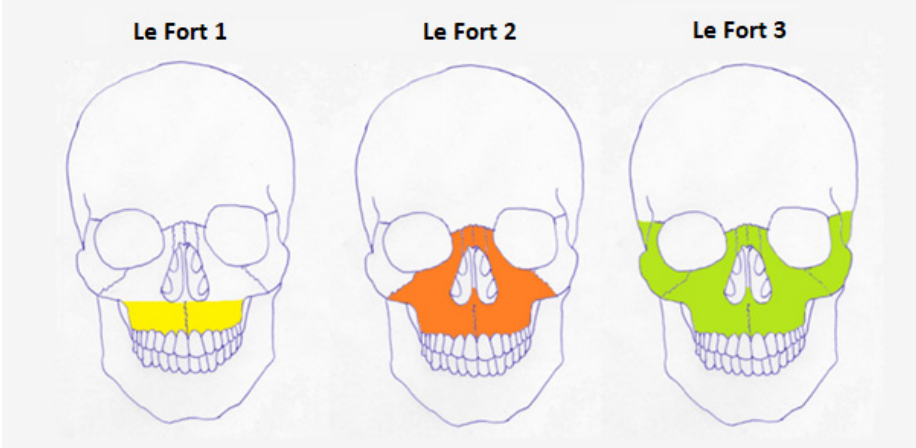

Figure 2. Le Fort fractures (L. Kannari).

Le Fort fractures are rarely pure class I, II, or III fractures, but are often combinations of each other or occur on only one side of the face or in combination with other fracture types (2). Le Fort fractures are encountered together with mandibular fractures in 4.3% of mandibular fracture cases (41).

2.1.2.3 ZYGOMATIC FRACTURES

Zygomatic fractures are classified as monopod, dipod, and tripod fractures. The monopod fractures include zygomaticofrontal, ZMC, or zygomatic arch fractures. The dipod fractures contain two of the previously mentioned sites, and the tripod fractures include all three sites (46). ZMC fractures are the facial fracture type most often (32.0%) associated with mandibular fractures (41).

2.1.2.4 ORBITAL FRACTURES

The bony orbit comprises seven bones, including the frontal, sphenoid, maxillary, palatine, zygomatic, ethmoid, and lacrimal bones (47). The orbit is one of the most commonly fractured areas in the facial region (47, 48). Orbital fractures are often characterized as blow-out or blow-in fractures (49). In blow-out fractures, the fracture fragments extend beyond the orbit into adjacent structures, and in blow-in fractures they buckle into the orbit (2). Blow-out fractures are more common than blow-in fractures (2). Orbital fractures are found in 3.1% of mandibular fracture patients with other associated facial fractures (41).

2.1.2.5 NASAL BONE FRACTURES

Nasal bone is very thin and prominent, which is why it fractures easily and with minimal force (2, 47). The nasal bone is the most frequently fractured bone in the facial area (47, 50-52), and nasal fractures have been reported in 2–4% of mandibular fracture patients (41, 53).

2.1.3 AGE AND SEX DISTRIBUTION OF FACIAL FRACTURE PATIENTS

All facial fracture types are more common in men (11, 54, 55), and the highest incidence is seen in the age group of 18–39 years (55). However, only minor differences are seen between the frequencies of the fracture types in different age groups. The highest incidence of Le Fort fractures has been reported in individuals aged 20–29 years (56), whereas nasal bone fractures occur most often in those aged 18–25 years (57).

In children, all facial fracture types are more common in males (54), whereas in the elderly, most facial fractures occur in women (58).

2.1.4 CAUSES OF FACIAL FRACTURES

In general, assault, fall, and motor vehicle accident (MVA) are the most common causes of facial fractures (11, 47, 55). However, some differences in the causes emerge between countries, ages, the sexes, and fracture types. In children, the most common cause of facial fractures is falls, followed by traffic accidents and sport injuries (58). In patients aged over 50 years, facial fractures are mostly the result of falls or traffic accidents, except in the case of zygomatic arch and panfacial fractures, where the main causes are traffic accidents and violence (10). In one study (10), in male patients aged 20–49 years, violence and traffic accidents were the most common causes of facial fractures, whereas in females of same age, traffic accidents were the most common reason.

Fracture types are associated with injury energy. Frontal bone fractures, for instance, occur mainly in high-energy injuries (39, 47, 59-61). Complex midfacial fractures are found especially in high-velocity MVAs, sports, and assaults (42, 62-66), whereas for orbital fractures the main causes are falls and occupational (47). Related to nasal fractures, there is a wide variation of injury mechanisms, such as physical violence, MVAs, falls, and sports accidents (47, 50, 57, 67-69).

2.1.5 DIAGNOSTICS, SYMPTOMS, AND TREATMENT OF FACIAL FRACTURES

Most often, facial fractures are diagnosed from a computed tomography (CT) image (2), but intraoral radiographs, dental panoramic tomography (DPR), and cone beam computed tomography (CBCT) can also reveal a fracture. In the case of isolated nasal fractures, the diagnosis is typically made based on clinical observation, and imaging is rarely needed (70). Careful clinical examination also is important when other fractures are suspected, but both external and internal palpation is needed when examining injuries in the mandible, maxilla, or nasal area (42, 70).

Typical symptoms and findings for facial fractures are pain, swelling, oedema, displacements, lacerations, step-offs, and crepitus (47, 71-73). In addition, in connection with an orbital injury, periorbital ecchymosis and restricted extraocular muscle movements are mentioned in the literature (71, 72). Fractures in the orbital area can affect the patient's vision, and therefore, a comprehensive ophthalmic examination is important for everyone with periocular or ocular trauma (47, 71, 73). In connection with nasal fractures, deformities, epistaxis, septal haematoma, and cerebrospinal fluid rhinorrhoea are reported (47, 73). Displaced fractures in the midfacial area can cause midfacial retrusion, widening, and noticeable deformity as well as loss of sensation in the infraorbital nerve, trismus, and malocclusion (74).

Non-surgical treatment is indicated for minimal, non-displaced fractures (75), but surgery is often needed especially in the case of an unstable fracture, dislocation, aesthetic defect, or functional change in occlusion (39, 54, 60, 74, 75). Surgical treatment typically includes open reduction and internal fixation (ORIF) (76). Fractures in the midface area are potentially life-threatening due to airway compromise (45).

2.2 MANDIBULAR FRACTURES

The mandible is the only mobile bone in the facial area and has an articular surface. Besides the maxilla, it is the only bone that contains teeth, and it plays an important role in eating and speech production, in addition to markedly affecting appearance. Mandibular fractures are reported to comprise 21.3–62.16% of all facial fractures (47, 55, 77, 78). Thus, mandibular fractures are common fracture types in the facial area (7-11).

2.2.1 INCIDENCE, AGE DISTRIBUTION, AND CAUSES OF MANDIBULAR FRACTURES

Table 1 presents a review of the literature regarding sex, age, injury mechanism, and fracture site distribution in studies on mandibular fractures.

2.2.1.1 AGE AND SEX DISTRIBUTION

According to the literature, most mandibular fractures occur in patients aged 20–30 years (Table 1). Overall, mandibular fractures are more common in men (22, 41, 80, 89), but among the elderly, the number of female patients has been reported to be higher in some studies (17, 90, 91). Also, in children, mandibular fractures are more common in boys, even in the youngest age groups (12, 13). In young children and the elderly, mandibular fractures are quite rare. For example, of the mandibular fractures observed in the study of Chrcanovic et al. (41), only 4.98% were in people aged under 10 years and 3.13% in people aged over 60 years.

2.2.1.2 CAUSES OF MANDIBULAR FRACTURES

The most common injury mechanisms of mandibular fractures have been reported to be MVA and violence (Table 1). In different studies, traffic accidents have been observed to be the cause of 27–47% and violence the cause of 31–49% of mandibular fractures (Table 1). However, the causes of fractures vary greatly between countries, age groups, and the sexes (92). In children, the most common causes are MVA and falls (12, 13, 93). Violence is a common mechanism of injury among adolescents and adults (15), while falling predominates in the elderly (17). Other typically reported causes for mandibular fractures are bicycle and sport accidents as well as accidents with animals (93). In men, assault is a more common cause of mandibular fractures than in women, whereas bicycle accidents prevail in women (82).

Changes in trauma mechanisms greatly reflect the physical activity of different age groups, changes in the environment, and social interactions as well as the weakening of the body with age. Physical violence hardly occurs in the youngest and oldest age groups (12, 17, 94, 95), but the possibility of violence should not be overlooked. As physical activity increases, but skills are still lacking, e.g. in young children, falls on bicycles become one of the main causes of mandibular fractures (12).

Table 1. Descriptive statistics in selected studies on facial fractures, arranged by anatomical region studied.

Study	Number of patients	Anatomical region studied	Age range (years) / age limit	Age group with the most fractures	Sex with the most fractures	Mean age	The most common mechanism of injury	The most common site of fracture
Bormann KH et al. (20)	444	mandible	10-96	16-25 (32%)	male (74%)	37	traffic accident (32%)	condyle (42%)
Afrooz PN et al. (21)	13142	mandible	not available	18-24	male (80%)	not available	assault (49.1%)	symphysis (19.2%)
Singleton C et al. (22)	205	mandible	14-92	20-30	male (88%)	29	assault (46%)	angle (31.9%)
	393	mandible	16-89	20-30	male (86%)	31.1	assault (43%)	angle (29.8%)
Gualtieri M et al. (23)	172	mandible	6-90	20-29 (30.2%)	male (80%)	35.4	assault (30.8%)	condyle (32%)
van den Bergh B et al. (79)	213	mandible	2-88	not available	male (55%)	32.5	traffic accident (42%)	Unilateral condyle fracture + body/ ramus/angle fracture (29.8%)
Morris C et al. (81)	2828	mandible	1-97	20-30 (33%)	male (83%)	38	low-velocity blunt injuries (62%)	angle (27%)
Sakr K et al. (80)	509	mandible	2-70	0-10	male (79%)	males: 22 years, females: 17 years	traffic accident (39%)	angle (22%)
Boffano P et al. (82)	*UNITO: 752	mandible	5–99	20-29 (30%)	male (75%)	34.8	assault (29%)	condyle (35%)
	**VUMC: 245	mandible	2–87	20-29 (34%)	male (69%)	32	assault (27%)	condyle (43%)
Chrcanovic BR et al. (41)	1023	mandible	0-87	20-30 (33.9%)	male (86%)	30.1	vehicle accidents (including automobile, motorcycle, and bicycle accidents) (43.9%)	condyle (30%)
de Matos FP et al. (83)	126	mandible	2-81	21-30	male (79%)	not available	traffic accident (47%)	condyle (28%)
Paza AO et al. (84)	114	mandibular angle	16-62	not available	male (89%)	27	assault (39%)	-
Sawazaki R et al. (85)	263	mandibular condyle	2-83	10-30 (60%)	male (75%)	28.4	traffic accident (57.8%)	subcondylar

Motamedi MH. (9)	237	maxillofacial	3-73	20-29 (59.0%)	male (89%)	not available	Car accidents (30.8%), motorcycle accidents (23.2%)	mandible (72.9%) in which condyle (32%)
van den Bergh B et al. (10)	579	maxillofacial	2-88	20–29	male (70%)	35.9	traffic accident	mandible (41.6%) in which the combination of mandibular body with mandibular condyle (26.8%)
Boffano P et al. (11)	3396	maxillofacial	not available	not available	male (78%)	29.9 to 43.9	assault (38.6%)	mandible in which condyle (34%)
Arangio P et al. (54)	83	maxillofacial	over 15 years of age	18-39	male (83%)	not available	traffic accident (35%)	zygoma, followed by the mandible (25%) in which (body 8%, angle 8%)
Yamamoto K et al. (86)	247	maxillofacial	aged 65 years old or older	70-74	male (51%)	not available	falling on a level surface (51.0%)	mandible (56.7%) in which condyle
Kyrgidis A et al. (87)	1239	maxillofacial	2-95	not available	male (82%)	29.6	two wheeler (49.2%)	mandible (64.1%) in which subcondylar (33.2%)
Al-Khateeb T et al. (88)	288	craniomaxillofacial	2-82	20-30 (42.7%)	male (88%)	27.3	traffic accident (56%)	mandible (70.5%) in which body

*UNITO = San Giovanni Battista Hospital, Turin

** VUMC = Vrije Universiteit University Medical Centre

2.2.2 TYPES OF MANDIBULAR FRACTURES

The mandible can be divided into the condyle, coronoid processes, ramus, and dentate regions. In addition, the condyle is often further divided into the condylar head and neck and the subcondylar region (Figure 3). Dentate area fractures can be categorized as angle, body, symphysis, and parasymphysis fractures, and fractures of the alveolar ridge. The most common fractured area varies depending on the study, but most fractures occur in the condyle, symphysis, and angle regions (41, 47, 80).

The mechanism of injury affects the location of the fracture (96). For example, in a previous study (41), as a result of violence and car crashes, the mandibular body was the most common fracture site (violence 31.71% and automobile crashes 25.18%), while in motorcycle and bicycle accidents as well as in falls, the condyle (30.32%, 42.04%, 46.79%, respectively) was most often affected. Lin et al. (96) also found that MVA- and struck-by-object injuries in comparison to motorcycle accidents tend to cause more often fractures in the body, angle and ramus.

The location of mandibular fracture also varies greatly between different age groups. In children, the condyle is the most often fractured part (12), while in the elderly with edentulous atrophic mandibles, most fractures locate in the body region (17).

Mandibular fractures often occur as multiple fractures (22). Singleton et al. (22) found that up to 61% of patients have more than one mandibular fracture (22).

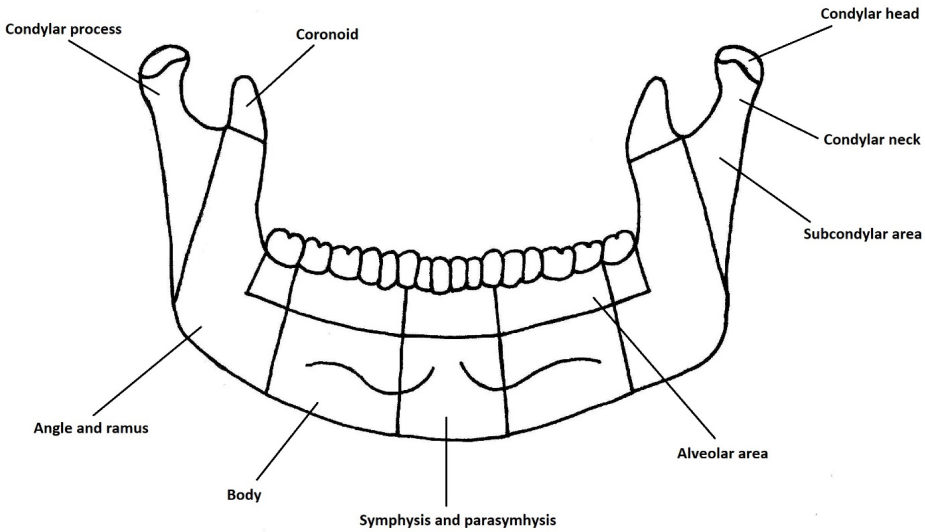

Figure 3. Parts of the mandible (L. Kannari).

2.2.3 SPECIAL FEATURES OF MANDIBULAR FRACTURES IN DIFFERENT AGE GROUPS

Different age groups have special features related to the location, mechanisms of injury, diagnosis, and treatment of mandibular fractures.

2.2.3.1 CHILDREN

The facial skeleton of children differs from that of adults, with small size of facial bones, low pneumatization of the paranasal sinuses, elastic bones, flexible suture lines, presence of developing teeth in jaws in primary and mixed dentition, and a rapid healing process. Furthermore, diagnosing and treating children may manifest with difficulty in compliance and cooperation (13, 97).

Young children often live in the protected environment of the home, and thus, they have a lower incidence of facial fractures (98), and violence is seldom a mechanism of injury (98, 99). Instead, the lack of motor skills is reflected in the number of falls and bicycle accidents (12). The most common fracture site in children is the condyle (12).

When diagnosing a fracture, poor cooperation may pose a challenge, and many symptoms can be missed due to the patient's lack of ability to report them (13). Deciduous teeth and teeth in the replacement phase also present challenges and affect the patient's treatment (13, 100, 101). A child's mouth is small and care must be taken regarding the developing teeth, e.g. in surgery (101). Moreover, the healing capacity is greater and more rapid in children, which should be considered when timing the treatment and the duration of immobilization (102, 103). The fracture line can also run close to the tooth buds and cause far-reaching consequences for the patient's permanent dentition as well (13, 101). The challenges of a growing jaw should also be taken into account. Treatment should not adversely affect the growth and development of the jaws (13, 100, 101, 103).

2.2.3.2 ADOLESCENTS AND ADULTS

In young adults, social contacts and substance abuse tend to increase, and assault becomes a more common mechanism of injury (15). Comparing different age groups, mandibular fractures are most common in this group (Table 1). Diagnosing trauma in young and adult patients is facilitated by the patient's ability to report their symptoms and observations.

2.2.3.3 THE ELDERLY

In the case of elderly (≥65 years) patients, the treatment of fractures must be considered with respect to the general health of the patient. With increasing age, the number of patients' long-term diseases and medications tend to rise, the body's ability to heal deteriorates, and general frailty increases (24-27). Long-term diseases, such as dementia, can pose challenges with the patient's cooperation and the ability to describe injuries and symptoms. Several long-term diseases and medications (such as osteoporosis and bone medicines) can affect the quality of patients' bones, resulting in treatment and bone healing being more challenging and complications more often occurring (104, 105). In old people, tooth loss also is more common. A toothless jaw is often resorbed and is very thin, which makes it easier to break and surgery can be very challenging (106, 107). During treatment, the patient's nutrition must also be considered so that the patient's general condition does not markedly deteriorate in a way that could potentially affect the rest of the patient's life (108).

2.2.4 INJURIES ASSOCIATED WITH MANDIBULAR FRACTURES

2.2.4.1 INJURIES OUTSIDE THE FACIAL REGION

Patients with traumatic mandibular fractures often have associated injuries (AIs) such as injuries to the head, chest, spine, and other regions of the body (109). In previous studies, AIs have been observed in 25.2–99.3% of facial fracture patients (109-111), and limb injuries are the most common AI type with facial fractures (109). The most frequent injury mechanisms leading to AI are falls from height and MVAs, and AIs are more common in elderly patients (109-111). AIs occur more frequently in patients with combined fractures, but they are also found with isolated facial fractures (109, 113).

Brain and spine injuries are also found in connection with facial fractures (113, 114). In some studies on patients with facial fractures, neurological injuries have occurred in up to 76% of patients (115). Brain injury has been reported to be the most common AI in patients with assault-related facial fractures (116). Brain injury is potentially lethal or may cause lifelong physical, psychological, emotional, behavioural, or cognitive changes to the patient (115). Hackl et al. (117) observed that 2.1% of patients with cervical spine injury had a concomitant facial injury, and thus, brain injury and injury to the cervical spine should be suspected in every patient with a facial fracture (111).

The possibility of blunt cerebrovascular injuries should also be remembered in the case of mandibular fractures. In craniomaxillofacial fracture patients, blunt cerebrovascular injuries have been reported most in

connection with mandibular fractures (12,5%) (118) and mandibular fractures are also predisposing factors for blunt cerebrovascular injuries in children (119).

2.2.4.2 DENTAL INJURIES

Also, injuries in the dentition are quite common in patients with mandibular fractures (120, 121). Hino et al. (120) found that 37.7% of patients with only mandibular fractures had associated dental injuries (DIs), most of which were caused by a fall. However, in connection with mandibular fractures, most DIs are observed in the upper jaw (121). Crown fracture is the predominant type of DI (122).

2.2.5 SYMPTOMS AND DIAGNOSIS OF MANDIBULAR FRACTURES

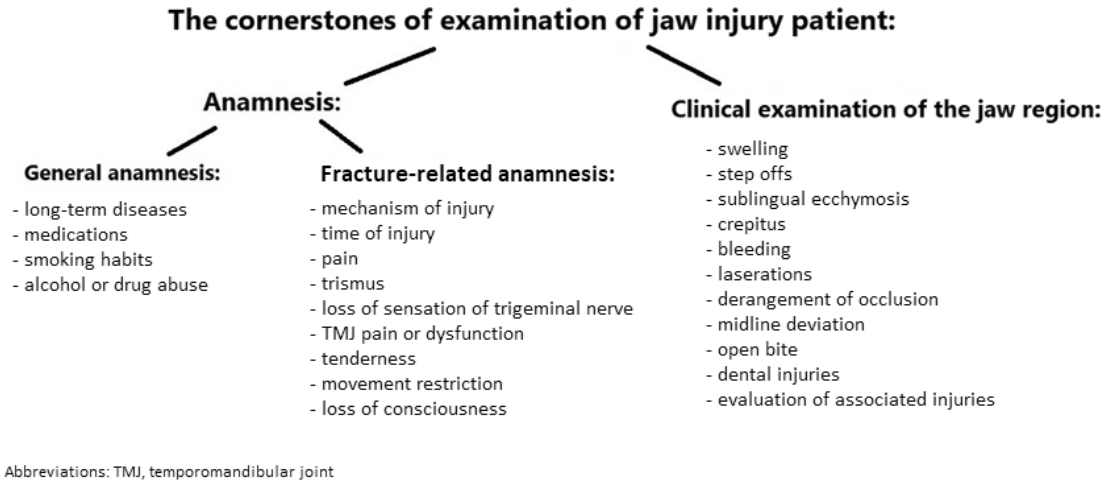

Figure 4. Cornerstones of examination of a patient with jaw injury. (L. Kannari).

In the literature, the clinical features of mandibular fracture are reported to include pain, swelling, trismus, derangement of occlusion, step deformity, sublingual ecchymosis, midline deviation, loss of sensation (nerve damage), bleeding, TMJ problems, tenderness, movement restriction, open bite, and crepitus (123-126).

In connection with superficial contusions on the face, it is also worth considering the possibility of jaw fractures. In the study of Myall et al. (127), chin laceration was the most common AI related to mandibular condyle fracture. Condylar fractures should also be suspected in patients with post-traumatic ear bleeding (128).

A mandibular fracture diagnosis is often made based on both clinical and radiological findings (Figure 4). Especially in young children, incomplete cooperation may complicate both clinical and radiological examination and even prevent access to diagnosis. DPR imaging is often the primary imaging method when seeking to exclude mandibular fractures (129, 130); its sensitivity for fractures is 92% (129). Three-dimensional imaging is, however, often needed for fracture diagnosis and treatment. CBCT was developed to image the teeth and jaws. CBCT is a low-dose scanning system that takes numerous individual x-ray images and constructs a three-dimensional view of them with the help of mathematical models. It is good for imaging hard tissues, but soft tissue detail is not displayed, unlike with conventional CT (131). Thus, CBCT is suitable for mandibular fracture diagnostics if there are no indications to image other areas of the face or for simultaneous imaging of the head, jugular veins, or cervical spine.

CT scan is often used when DPR imaging does not reveal a fracture despite high suspicion of mandibular fracture (132). CT scan is also needed when evaluating the degree of displacement of the fracture area (133, 134). If a patient undergoes a CT scan for head or cervical spine injury, it is often worthwhile imaging the mandibular area at the same time (47). Magnetic resonance imaging is useful for evaluation of TMJs and condyles as well as soft tissue injuries (135-137); however, primary fracture diagnostics is based on DPR, CBCT, and CT images.

2.2.6 TREATMENT OPTIONS OF MANDIBULAR FRACTURES

The treatment of mandibular fractures aims at re-establishing the patient's preinjury dental occlusion, good mastication function and swallowing, and an optimal environment for bony healing (to ensure adequate blood supply, immobilization, and proper alignment of fracture segments) (35, 135). Many factors affect the patient's treatment options such as the location and type of fracture, the degree of dislocation, the condition of dentition, the patient's age, cooperation, and general health, the bone quality, and the patient's wishes (138).

The complete healing of a fracture consists of three phases: inflammatory, repair, and remodelling phases (139). The ossification time is influenced, among other things, by the patient's age and general health and the degree of dislocation.

In treatment of fractures in children, the goal is to manipulate the facial skeleton as little as possible (123). Children have greater osteogenic potential and faster healing rates than adults. Therefore, anatomic reduction must be accomplished sooner, and immobilization time should be shorter than in adults (13, 102). In children, the growth of the condyles and the eruption of permanent

teeth compensate for the shortening of the condyle caused by condyle fractures and spontaneously correct the bite (94). Maxillomandibular immobilization is more difficult in children than in adults due to the mixed dentition (94). Although complications in healing are quite rare, children must be followed longitudinally, until after the pubertal growth spurt, for late complications such as damage of permanent teeth, TMJ dysfunction, and growth disturbances (33, 94).

Very well-positioned and stable mandibular fractures where the bite has not changed can be treated mainly with soft food and pain medication. The treatment options for mandibular fractures also include ORIF, intermaxillary fixation (IMF), or a combination of these two procedures (138).

2.2.6.1 CLOSED REDUCTION AND INTERNAL FIXATION

When the patient is not suitable for surgery, but the fracture requires stabilization, the treatment can be performed with closed reduction. In IMF (e.g. Kirschner wires and Erich arch), the upper and lower jaws are brought together with steel wires attached around the teeth (35, 135). Closed reduction does not traumatize the vascular envelope or endanger the roots of the teeth, but it does require long-term immobilization and closure of the jaws, thus hindering the patient's nutrition and oral hygiene and causing discomfort (35, 135, 138, 140). IMF requires intact dentition or at least, minimally, a stable occlusion (135).

In a four-point fixation, the jaws are also fastened together, not with the help of teeth but with screws installed in the jaws (135, 138). This technique enables closed reduction also for edentulous jaws with dentitions in the replacement phase (135). However, it increases the risk of tooth injury (135, 138).

Closed reduction is the most common treatment method in children (13, 94), while in adults absolute reduction and fixation of fracture are often needed (123). IMF can also be used during surgery as an aid to surgical treatment.

2.2.6.2 OPEN REDUCTION AND INTERNAL FIXATION

In ORIF, the parts of the fracture are joined together with plates and screws. With this technique, bony healing takes less time and the patient can more quickly resume eating normal food and practising good oral hygiene. If the patient's compliance creates challenges, ORIF may be better option than IMF because with ORIF the risk of premature crushing of the closed fixation caused by the patient and the resulting complications can be reduced (135). However, ORIF is often a challenging surgical procedure and requires general anaesthesia and special skills of the clinician (141). The plate length and thickness and the

screw type and size must be considered carefully in every surgical procedure (135). Especially multiple fractures and fractures with large displacement often require ORIF, which is the most common treatment for symphyseal and parasymphyseal fractures (35).

As all surgical procedures, ORIF also has potential complications such as haemorrhage, infections, nerve injuries, and dental injuries (35). These can necessitate new surgical procedures, protracted periods of treatment, and prolonged pain. However, ORIF offers many advantages like better reduction and reposition of the fracture with immediate mobilization (142).

2.2.7 COMPLICATIONS IN MANDIBULAR FRACTURE TREATMENT

Complications associated with mandibular fractures have been reported to be infections of fracture sites, dental infections, dehiscence, angulation, malunion, non-union, facial and trigeminus nerve damage, malocclusion, TMJ dysfunction, restricted mouth opening, prolonged pain, and damage to dental roots (22, 47, 135). In previous studies, complications have been observed in 9–36% of mandibular fracture patients (79). Complications can lead, among other things, to secondary surgery, corrective osteotomy, and long orthodontic treatments. Patient-related factors, such as smoking, alcohol abuse, poor oral hygiene, and long-term diseases, can predispose to complications (143-145).

Especially in children, long follow-ups are appropriate because of late complications, including damage to permanent teeth, temporomandibular disorders, and growth disturbances (94). Previous studies have shown that the incidence of surgical complications increases stepwise in every decade of life, explaining why elderly patients are more likely to experience extended length of hospital stay (LHOS) (146, 147).

3 AIMS OF THE STUDY

Due to the rarity of mandibular fractures in children and the elderly, the scientific evidence for the diagnosis and treatment of this condition in these two patient groups is scant. The aim of this study was to investigate the special characteristics of mandibular fractures as well as the diagnosis and treatment in these patient groups at both ends of life.

Specific aims were as follows:

1. To evaluate possible challenges in fracture diagnostics leading to treatment delay in paediatric mandibular fracture patients (Study I).

2. To evaluate possible challenges in fracture diagnostics leading to treatment delay in elderly mandibular fracture patients (Study II).

3. To determine the occurrence and types of dental injuries in developing dentition with mandibular fractures (Study III).

4. To clarify the effect of age on occurrence and types of other than surgical site-related complications in mandibular fracture patients (Study IV).

4 PATIENTS AND METHODS

4.1 PATIENTS

The studies included patients presenting at the Emergency Unit of the Oral and Maxillofacial Surgery at Helsinki University Hospital (Studies I-IV) during 2013–2018 (Studies I-III) and 2018–2021 (Study IV). Studies I and III were based on data on children and adolescents (Study I: 182 patients <20 years, and Study III: 118 patients <18 years). Study II included elderly patients (135 patients ≥60 years), and Study IV, comprised 314 patients aged 16 years or more. Patients with a recent mandibular fracture were accepted into Studies I–III, while in Study IV only patients undergoing surgery for mandibular fracture were accepted.

4.2 STUDY DESIGN

All studies were conducted retrospectively (Studies I-IV), and patient data were collected from electronic patient records.

4.3 STUDY VARIABLES

4.3.1 OUTCOME VARIABLES

Primary outcome variables were missed mandibular fracture (Studies I and II), DI (Study III), and non-surgical site-related postoperative complication (Study IV). The secondary outcome variable was type of complication (Study IV).

A missed diagnosis in Studies I and II was determined when a fracture was not suspected or diagnosed during the patient's first assessment in primary health care.

DI was defined as any clinically and/or radiologically detected injury of the dentition that had been caused by the trauma leading to mandibular fracture.

Non-surgical site-related postoperative complications included complications detected during hospital stay and after discharge that required additional medical treatment or intervention. The complication types were categorized as pulmonary complications, urinary complications, general infections, electrolyte imbalance, cardiac complications, gastrointestinal complications, and death.

4.3.2 PREDICTOR VARIABLES

4.3.2.1 AGE

In all studies (I-IV), age was a predictor variable. It was categorized as age groups (Studies I, II, and IV), patients' age as a continuous variable (Studies I, II, and IV), and age subgroups (Studies I– IV).

Table 2. Age categorization in Studies I–IV.

Predictor variable	Study I	Study II	Study III	Study IV
Age groups (years)	<13 13≥19	≥60<80 ≥80	–	≥16<60 ≥60
Age continuous	<20	60<	–	16<
Age subgroups	<7 ≥7<13 ≥13<16 ≥16<18 ≥18<20	≥60<70 ≥70<80 ≥80<90 ≥90	<7 ≥7<13 ≥13<16 ≥16<18	≥16<20 ≥20<30 ≥30<40 ≥40<50 ≥50<60 ≥60<70 ≥70<80 ≥80<90

4.3.2.2 OTHER PREDICTOR VARIABLES

In Study III, the other predictor variables were sex, mechanism of injury, type of mandibular fracture, and other associated facial fracture(s).

In Study IV, secondary predictor variables were other patient-related or injury-related risk factors. Patient-related risk factors were sex (female/male), any long-term disease(s) requiring regular intervention or medication (psychiatric disease, cardiovascular disease, asthma/chronic obstructive pulmonary disease (COPD), diabetes, autoimmune disease, other), smoking, and alcohol and/or drug abuse. Injury-related risk factors were injury mechanism (assault, ground-level fall, bicycle/scooter accident, MVA, fall from height, and other (i.e. none of the previous five categories)), type (classified as multiple mandibular fractures, isolated mandibular fracture in the tooth-bearing region, or isolated unilateral fractures of the mandibular condyle, ramus, or both) and site (categorized as body-symphysis area, condyle-ramus area, or angle area) of mandibular fracture, combined craniofacial fracture(s) (including any fractures of the craniofacial skeleton other than the mandible), and AI(s) (including injuries of body parts other than the craniofacial skeleton).

4.3.3 EXPLANATORY VARIABLES

The explanatory variables in Studies I and II were sex, injury mechanism, and type of mandibular fracture. In addition, explanatory variables in Study II included combined other facial fracture, edentulous mandible/maxilla/both, surgical mandibular fracture treatment, and scene of injury.

4.3.4 OTHER VARIABLES

The other variables in Studies I and II were clinical symptoms and findings categorized as skin wounds and contusions, mucosal wounds, pain, swelling of the face, bruise on facial area, change in occlusion, neurosensory disturbance, restricted mouth opening, DI, and bleeding from the ear.

In addition, the number of days from injury to fracture diagnosis as well as the association between delayed assessment and missed diagnosis were reported (Studies I and II).

In addition, types and locations of the DIs and tooth loss as well as the duration of the follow-up in hospital, hospital outpatient care, or both were listed (Study III).

The association between LHOS and complications was also reported (Study IV).

4.4 STATISTICAL ANALYSES

Data were analysed using GraphPad Prism version 5.00 (GraphPad Inc.) in Studies I–III. Study IV data were analysed using a statistical software package (SPSS for Macintosh version 28, IBM, and Stata version 18, StataCorp LLC). A two-tailed Mann-Whitney U test was used to assess the significance of differences in continuous variables. Fisher's exact test was used to examine the association between categorical variables. The risk ratio between the outcome and predictor variables was calculated. Furthermore, in Study IV, univariate logistic regression analyses on patient-related explanatory variables and combined craniofacial fractures were examined for postoperative non-surgical site complication as the outcome; significant variables were selected into the multivariate model. P-values of less than 0.05 were considered statistically significant.

5 RESULTS

5.1 DESCRIPTIVE STATISTIC

5.1.1 AGE AND SEX DISTRIBUTION

The patient data of Studies I–IV consisted of 118–314 patients. Studies I and III comprised children and adolescents, while Study II comprised an elderly population. Study IV consisted of adolescents, adults, and the elderly. In Studies I, III, and IV, there were more male patients in the data (72.9–78.3%). In Study II, slightly more than half of the patients were female (56.3%). Age and sex distribution are shown in Table 3.

Table 3. Age and sex distribution of patients in Studies I–IV.

Study	Total patient number	Female		Male		Age range (years)	Mean	Median
		n	% of patients	n	% of patients			
I	182	44	24.2	138	75.8	0.5-20.0	15.3	16.9
II	135	76	56.3	59	43.7	60.6-94.2	73.7	72.9
III	118	32	27.1	86	72.9	0.5-17.9	13.3	14.6
IV	314	68	21.7	246	78.3	16-89	38	33

5.1.2 MECHANISM OF INJURY

In Studies I and IV, assault was the most common mechanism of injury, followed by ground-level fall and bicycle/scooter accident. In Studies II and III, the most common mechanism of injury was ground-level fall, followed by bicycle/scooter accident. The distribution of injury mechanisms in Studies I–IV is shown in Table 4.

Table 4. Distribution of injury mechanism in Studies I–IV.

	Study I		Study II		Study III		Study IV	
Mechanism of injury	**No. of patients**	**% of 182**	**No. of patients**	**% of 135**	**No. of patients**	**% of 118**	**No. of patients**	**% of 314**
Assault	46	25.3	4	3.0	18	15.3	137	43.6
Ground-level fall	40	22.0	111	82.2	28	23.7	99	31.5
Bicycle/ scooter accident	33	18.1	7	5.2	27	22.9	41	13.1
Motor vehicle accident	20	11.0	5	3.7	14	11.9	12	3.8
Fall from height	18	9.9	4	3.0	12	10.2	11	3.5
Other	25	13.7	4	3.0	19	16.1	14	4.5

5.2 TYPE AND SITE OF FRACTURE

Table 5 presents the distribution of mandibular fracture type and site in Studies I–IV. In three studies (I, III, and IV), multiple fractures of the mandible was the most common fracture type. In Study II (i.e. patients aged >60 years) only, isolated tooth-bearing region fracture was the most frequent fracture type.

Table 5. Distribution of mandiblar fracture type and site in Studies I–IV.

	Study I		Study II		Study III		Study IV	
	No. of patients	**% of 182**	**No. of patients**	**% of 135**	**No. of patients**	**% of 118**	**No. of patients**	**% of 314**
All	182	100	135	100	118	100	314	100
Mandibular fracture type								
Multiple fracture	84	46.2	49	36.3	51	43.2	205	65.3
Isolated fracture of tooth bearing region	38	20.9	78	57.8	18	15.3	76	24.2
Isolated unilateral condyle-ramus fracture	60	33.0	8	5.9	49	41.5	33	10.5
Mandibular fracture site								
Body-symphysis area	99	54.4	37	27.4	51	43.2	233	74.2
Condyle-ramus	104	57.1	124	91.9	81	68.6	177	56.4
Angle	56	30.8	5	3.7	23	19.5	94	29.9

Condyle-ramus region was the most involved fracture site when only children, adolescents, and the elderly (Studies I–III) were examined. In the

population of adults, fractures of the body-symphysis area occurred most often (Study IV).

5.3 TREATMENT DELAY

Table 6. Association between predictor variables and patients with and without missed diagnosis in Studies I and II.

	Patients with missed diagnosis				Patients without missed diagnosis				p (Children)	p (Elderly)
	Children		Elderly		Children		Elderly			
	n	%	n	%	n	%	n	%		
All	27	14.8	27	20.0	155	85.2	108	80.0		
Gender										
Male	17	12.3	14	23.7	121	87.7	45	76.3	ns	ns
Female	10	22.7	13	17.1	34	77.3	63	82.9		
Age group										
< 13	15	33.3	–	–	30	66.7	–	–	**<0.01**	
≥13<20	12	8.8	–	–	125	91.2	–	–		
≥60<80	–	–	21	20.4	–	–	82	79.6		ns
≥80	–	–	6	18.8	–	–	26	81.3		
Injury mechanism										
Ground-level fall	7	17.5	23	20.7	33	82.5	88	79.3	ns	ns
Bicycle accident	9	27.3	2	28.6	24	72.7	5	71.4		
Traffic accident	1	5.0	0	0.0	19	95.0	5	100.0		
Assault	5	10.9	1	25.0	41	89.1	3	75.0		
Fall from height	3	16.7	0	0.0	15	83.3	4	100.0		
Sport accident	2	10.5	–	–	17	89.5	–	–		
Other	0	0.0	1	25.0	6	100.0	3	75.0		
Mandibular fracture										
Multiple mandibular fracture	10	11.9	9	18.4	74	88.1	40	81.6	ns	ns
Isolated unilateral condyle-ramus fracture	12	20.0	15	19.2	48	80.0	63	80.8		
Isolated tooth-bearing region fracture	5	13.2	3	37.5	33	86.8	5	62.5		
Combined other facial fracture										
Yes	0	0.0	3	13.0	20	100.0	20	87.0	ns	ns
No	27	16.7	24	21.4	135	83.3	88	78.6		

	Patients with missed diagnosis				Patients without missed diagnosis				p (Children)	p (Elderly)
	Children		Elderly		Children		Elderly			
	n	%	n	%	n	%	n	%		
Memory disorder										
Yes	–	–	6	46.2	–	–	7	53.9		**0.02**
No	–	–	21	17.2	–	–	101	83.0		
Scene of injury										
Hospital/ Nursing home	–	–	5	45.5	–	–	6	54.6		0.02
Home	–	–	3	9.4	–	–	29	90.6		
Other	–	–	19	20.7	–	–	73	79.4		
Symptom	**n**	**% of 27 patients**	**n**	**% of 27 patients**	**n**	**% of 155 patients**	**n**	**% of 108 patients**		
Pain	21	77.8	22	81.5	124	80.0	84	77.8	ns	ns
Restricted mouth opening	19	70.4	12	44.4	89	57.4	46	42.6	ns	ns
Skin wound of the jaw	17	63.0	16	59.3	53	34.2	64	59.3	**0.01**	ns
Change in occlusion	8	29.6	10	37.0	59	38.0	33	30.6	ns	ns
Dental injury	10	37.0	7	25.9	56	36.1	35	32.4	ns	ns
Mucosal wound	5	18.5	4	14.8	39	25.3	21	19.4	ns	ns
Skin contusion on mandible	6	22.2	5	18.5	29	18.7	21	19.4	ns	ns
Neurosensory disturbance	2	7.4	1	3.7	17	10.9	2	1.9	ns	ns
Bleeding from the ear	1	3.7	2	1.9	8	5.2	10	9.3	ns	ns

Abbreviations: ns, not significant

The occurrence of primarily missed mandibular fractures was investigated in children and adolescents (Study I) as well as in elderly patients (Study II) with a surgically treated mandibular fracture. In children and adolescents, mandibular fractures were missed in 14.8% of the 182 patients (Study I) and in elderly patients in 20.0% of the 135 patients during their first health care assessment (Study II). Statistically significant associations between missed fractures and sex, fracture type, or injury mechanism were not found in either study.

Mandibular fracture was missed significantly more often in patients aged under 13 years than in teenagers (33.3% vs. 8.8%, $p<0.01$). The only significant symptom or clinical finding associated with missed fractures was skin wound of the jaw ($p<0.01$) (Study I) (Table 6, Figure 5a and b).

In elderly patients, memory disorder ($p=0.02$) and scene of injury ($p=0.02$) were associated statistically significantly with missed fractures. Fractures were missed more frequently in patients who were in hospital or in a nursing home at the time of injury (Study II) (Table 6).

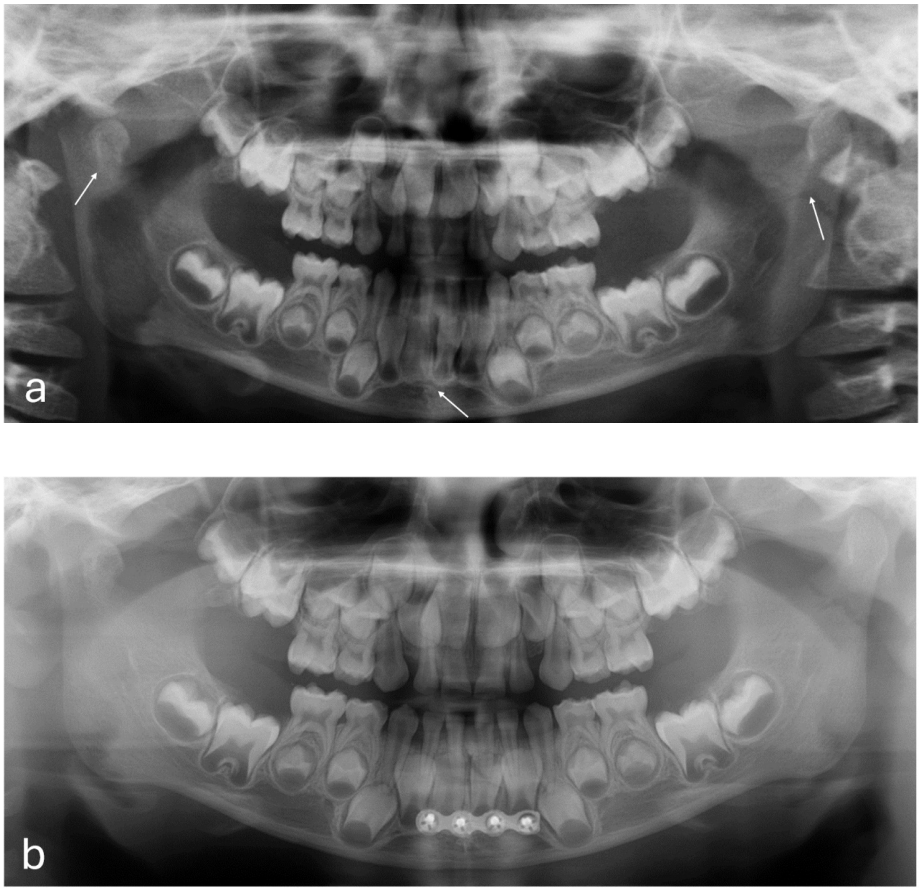

Figure 5. a) DPR of a 5-year-old boy who fell off a bicycle and hit his jaw on the ground. The jaw wound was sutured at the health care centre on the same day. He was examined by a dentist the next day for persistent symptoms (pain, restricted mouth opening, change in occlusion, mucosal wound, and diastema). In DPR, three fractures (arrows) were detected in both mandibular condyles and in the symphysis region, which was hardly detectable in the radiological view. The symphyseal fracture was, however, clinically detectable due to diastema between the lower medial incisors.

b) Due to a greenstick fracture and consequent mandibular widening in the mandibular symphysis region, the premolar and molar region were turned to the sides. The symphysis region fracture was reduced and fixed with titanium osteosynthesis material under general anaesthesia. The condyle fractures were treated without surgery, i.e. by soft diet and pain medication.

5.4 SYMPTOMS OF MANDIBULAR FRACTURES

Symptoms and clinical findings observed in connection with mandibular fractures were evaluated in Studies I and II. In both patient populations, most of the patients had more than one clinical finding or symptom. The most frequent symptom was pain, followed by restricted mouth opening and skin wound on the lower face (Table 7).

In Study I, the incidence of symptoms was also evaluated in different age groups. Neurosensory disturbance ($p<0.01$) and change in occlusion ($p<0.01$) were reported more often in teenagers and adolescents than in children. By contrast, skin wound of the jaw was observed significantly more often in children than in teenagers or adolescents ($p<0.01$).

Table 7. Symptoms and findings in children, adolescents, and adults with mandibular fractures (Table modified from Studies I and II).

	Study I							Study II	
	All		<13 years		≥13 to <20 years			All	
Symptom	**n**	**% of 182 patients**	**n**	**% of 45 patients**	**n**	**% of 137 patients**	**p**	**n**	**% of 135 patients**
Pain	145	79.7	34	75.6	111	81.0	ns	106	78.5
Restricted mouth opening	108	59.3	24	53.3	84	61.3	ns	58	43.0
Skin wound of the jaw	70	38.5	30	66.7	40	29.2	**<0.01**	80	59.3
Change in occlusion	67	36.8	9	20.0	58	42.3	**<0.01**	43	31.9
Dental injury	66	36.3	18	40.0	48	35.0	ns	42	31.1
Mucosal wound	44	24.2	11	24.4	33	24.1	ns	25	18.5
Skin contusion on mandible	35	19.2	11	24.4	24	17.5	ns	26	19.3
Neurosensory disturbance	19	10.4	0	0.0	19	13.9	**<0.01**	3	2.2
Bleeding from the ear	9	4.9	1	2.2	8	5.8	ns	12	8.9
Swelling	–	–	–	–	–	–	–	43	31.9
Facial bruises	–	–	–	–	–	–	–	48	35.6

Abbreviations: ns, not significant

5.5 DENTAL INJURIES

In Study III, DIs were detected in 34.7% (n=41) out of 118 patients (Table 8). Patients with tooth injury had on average 3.5 injured teeth. The maxillary medial incisors were the most frequently injured teeth among both deciduous and permanent teeth (Figures 6 and 7). Non-complicated crown fracture (50.7%) was the most common DI type. Altogether 16.2% of the injured teeth

were lost, typically at the time of injury. Loss of at least one tooth was found in 10.2% of patients. Avulsion was the most common cause for tooth loss (52.2%). Statistically significant associations between studied variables and DIs were not detected (Table 8).

Table 8. Data of 118 mandibular fracture patients aged under 18 years with and without dental injury (modified from Study III).

	Total n	Patients with dental injury	% of n	Patients without dental injury	% of n	
All	118	41	34.7	77	65.3	
Sex						
Male	86	29	33.7	57	66.3	ns
Female	32	12	37.5	20	62.5	
Age group						
<7	15	6	40.0	9	60.0	ns
≥7 to <13	30	12	40.0	18	60.0	
≥13 to <16	28	10	35.7	18	64.3	
≥16 to <18	45	13	28.9	32	71.1	
Mechanism of injury						
Ground-level fall	28	13	46.4	15	53.6	ns
Bicycle accident	27	11	40.7	16	59.3	
Assault	18	2	11.1	16	88.9	
Traffic accident	14	6	42.9	8	57.1	
Sport accident	14	3	21.4	11	78.6	
Fall from height	12	5	41.7	7	58.3	
Other	5	1	20.0	4	80.0	
Mandibular fracture type						
Tooth bearing region	16	4	25.0	12	75.0	ns
Non tooth bearing region	67	23	34.3	44	65.7	
Combined	35	14	40.0	21	60.0	
Mandible with other facial fracture						
Yes	13	5	38.5	8	61.5	ns
No	105	36	34.3	69	65.7	

Abbreviations: ns, not significant

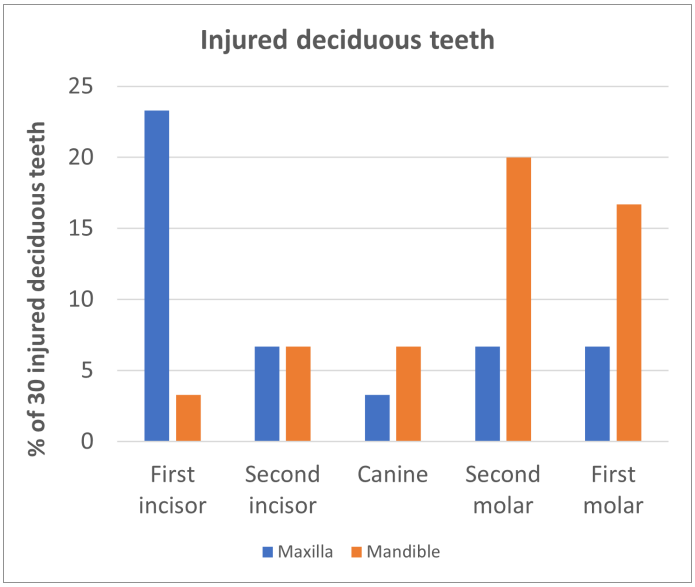

Figure 6. Injured deciduous teeth in the mandible and maxilla of patients aged under 18 years with mandibular fracture (figure modified from Study III).

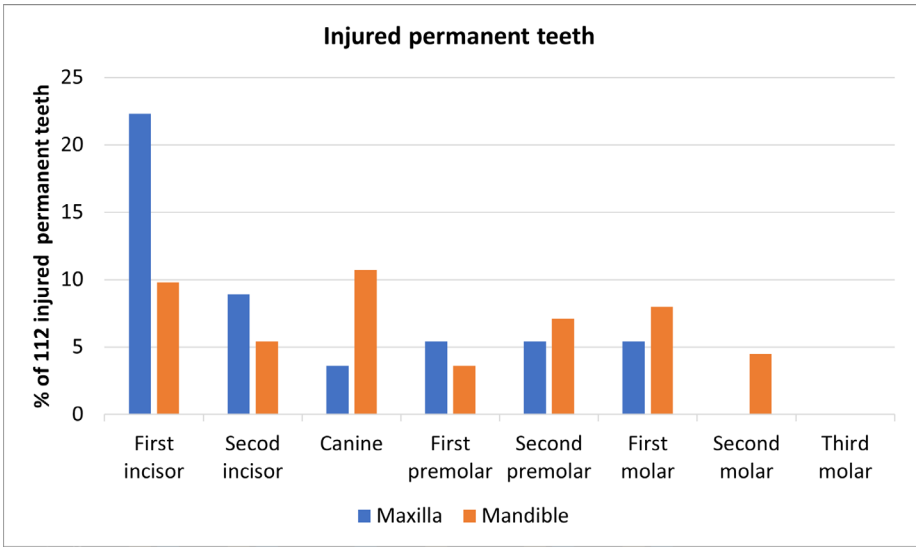

Figure 7. Injured permanent teeth in the mandible and maxilla of patients aged under 18 years with mandibular fracture (figure modified from Study III).

5.6 SITE-RELATED POSTOPERATIVE COMPLICATIONS

Non-surgical site-related postoperative complications occurred in 6.7% of the 314 mandibular fracture patients. All in all, 25 complications were observed in 21 patients. The most common complication type was pulmonary (36.0%), followed by urinary complications (20.0%) and general infection (16.0%). Pulmonary complications occurred more often in elderly patients, whereas urinary complications were more common in younger patients (Figure 8).

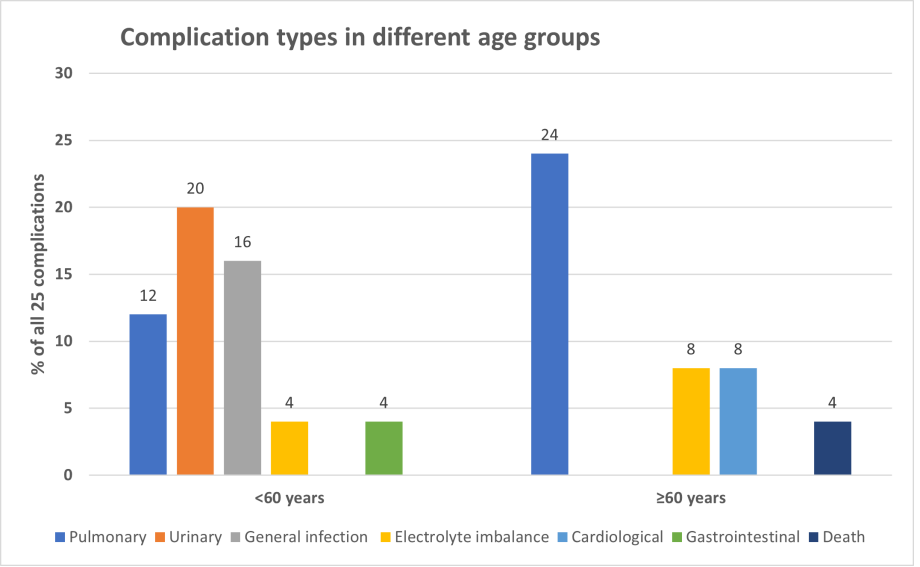

Figure 8. Distribution of complication types in adult patients with mandibular fractures (figure modified from Study IV).

Postoperative non-surgical site-related complications were most likely to occur in patients who were elderly (aOR 5.55; 95% CI 1.92–16.21; p<0.01), had combined craniofacial fractures (aOR 2.92; 95% CI 1.06–8.03; p=0.04), and abused alcohol or drugs (aOR 4.51; 95% CI 1.70–11.96; p<0.01) (Table 9) (Study IV).

Table 9. Logistic regression model predicting the likelihood of non-surgical site postoperative complication in mandibular fracture patients (modified from Study IV).

	Univariate logistic regression analyses			Multivariate logistic regression analyses		
Variable	**OR**	**95% CI**	**p-value**	**aOR**	**95% CI**	**p-value**
Combined craniofacial fracture(s), ref. no combined craniofacial fractures	2.8	1.1–7.2	0.04	2.9	1.1–8.0	0.04
Age group ≥ 60 years, ref. age <60 years	4.1	1.5–10.9	<0.01	5.6	1.9–16.2	<0.01
Alcohol and/or drug abuse, ref. no abuse	3.3	1.3–8.0	0.01	4.5	1.7–12.0	<0.01

OR = odds ratio

CI = confidence interval

aOR = adjusted odds ratio

Complications were significantly associated with prolonged LHOS ($p<0.01$). The median stay was one day longer in patients with complications than in those without complications.

6 DISCUSSION

6.1 DESCRIPTIVE STATISTICS

Mandibular fractures were more frequent in males than females in almost all of the studies included. Only in Study II, which examined the elderly population, were mandibular fractures slightly more often observed in women. This can be explained by the fact that in Finland women live longer than men, on average (148). Hence, there are more women in the oldest age groups, and thus, it is more likely that more fractures are also observed in women in these groups. Our studies confirm previous reports showing mandibular fractures to occur more often in men than in women in all age groups, except for the oldest age groups (17, 22, 41, 80, 90).

In Studies I and IV, assault was the most common mechanism of injury, while in Studies II and III, it was ground-level fall. Moreover, when considering the injury mechanisms in different age groups within the studies, it can be noted that assault is a very rare mechanism of injury in the youngest and oldest age groups. Nevertheless, from teenagers to adults, assault becomes the most common mechanism. This can be explained by children and the elderly living a well-protected life, with less time spent and moving around outside the home. The use of substances also often is not a factor until the teenage years (149). Naturally, ground-level fall is the most common mechanism of injury in young children and the elderly because balance and motor skills are weaker at both ends of life (150-152). Moreover, it should be noted that alcohol consumption also occurs in the elderly age group, and the combined use of alcohol and medications easily leads to falls (153).

The type and site of the fracture differed between different age groups in these studies (Studies I-IV). In children, adolescents, and adults (Studies I, III, and IV), multiple fractures of the mandible were the most common fracture type, while in the elderly population (Studies II and IV) isolated mandibular fractures predominated. This could be explained by the fact that in children and adults the injury energies leading to fractures are probably higher, resulting in multiple fractures. In frail elderly people, on the other hand, even a lower injury energy is sufficient to cause a fracture, and the alveolar bone may already be resorbed because of missing teeth. As a result of resorption, the mandible weakens, and fractures occur more easily.

Fractures in the condyle-ramus region were the most common sites in children, adolescents, and the elderly (Studies I-IV), while in the predominantly adult population (16–59 years) in Study IV the most common site of fracture

was the angle region. However, in the group aged under 60 years (Study IV), there were no major differences between different fracture sites. Fracture site variation between different age groups likely arises from differences in injury mechanisms: in children and the elderly ground-level falls, and in adults assault.

6.2 TREATMENT DELAY

Fractures were missed at the first health care contact most often at both far ends of life. In Study I, preschool-aged and primary school children were found to be at high risk of misdiagnosis of mandibular fractures relative to teenagers or adolescents. In Study II, an alarming 20.0% of mandibular fractures were not diagnosed at the first health care contact in patients aged over 60 years.

The results show that diagnosing fractures of young children and the elderly is often challenging, and symptoms indicating fractures are often undetected or ignored. In children, cooperation, here defined as the ability to describe symptoms and discuss the accident, may be limited. Also, a developing dentition or, on the other hand, toothlessness can cause challenges for the clinician. In elderly patients, especially memory disorders proved to be a significant predictor for diagnostic misses. Impaired hearing can also cause challenges in a clinical examination. At both ends of life, the importance of a careful and comprehensive clinical examination by a clinician is therefore emphasized.

6.3 SYMPTOMS OF MANDIBULAR FRACTURES

Pain, restricted mouth opening, and skin wound in the lower jaw were the most common symptoms and findings in paediatric and elderly patients with missed mandibular fracture. Skin wound in the lower jaw was the only significant symptom or clinical finding in children with missed mandibular fracture, while none of the symptoms or findings were statistically significant in elderly patients with missed fracture. Focusing on symptom care such as wound cleaning and suturing may divert the clinician's attention, while the simultaneous symptoms and findings of the mandibular fracture go unnoticed. Additional training is essential for clinicians working in emergency departments to suspect mandibular fractures based on clinical examination. Although conducting a good clinical examination can be challenging in children and elderly patients, many symptoms of mandibular fractures, such as restricted mouth opening and TMJ pain, are easily detectable by any health care professional.

6.4 DENTAL INJURIES

DIs are common findings in paediatric mandibular fracture patients. In Study III, DIs were observed in more than one-third (34.7%) of patients. Up to 16% of injured teeth were lost, and traumatic tooth loss was most often seen in the upper incisive region. Tooth loss not only affects the patient's masticatory function but can have long-term effects on the patient's well-being and self-esteem. Teeth have a considerable impact on appearance (154, 155), and thus, especially in teenagers, an aesthetically visible loss of front teeth can lead to social isolation, bullying, and depression.

Of the lost teeth, 52.2% were lost due to avulsion, failed replantation of an avulsed permanent tooth, or both. Half of the avulsed teeth were permanent, and half were deciduous teeth. However, only 22% of replanted teeth were lost during follow-up. Thus, early immediate replantation of a permanent tooth and careful follow-up are important (156) and may result in successful or at least long-term benefit especially in children because dental implant reconstruction is not recommended until the end of growth. Premature implantation can lead to complications such as infraocclusion and rotation of dental implants (157-160).

Non-complicated crown fracture was the most common DI type in this study. Although such DIs are rarely serious, their treatment and follow-up can be very challenging, especially in young children, due to poor cooperation and communication challenges. Also determining the vitality of a tooth in a child can be difficult. Regular comprehensive clinical examinations combined with radiological evaluations are often required for up to 5 years after injury depending on the tooth injury (161-163), and DI treatment may necessitate numerous visits and, in children, general anaesthesia.

In Study III, DIs were more prevalent in younger age groups, albeit without statistically significant difference. In young children, motor skills are still developing and facial protection at the time of injury may be deficient. Primary teeth are also slightly softer than permanent teeth (164, 165) and are thus more prone to fractures. The structure of a child's face also changes with age, which can partly explain the higher number of DIs in young children. The convexity of the face decreases gradually due to differential growth of the maxilla and mandible, with the mandible growing markedly in all three dimensions. A notable change in the midfacial region is the development of the paranasal sinuses. The factors explaining the frequency of the dental injuries particularly in the maxillary anterior region include lip incompetency and, most importantly, horizontal overjet (166).

6.5 NON-SURGICAL SITE-RELATED POSTOPERATIVE COMPLICATIONS

Non-surgical site-related postoperative complications occurred in 6.7% of 314 patients. Although complications were observed in both younger and older age groups, older age significantly increased the risk of complications. Elderly people often have several long-term diseases, and they are frailer and have lower healing capacity after diseases and injuries (24-30). Therefore, the risk of anaesthesia and surgery should be evaluated, especially in the elderly. If the indication for surgical treatment is low or other treatment methods are available, a non-surgical treatment should be considered. However, it is important to note that serious (e.g. fatal) complications were very rare in the study, and thus, fear of complications is not a valid reason to avoid surgery in elderly patients when it is deemed necessary. Long-term diseases or AIs did not increase the occurrence of non-surgical site-related postoperative complications. By contrast, patients with combined craniofacial fractures as well as alcohol and/or drug users were more likely to have postoperative complications than those without such history. Also, patients with multiple mandibular fractures were associated with complications, emphasizing that the severity of craniofacial fractures affects the likelihood of complications.

Non-surgical site-related complications significantly extended the hospital stay, and therefore, it is also important in terms of cost-effectiveness to try to prevent complications and to detect and treat them at an early stage.

The complication types varied according to age. Cardiac complications occurred in elderly patients, while urinary complications and general infections were found in younger patients. Earlier studies have shown that urinary retention is common after surgery and anaesthesia (167); it is most likely not directly a complication of mandibular fracture surgery but rather of the drugs used in anaesthesia and pain treatment.

Regarding all evaluated adult patients, pulmonary complications were the most common complication type. Intubation difficulties are known to increase the risk of pneumonia (168), and mandibular fractures as well as other facial fractures may cause difficulties with intubation (169, 170). In earlier studies of patients with severe odontogenic infection, pneumonia was the most common postoperative infection complication (171, 172). Thus, oral procedures may predispose these patients to pulmonary complications. The total incidence of pulmonary complications (2.9%) was, however, low in comparison to the reported incidence of postoperative pulmonary complications (5-10% of non-high-risk patients) after non-cardiothoracic surgery (173).

6.6 LIMITATIONS

Limitations of this study comprise the relatively small number of patients and its retrospective nature. None of the studies included patient data for the entire population. Studies I and III included only children and adolescents, while Study II focused on the elderly population. Study IV included all age groups except children. Mandibular fractures in children and elderly patients are relatively rare, and while data have been collected over several years, the number of patients remains moderate.

Due to their nature, retrospective studies may contain erroneous/inadequate data. There is a risk that, for example, all symptoms are not recorded in the patient records.

In addition, in Studies I and II, data from patients with completely missed fracture could not be included. Also, in Study III, limited follow-up time can induce bias regarding dental injuries. For example, an eventual loss of an injured tooth after a very long time may have gone undetected. In Study IV, the challenge was the determination of complications, so we had to narrow down less concrete complications such as headaches and psychological symptoms. The patient data also did not reveal the duration of the surgeries, which would have been good in terms of assessing its effect on the occurrence of postoperative complications.

6.7 FUTURE ASPECTS

In future studies, significant additional information could be provided if treatment delay was evaluated at the level of the entire population. It would also be useful to consider the effect of the duration of surgeries on the incidence of complications.

The findings of this study should be deployed in clinical work and the observed deficiencies corrected with the help of training, teaching, and systematic protocols in the examination of patients.

7 CONCLUSIONS

1. Mandibular fractures are often missed in primary examination at the first health care contact in both young children and the elderly. Fractures often go undiagnosed even when clinical symptoms and findings are typical for mandibular fractures. More training is needed for medical doctors, dentists, and other health care professionals to ensure sufficient examination of mandibular fracture and other trauma patients (Studies I and II).

2. Dental injuries are common in paediatric mandibular fracture patients, and they often lead to tooth loss. Replantation of avulsed permanent teeth should take place as soon as possible, and careful dental evaluation and follow-up are warranted for all paediatric mandibular fracture patients (Study III).

3. Non-surgical site-related complications after mandibular fracture surgery occur in all adult age groups but are significantly more common in elderly patients. Also, the types of complications vary between age groups. All clinicians treating mandibular fractures should be aware of the possibility of site-related postoperative complications and their management (Study IV).

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