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Diagnostic accuracy of physical examination findings for midfacial and mandibular fractures

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A B S T R A C T

Objectives: To assess the diagnostic accuracy of physical examination findings used to identify patients at risk for midfacial or mandibular fractures.

Materials and Methods: A five-year retrospective cohort was constructed from all emergency department patients with a midfacial or mandibular trauma. The sensitivity, specificity, pre-test probability, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio data was calculated for 19 and 14 physical examination findings for midfacial and mandibular fractures respectively. Computed Tomography and panoramic radiography were used as index tests.

Results: A total of 1484 patients were identified among whom 40.4% midfacial and 33.4% mandibular fractures were diagnosed. Overall, specificity was found to be higher than sensitivity. Regarding midfacial fractures, high specificity was found for raccoon eyes, malar eminence flattening and all the findings that are related to palpation, the nasal, ocular and intra-oral assessment. Malar eminence flattening, external nasal deformity, nasal septum hematoma, change of globe position and palpable step-off had ad high positive predictive value and positive likelihood ratio. Regarding mandibular fractures high specificity was found for mouth opening restriction, auditory canal bleeding, intra-oral assessment related findings, palpable step-off, inferior alveolar nerve paresthesia, the angular compression test and chin axial pressure test.

Conclusions: The diagnostic accuracy of relevant physical examination findings were identified for the prediction of midfacial and mandibular fractures.

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Introduction

Maxillofacial injuries comprise a substantial part of head and neck trauma's in today's emergency department. The primary and secondary assessments are used to evaluate all injuries and to identify critically injured patients. For the maxillofacial region, patients are assessed clinically to determine which patients are at risk for midfacial and mandibular fractures and require radiological imaging.

The physical examination of the midface and mandible is characterized by the complex anatomy and broad range of potential fracture type outcomes. Hence, the physical examination should cover all aspects such as the visual appearance, palpable abnormalities, sensory disturbances and ocular related findings. Previous studies assessed how a selection of these physical examination findings can be used to predict midfacial and mandibular fractures [1–3]. However, those studies only investigated a selection of physical examination findings, and data from other findings regarding predictability is lacking.

Thus, evidence is required regarding the diagnostic accuracy of all a potential midfacial and mandibular physical examination findings and understanding them could be used for a better diagnostic work-up and a potential reduction in unnecessary radio-

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logical investigations. Therefore, we gathered a large retrospective cohort of emergency department patients with either a midfacial or mandibular trauma to assess the diagnostic accuracy of related physical examination findings.

Material and methods

Study design

A retrospective cohort study was conducted of maxillofacial trauma patients admitted to the emergency department. Chart review was conducted to calculate the diagnostic accuracy of physical examination findings for midfacial and mandibular fractures. The local Medical Ethical Review Board reviewed the study design and waived further need for approval (ref.nr. M17.212837). The study was reported using the STARD guidelines (Standards for Reporting of Diagnostic Accuracy Studies) [4].

Study cohort

The cohort consisted of patients with midfacial or mandibular trauma that were admitted consecutively to the emergency department of the level I trauma center of the University Medical Center Groningen, the Netherlands between 2013 and 2017. The patients who had undergone computed tomography (CT) or panoramic radiography of the head and neck region were identified from all the emergency department records. Patient selection was based on age (≥16 yr.), trauma related visits, radiological imaging protocols and full availability of medical records. Subsequently, each medical record was individually consulted to assess whether the patients had sustained trauma of the midfacial and/or mandibular regions.

Index test

CTs of the maxillofacial region and panoramic radiography of the mandible were used as an index test. The outcome was the diagnosis of any midfacial or mandibular fracture. A midfacial fracture was defined as any fracture of the frontal sinus, orbital rim and walls, maxillary sinus, zygomaticomaxillary complex, nasoorbitoethmoid complex, nasal bone, Le Fort I, II, III complex and maxillary dentoalveolar complex fractures. A mandibular fracture was defined as any fracture of the median, paramedian, corpus, angular, coronoid and condylar process, and fractures of the mandibular dentoalveolar complex. The CT and panoramic radiography data was examined by a board-certified radiologist or oral and maxillofacial surgeon. The interpretation of the index test could not be blinded due the retrospective study design.

Reference standard

Physical examination findings related to midfacial and mandibular traumas were used as the reference standard. A pre-defined selection of 19 parameters for midfacial and 14 parameters for mandibular trauma patients was extracted from the data collected from the medical records of the emergency department's primary and secondary assessments of the patients (supplementary material 1). The data was categorized as absent, present, not assessable, or not reported. The following parameters were considered as not assessable for patients who had been sedated and intubated during the clinical examination: ocular movements, diplopia, visual acuity, occlusal changes, infraorbital nerve paresthesia, inferior alveolar nerve paresthesia, compression pain, and axial chin pressure pain. The following parameters were considered as not assessable for fully removable denture or edentulous patients: occlusal changes, tooth mobility, luxation or avulsion. Blinding of the reference test could not be controlled due the retrospective study design.

Data extraction

The data was extracted using a chart review template. Additional data on gender, age distribution, treatment urgency, time of admission and mechanism of injury, was collected and categorized according to the Manchester Triage System (MTS) [5].

Statistical analysis

The Statistical Package for the Social Sciences was used for the data analysis (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23.0). Continuous variables were reported as median and interquartile range and categorical variables were presented as frequency distributions and percentages. Contingency tables were constructed for the individual physical examination findings to calculate their sensitivity, specificity, pre-test probability, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+) and negative likelihood ratio (LR-), with corresponding standard error and 95% confidence interval [6]. The calculations were performed according to whether the physical examination reported "present" and "absent" findings or "did not report absent" findings. Additional calculations were performed on only "present" and "absent" reported physical examination findings.

Results

Patient characteristics

A total of 1484 maxillofacial trauma patients were identified (Fig. 1). From this population, 1375 had sustained a midfacial trauma and 556 (40.4%) of these patients were diagnosed with a midfacial fracture. Of the 347 patients with a mandibular trauma, 116 (33.4%) were diagnosed with a mandibular fracture. A total of 236 (15.9%) patients were diagnosed with both a midfacial and mandibular trauma. The patient characteristics are summarized in table 1 and Fig. 2.

Reported physical examination findings

The data form the reported physical examination findings are summarized in table 2. Among the midfacial traumas, swelling (44.1%), lacerations (52.2%) and peri–orbital hematoma (50.1%) were the most commonly reported physical examination findings. Swelling (14.2%), mouth opening restriction (15.7%), mandibular movement pain (16.2%) and malocclusion (21.1%/ 15.0%) were the most commonly reported physical examination findings for mandibular trauma's. The highest rates physical examination findings considered not assessable were found for ocular movement limitations, diplopia, visual acuity changes, malocclusion, dental injury, angular compression test, chin axial pressure test and assessment of infra-orbital- and inferior alveolar nerve paresthesia.

Diagnostic accuracy for midfacial and mandibular fractures

Table 3 shows the diagnostic accuracy of the physical examination findings for midfacial fractures. Overall, specificity was found to be higher than sensitivity. High rates of specificity were found for raccoon eyes (98.2%), malar eminence flattening (99.6%), external nasal deformity (99.4%), epistaxis (93.8%), nasal septum hematoma (100%), subconjunctival hemorrhage (97.6%), ocular movement limitations (97.6%), diplopia (98.5%), visual acuity changes (97.5%), change of globe position (100%), malocclusion (99.1/98.2%), tooth mobility or luxation (97.2%), tooth avulsion (98.1%), palpable step-off (99.6%), bony crepitus (99.4%) and infraorbital nerve paresthesia (98.1%). High PPV and LR+ rates

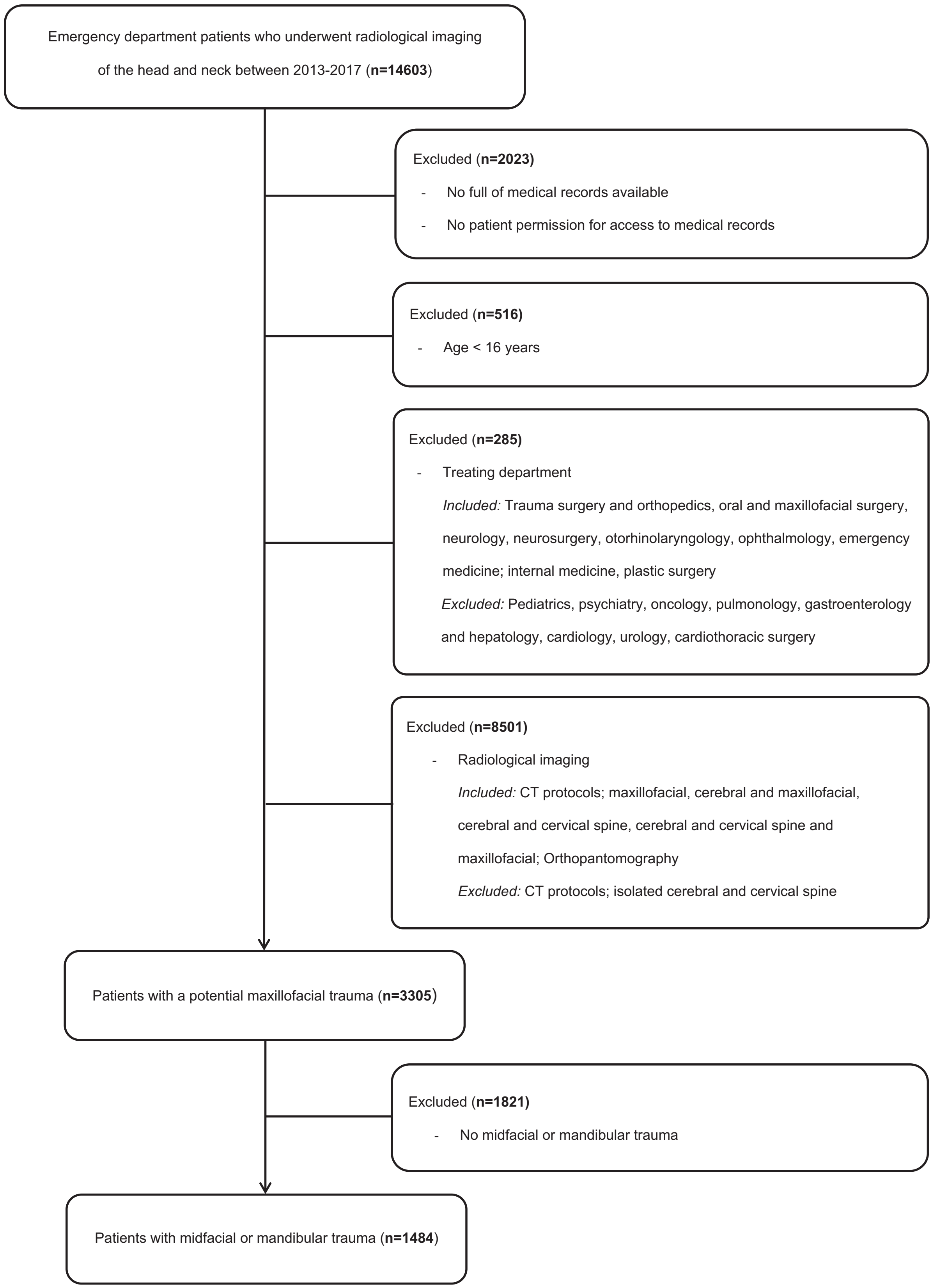

Fig. 1. Flowchart of midfacial and mandibular trauma patient identification.

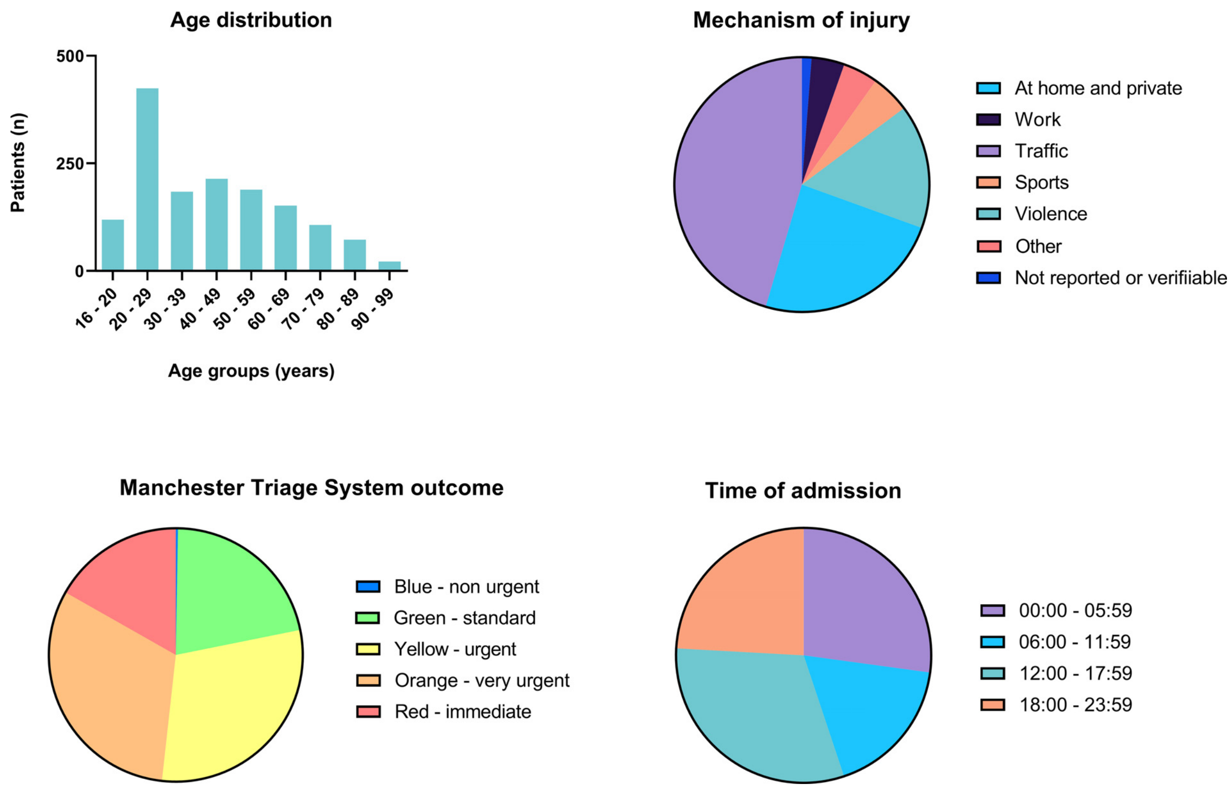

Fig. 2. Patient characteristics.

Table 1
Patient characteristics.

Total patients (n)	1484
Gender distribution (n(%))	
Male	1021 (68.8)
Female	463 (31.2)
Age	
Median and interquartile range (years)	40 (34.75)
Range (years)	16–96
Age distribution (n(%))	
16–19 years	119 (8)
20–29 years	424 (28.6)
30–39 years	184 (12.3)
40–49 years	214 (14.4)
50–59 years	189 (12.6)
60–69 years	152 (10.1)
70–79 years	107 (7.4)
80–89 years	73 (5.0)
90–99 years	22 (1.4)
Mechanism of injury (n(%))	
At home and private	357 (24.1)
Work related	62 (4.2)
Traffic	674 (45.4)
Sports	73 (4.9)
Violence	234 (15.8)
Other	66 (4.4)
Not reported or verifiable	18 (1.2)
MTS urgency triage code (n(%))	
Blue – Non urgent	4 (0.3)
Green – Standard	320 (21.6)
Yellow - Urgent	444 (29.9)
Orange – Very Urgent	467 (31.5)
Red – Immediate	249 (16.8)
Time of admission (n(%))	
Night (00:00–05:59)	403 (27.2)
Morning (06:00–11:59)	263 (17.7)
Afternoon (12:00–17:59)	460 (31.0)
Evening (18:00–23:59)	358 (24.1)

MTS Manchester Triage System.

were found for malar eminence flattening, external nasal deformity, nasal septum hematoma, change of globe position and palpable step-off.

For mandibular fractures, the diagnostic accuracy of physical examination findings are presented in table 4. High specificity was found for mouth opening restriction (90.2%), auditory canal bleeding (96.1%), malocclusion (90.8%/92.8%), tooth mobility or luxation (94.5%), tooth avulsion (99.1%), intra-oral hematoma (93.8%), angular compression test pain (98.6%), chin axial pressure test pain (99.1%), palpable step-off (99.1%) and inferior alveolar nerve paresthesia (99.5%). A high PPV was found for inferior alveolar nerve paresthesia and a high LR+ was found for angular compression test pain, chin axial pressure test pain and inferior alveolar nerve paresthesia.

The outcomes of the calculations performed on only "absent" and on only "present" reported physical examination findings are given in supplementary Tables 2a and 2b. Contingency tables can be found in supplementary material 3.

Discussion

Emergency department patients with head and neck trauma require a systematic assessment of the maxillofacial region. Abnormal physical examination findings are used to assess the injury severity and guide the need for radiological imaging. Emergency department workers need an insight into the diagnostic properties of these findings to identify any patients at risk for midfacial and mandibular fractures. This large retrospective cohort study of 1484 patients calculated the diagnostic accuracy of individual physical examination findings for both midfacial and mandibular fractures. The presented data for a total of 19 and 14 physical examination findings for midfacial and mandibular trauma patients respectively, has not been studied before.

For midfacial fractures, a variety of studies focused on the diagnostic accuracy of physical examination findings. A retrospective

Table 2
– Reported physical examination findings characteristics.

		Reported data (n(%))				
	Prevalence (%)	No fracture Present	Fracture Present	Total Absent	Not assessable	Not reported
Midface						
Swelling	44.1	297 (21.6)	310 (22.5)	70 (5.1)	0 (0)	698 (50.8)
Laceration	52.2	431 (31.3)	287 (20.9)	108 (7.9)	0 (0)	549 (39.9)
Peri-orbital hematoma	50.1	400 (29.1)	289 (21.0)	48 (3.5)	0 (0)	638 (46.4)
Raccoon eyes	3.4	15 (1.1)	32 (2.3)	21 (1.5)	0 (0)	1307 (95.1)
External nasal deformity	3.3	5 (0.4)	40 (2.9)	65 (4.7)	1 (0.1)	1264 (91.9)
Malar eminence flattening	4.1	3 (0.2)	53 (3.9)	83 (6.0)	5 (0.3)	1231 (89.5)
Epistaxis	12.1	51 (3.7)	115 (8.4)	57 (4.1)	0 (0)	1152 (83.8)
Nasal septal hematoma	0.2	0 (0.0)	3 (0.2)	145 (10.5)	2 (0.1)	1225 (89.1)
Subconjunctival hemorrhage	5.6	20 (1.5)	56 (4.1)	124 (9.0)	7 (0.5)	1168 (84.9)
Ocular movement limitations	1.8	5 (0.4)	19 (1.4)	557 (40.5)	137 (10.0)	657 (47.8)
Diplopia	2.5	12 (0.9)	22 (1.6)	321 (23.3)	129 (9.4)	891 (64.8)
Visual acuity changes	2.4	20 (1.5)	12 (0.9)	245 (17.8)	122 (8.9)	976 (71.0)
Change of globe position	0.3	0 (0.0)	4 (0.3)	26 (1.9)	4 (0.3)	1341 (97.5)
Malocclusion (solitary midfacial traumas)	0.9	6 (0.5)	5 (0.4)	213 (18.7)	118 (10.4)	797 (70.0)
Malocclusion (all midfacial traumas) [a]	2.5	14 (1.0)	20 (1.5)	295 (21.5)	165 (12.0)	881 (64.1)
Tooth mobility or luxation	4.5	23 (1.7)	38 (2.8)	249 (18.1)	41 (3.0)	1024 (74.5)
Tooth avulsion	2.5	15 (1.1)	19 (1.4)	261 (19.0)	41 (3.0)	1039 (77.3)
Palpable step-off	5.4	3 (0.2)	71 (5.2)	314 (22.8)	23 (1.7)	964 (70.1)
Bony crepitus	2.4	5 (0.4)	27 (2.0)	84 (6.1)	1 (0.1)	1258 (91.5)
Infraorbital nerve paresthesia	5.3	15 (1.1)	58 (4.2)	359 (26.1)	92 (6.7)	851 (61.9)
Mandible						
Swelling	14.2	26 (7.5)	23 (6.7)	16 (4.6)	0 (0)	280 (81.2)
Extra-oral lacerations	34.8	70 (20.3)	50 (14.5)	18 (5.2)	0 (0)	207 (60.0)
Mouth opening restriction	15.7	22 (6.4)	32 (9.3)	60 (17.4)	11 (3.2)	220 (63.8)
Mandibular movement pain	16.2	28 (8.1)	28 (8.1)	25 (7.2)	11 (3.2)	253 (73.3)
Auditory canal bleeding	4.9	9 (2.6)	8 (2.3)	14 (4.1)	0 (0)	314 (91.0)
Malocclusion (solitary mandibular traumas)	21.1	6 (5.5)	17 (15.6)	45 (41.3)	3 (2.8)	38 (34.9)
Malocclusion (all mandibular traumas) [a]	15.0	15 (4.3)	37 (10.7)	128 (37.1)	50 (14.5)	115 (33.3)
Tooth mobility or luxation	9.0	12 (3.5)	19 (5.5)	121 (35.1)	13 (3.8)	180 (52.2)
Tooth avulsion	2.6	2 (0.6)	7 (2.0)	127 (36.8)	13 (3.8)	196 (56.8)
Intra-oral hematoma	11.5	15 (4.3)	25 (7.2)	102 (29.6)	2 (0.6)	201 (58.3)
Intra-oral lacerations	13.1	24 (7.0)	21 (6.1)	66 (19.1)	1 (0.3)	233 (67.5)
Angular compression test pain	6.7	3 (0.9)	20 (5.8)	59 (4.6)	25 (7.2)	238 (69.0)
Chin axial pressure test pain	4.1	2 (0.6)	12 (3.5)	42 (12.2)	25 (7.2)	264 (76.5)
Palpable step-off	2.9	3 (0.9)	7 (2.0)	41 (11.9)	5 (1.4)	290 (84.1)
Inferior alveolar nerve paresthesia	3.2	1 (0.3)	10 (2.9)	49 (14.2)	25 (7.2)	260 (75.4)

[a] Including patients with both a midfacial and mandibular trauma.

study of 525 maxillofacial trauma patients assessed the diagnostic accuracy of eight physical examination findings [1]. They found high sensitivity for swelling (81.0%), lacerations (69.3%), any contusion (87.4%) and peri–orbital contusion (74.1%) and high specificity for sensory loss (95.9%), bony step-off or instability (89.6%), malocclusion (92.7%) and tooth absence (97.9%). Within their analysis, no differentiation was made between midfacial and mandibular fractures. Another blinded prospective study of 57 patients found high sensitivity for tenderness (88%) in nasal bone fractures, subconjunctival hemorrhage (76%) associated with orbital floor fractures, and cheek flatness (72%) related to zygomaticomaxillary fractures [2]. Our study's physical examination findings did not demonstrate high sensitivity. However, we did find a high specificity for raccoon eyes, malar eminence flattening, external nasal deformity, epistaxis, nasal septum hematoma, subconjunctival hemorrhage, ocular movement limitations, diplopia, visual acuity changes, change of globe position, malocclusion, tooth mobility or luxation, tooth avulsion, palpable step-off, bony crepitus and infra-orbital nerve paresthesia. Any findings that do not appear abnormal seem particularly useful for excluding midfacial fractures. Malar eminence flattening, external nasal deformity, nasal septum hematoma, change of globe position and palpable step-off resulted in a high PPV and LR+. The LR+ for nasal septum hematoma and change of globe position was infinite and thus pathognomonic. As these physical examination findings strongly suggest the presence of a midfacial fracture, radiological imaging should be strongly considered.

Publications of the diagnostic accuracy of mandibular fracture related physical examination findings are limited. A prospective study of 119 patients found a high specificity for malocclusion (96%), facial asymmetry (96%), crepitus (96%) and sublingual hematoma (96%) [3]. Furthermore, they noted a high PPV and NPV for malocclusion (92%/87%) and facial asymmetry (88%/76%). The authors also assessed the so called tongue blade test, resulting in a sensitivity of 95% and a NPV of 96%. They stated this test is useful for excluding mandibular fractures. Other studies corroborated this statement [7,8]. However, in their study, the authors used conventional radiography as an index test. As far as we know, our present study provides the diagnostic accuracy of mandibular fractures related to physical examination findings that have not been published before. We find high specificity for mouth opening restriction, auditory canal bleeding, malocclusion, tooth mobility or luxation, tooth avulsion, intra-oral hematoma, angular compression test pain, chin axial pressure test pain, palpable step-off and inferior alveolar nerve paresthesia. Furthermore, a high PPV and LR+ was found for angular compression test pain, chin axial pressure test pain and inferior alveolar nerve paresthesia. These results emphasize that both extra and intra-oral assessments should be part of the standardized assessment of mandibular trauma patients. The intra-oral assessment should include evaluation of occlusal changes, dental injury, gingival or mucosal lacerations and musical or sublingual hematoma.

Table 3
Diagnostic accuracy of physical examination findings for midfacial fractures *.

	Sens. (CI)	Spec. (CI)	Pr (CI)	PPV (CI)	NPV (CI)	LR+ (CI)	LR- (CI)
Extra-oral assessment							
Swelling	55.8 (51.6–59.8)	63.7 (60.4–67.0)	40.4 (37.9–43.1)	51.1 (47.1–55.0)	68.0 (64.6–71.2)	1.5 (1.4–1.7)	0.7 (0.6–0.8)
Laceration	51.6 (47.5–55.7)	47.4 (44.0–50.8)	40.4 (37.9–43.1)	40.0 (36.5–43.6)	59.1 (55.3–62.8)	1.0 (0.9–1.1)	1.0 (0.9–1.1)
Periorbital hematoma	52.0 (47.8–56.1)	51.2 (47.7–54.6)	40.4 (37.9–43.1)	41.9 (38.3–45.7)	61.1 (57.4–64.7)	1.1 (1.0–1.2)	0.9 (0.8–1.0)
Raccoon eyes	5.8 (4.1–8.0)	98.2 (97.0–98.9)	40.4 (37.9–43.1)	68.1 (53.8–79.6)	60.5 (57.9–63.1)	3.1 (1.7–5.7)	1.0 (0.9–1.0)
Malar eminence flattening	9.6 (7.4–12.4)	99.6 (98.9–99.9)	40.2 (37.7–42.8)	94.6 (85.4–98.2)	62.1 (59.4–64.7)	26.3 (8.2–83.6)	0.9 (0.9–0.9)
Nasal assessment							
External nasal deformity	7.2 (5.3–9.6)	99.4 (98.6–99.7)	40.5 (37.9–43.1)	88.9 (76.5–95.2)	61.2 (58.5–63.8)	11.8 (4.7–29.6)	0.9 (0.9–1.0)
Epistaxis	20.7 (17.5–24.2)	93.8 (91.9–95.2)	40.4 (37.9–43.1)	69.3 (61.9–75.8)	63.5 (60.8–66.2)	3.3 (2.4–4.5)	0.8 (0.8–0.9)
Nasal septum hematoma	0.5 (0.2–1.6)	100.0 (99.5–100.0)	40.3 (37.8–43.0)	100.0 (43.8–100.0)	59.8 (57.2–62.3)	∞	1.0 (1.0–1.0)
Ocular assessment							
Subconjunctival hemorrhage	10.2 (7.9–13.0)	97.6 (96.3–98.4)	40.2 (37.6–42.8)	73.7 (62.8–82.3)	61.8 (59.1–64.4)	4.2 (2.5–6.9)	0.9 (0.9–0.9)
Ocular movement limitations	4.2 (2.7–6.5)	99.4 (98.5–99.7)	36.6 (34.0–39.3)	79.2 (59.5–90.8)	64.3 (61.5–66.9)	6.6 (2.5–17.5)	1.0 (0.9–1.0)
Diplopia	4.8 (3.2–7.2)	98.5 (97.4–99.1)	36.8 (34.2–39.6)	64.7 (47.9–78.5)	63.9 (61.2–66.6)	3.1 (1.6–6.3)	1.0 (0.9–1.0)
Visual acuity changes	2.6 (1.5–4.5)	97.5 (96.1–98.4)	37.0 (34.4–39.7)	37.5 (22.9–54.7)	63.0 (60.2–65.6)	1.0 (0.5–2.1)	1.0 (1.0–1.0)
Change of globe position	0.7 (0.3–1.8)	100.0 (99.5–100.0)	40.3 (37.8–43.0)	100.0 (51.0–100.0)	59.8 (57.2–62.4)	∞	1.0 (1.0–1.0)
Intra-oral assessment							
Malocclusion (solitary midfacial traumas)	1.5 (0.6–3.5)	99.1 (98.1–99.6)	32.7 (29.9–35.7)	45.5 (21.3–72.0)	67.4 (64.5–70.2)	1.7 (0.5–5.6)	1.0 (1.0–1.0)
Malocclusion (all midfacial traumas)	4.6 (3.0–7.0)	98.2 (97.0–98.9)	36.1 (33.5–38.9)	58.8 (42.2–73.6)	64.5 (61.8–67.2)	2.5 (1.3–5.0)	1.0 (1.0–1.0)
Tooth mobility or luxation	7.2 (5.3–9.8)	97.2 (95.8–98.1)	39.4 (36.8–42.0)	62.3 (49.7–73.4)	61.7 (59.0–64.4)	2.5 (1.5–4.2)	1.0 (0.9–1.0)
Tooth avulsion	3.6 (2.3–5.6)	98.1 (97.0–98.9)	39.4 (36.8–42.0)	55.9 (39.5–71.1)	61.1 (58.4–63.7)	2.0 (1.0–3.8)	1.0 (1.0–1.0)
Palpation							
Palpable step-off	13.2 (10.6–16.3)	99.6 (98.9–99.9)	39.9 (37.3–42.5)	95.9 (88.7–98.6)	63.4 (60.7–66.0)	35.7 (11.3–112.8)	0.9 (0.8–0.9)
Bony crepitus	4.9 (3.4–7.0)	99.4 (98.6–99.7)	40.4 (37.8–43.0)	84.4 (68.2–93.1)	60.7 (58.0–63.2)	8.0 (3.1–20.6)	1.0 (0.9–1.0)
Infraorbital nerve paresthesia	11.9 (9.3–15.0)	98.1 (96.9–98.9)	38.1 (35.5–40.8)	79.5 (68.8–87.1)	64.4 (61.6–67.0)	6.3 (3.6–11.0)	0.9 (0.9–0.9)

Abbreviations: Sens. sensitivity, spec. specificity, Pr Pre-test probability, PPV positive predictive value, NPV negative predictive value, LR+ positive likelihood ratio, LR- negative likelihood ratio.
* Calculations were performed by considering the reported physical examination findings as “present” or as “absent”, or “not reported as absent”.

Table 4
– Diagnostic accuracy of physical examination findings for mandibular fractures *.

	Sens.	Spec.	Pr	PPV	NPV	LR+	LR-
Extra-oral assessment							
Swelling	19.8 (13.6–28.0)	88.6 (83.9–92.1)	33.6 (28.8–38.8)	46.9 (33.7–60.6)	68.6 (63.1–73.6)	1.7 (1.0–2.9)	0.9 (0.8–1.0)
Laceration	43.1 (34.5–52.2)	69.4 (63.2–75.0)	33.6 (28.8–38.8)	41.7 (33.2–50.6)	70.7 (64.4–76.2)	1.4 (1.1–1.9)	0.8 (0.7–1.0)
Mouth opening restriction	29.4 (21.6–38.5)	90.2 (85.6–93.5)	32.6 (27.8–37.8)	59.3 (46.0–71.3)	72.5 (67.0–77.4)	3.0 (1.8–4.9)	0.8 (0.7–0.9)
Mandibular movement pain	25.7 (18.4–34.6)	87.6 (82.6–91.2)	32.6 (27.8–37.8)	50.0 (37.3–62.7)	70.9 (65.3–75.9)	2.1 (1.3–3.3)	0.8 (0.8–1.0)
Auditory canal bleeding	6.9 (3.5–13.0)	96.1 (92.7–97.9)	33.6 (28.8–38.8)	47.1 (26.2–69.0)	67.1 (61.8–71.9)	1.8 (0.7–4.4)	1.0 (0.9–1.0)
Intra-oral assessment							
Malocclusion (solitary mandibular trauma)	41.5 (27.8–56.6)	90.8 (81.3–95.7)	38.7 (30.0–48.2)	73.9 (53.5–87.5)	71.1 (60.6–79.7)	4.5 (1.9–10.5)	0.6 (0.5–0.8)
Malocclusion (all patients)	42.5 (32.7–53.0)	92.8 (88.4–95.6)	29.5 (24.6–34.9)	71.2 (57.7–81.7)	79.4 (73.9–84.0)	5.9 (3.4–10.2)	0.6 (0.5–0.7)
Tooth mobility or luxation	16.8 (11.0–24.8)	94.5 (90.7–96.8)	34.0 (29.1–39.3)	61.3 (43.8–76.3)	68.8 (63.3–73.7)	3.1 (1.5–6.1)	0.9 (0.8–1.0)
Tooth avulsion	6.2 (3.0–12.2)	99.1 (96.7–99.7)	34.0 (29.1–39.3)	77.8 (45.3–93.7)	67.2 (61.9–72.1)	6.8 (1.4–32.1)	0.9 (0.9–1.0)
Hematoma	21.9 (15.3–30.4)	93.4 (89.5–96.0)	33.2 (28.5–38.4)	62.5 (47.0–75.8)	70.6 (65.3–75.5)	3.3 (1.8–6.1)	0.8 (0.8–0.9)
Laceration	18.3 (12.3–26.3)	89.5 (84.9–92.9)	33.4 (28.7–38.6)	46.7 (32.9–60.9)	68.6 (63.1–73.6)	1.7 (1.0–3.0)	0.9 (0.8–1.0)
Palpation							
Angular compression test pain	19.8 (13.2–28.6)	98.6 (96.1–99.5)	31.6 (26.7–36.8)	87.0 (67.9–95.5)	72.7 (67.4–77.5)	14.5 (4.4–47.5)	0.8 (0.7–0.9)
Chin axial pressure test pain	11.9 (6.9–19.6)	99.1 (96.7–99.7)	31.6 (26.7–36.8)	85.7 (60.1–96.0)	70.9 (65.6–75.7)	13.0 (3.0–57.1)	0.9 (0.8–1.0)
Palpable step-off	6.1 (3.0–12.1)	99.1 (96.8–99.8)	33.5 (28.7–38.7)	77.8 (45.3–93.7)	67.7 (62.5–72.5)	6.9 (1.5–32.9)	0.9 (0.9–1.0)
Inferior alveolar nerve paresthesia	9.9 (5.5–17.3)	99.5 (97.5–99.9)	31.6 (26.7–36.8)	90.9 (62.3–98.4)	70.6 (65.2–75.4)	21.7 (2.8–167.1)	0.9 (0.8–1.0)

Abbreviations Sens. sensitivity, spec. specificity, Pr Pre-test probability, PPV positive predictive value, NPV negative predictive value, LR+ positive likelihood ratio, LR- negative likelihood ratio.
* Calculations were performed by considering the reported physical examination findings as "present" or as "absent", or "not reported as absent".

Although oral and maxillofacial surgeons are trained to specifically assess midfacial and mandibular trauma patients, one should realize that the primary assessment is mostly performed by either emergency physician and specialized trauma surgeons. Furthermore, primary care physicians, such as general practitioners and dentists, are also faced with these patients and requested to provide adequate diagnostic management in the absence of immediate availability of radiological imaging. For that reason, the diagnostic accuracy of physical examination findings found in this study can be used for the initial management for these patients. Especially findings that produced a PPV and LR+ may aid in identifying patients who have a high risk of a fracture and, subsequently, should be referred for radiological imaging or additional assessment by an oral and maxillofacial surgeon. Above all, our data emphasizes the need to standardize the physical examination for each maxillofacial trauma patient. Other authors suggested the use of a structured record keeping tool to improve documentation [9]. In our study, we chose a stratification between extra- and intraoral assessment, nasal, ocular, and palpation related parameters, which is a feasible structure for the routine assessment of midfacial and mandibular trauma patients. Despite the findings found during the physical examination, interpretation should always be conducted in relation to the patient's history, mechanism of injury and trauma severity.

In our study, diagnostic accuracy calculations were performed for individual physical examination findings. However, decision making in the emergency department is the result of a multitude of abnormal physical examination findings. Although our study was conducted to assess individual physical examination findings, other studies proposed a combination of findings as a decisional instrument. Authors from the university of Wisconsin provided the eponymous criteria by manually assembling five findings including bony step-off or instability, malocclusion, tooth absence, periorbital swelling or contusion and a Glasgow Coma Scale score of less than 14 resulting in a sensitivity of 98.2% [1]. Although internal validation resulted in a sensitivity of 97.4%, the attempt to validate the instrument externally, with a sensitivity of 81%, was unsuccessful [10,11]. These Wisconsin criteria were compared to the results of a blinded prospective study of 57 patients using grouped physical examination findings for area specific fractures. Sensitivities of 89%, 92%, 88% and 100% were found for zygomaticomaxillary, orbital floor, nose and mandible fractures respectively. Another study proposed a decisional instrument for displaced zygomaticomaxillary fractures, combing palpable step-off, subconjunctival hemorrhage, infraorbital nerve paresthesia and palpable emphysema, resulting in a sensitivity of 100% and a specificity of 72.6% [12]. In contrast to our study, they chose a specific fracture type as an outcome. However, from a clinical perspective, emergency department workers are blinded to a broad spectrum of potential midfacial and mandibular fractures as outcomes. Therefore, we believe that the physical examination of the midfacial and mandibular regions should be done separately since specific physical examination findings are associated with fractures in these regions. All things considered, there is need for a well validated and reproducible decision instrument that is generalizable for different institutions. Data from the current study and previous studies should be used for the conceptualization of a prospective multicenter study to produce a clinical decision aid consisting of standardized physical examination parameters.

The above was the main limitation of the present study, due the inability to standardize the physical examination. A common phenomenon of retrospectively designed studies is that the data is exposed to bias due to uncontrolled variables, inconsistency of data accumulation and missing data. We noted that the outcomes of physical examination findings are not systematically reported, resulting in high rates of missing data. Although, multiple imputation with chained equations is suggested for such situations, these statistical models are not usable with a high degree of missing data [13]. Consequently, the diagnostic accuracy was also calculated for only "absent" and "present" reported physical examination findings, resulting in higher sensitivity and lower specificity outcomes. Using this approach, we provide an appropriate representation of the range of diagnostic accuracy for each physical examination finding. Another limitation of our study was that only patients were included which received CT or panoramic radiography. In these patients, physical examination findings are more likely to be present. Therefore, future research should include a reference standard for each patient, regardless the likelihood of a maxillofacial fracture.

In conclusion, the diagnostic accuracy of individual physical examination findings was calculated for both midfacial and mandibular fractures. The identified relevant findings are suitable as 'a priori' knowledge for emergency department physicians for the assessment of midfacial and mandibular trauma patients. Prospective multicenter data is needed to contribute towards the standardization of the physical examination and the consecutive construction of a validated clinical decision aid.

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Ethical approval

The local Medical Ethical Review Board reviewed the study design and waived further need for approval (ref.nr. M17.212837).

Patient consent

Not applicable for this study.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2021.05.037.

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