Maxillofacial Fractures in Electric and Conventional Bicycle-Related Accidents

REDUCTION study group members; van der Zaag, Pieter Date; Rozema, Romke; Poos, Hiëronymus P A M; Kleinbergen, Jurrijn Y J; van Minnen, Baucke; Reininga, Inge H F

Published in:
Journal of Oral and Maxillofacial Surgery

DOI:
10.1016/j.joms.2022.03.020

Maxillofacial Fractures in Electric and Conventional Bicycle-Related Accidents

Pieter Date van der Zaag, MD, [*] *Romke Rozema, MD,* [*] *Hiëronymus P. A. M. Poos, MD,* [†]
Jurrijn Y. J. Kleinbergen, MD, DMD, [‡]
Baucke van Minnen, MD, DMD, PhD, [§] *and*
Inge H. F. Reininga, PhD [||] *REDUCTION study group members* [*]

Purpose: With the increased use of both e-bike and conventional bicycle, the number of bicycle-related accidents has increased accordingly. To determine whether there are differences in maxillofacial injuries between these 2 types of bicycle accidents, e-bike and conventional bicycle accidents were compared.

Material and Methods: A retrospective cohort study was conducted for all the consecutive patients with maxillofacial injury due to e-bike and conventional bicycle accidents attending the emergency department of 4 hospitals in the Netherlands between May 2018 and October 2019. Primary outcomes are maxillofacial fractures present or absent and the severity of maxillofacial injury using the Maximum Abbreviated Injury Scale and Facial Injury Severity Scale (FISS) after e-bike and conventional bicycle accidents. A binary logistic regression analysis was used to assess differences in risk between an e-bike and conventional bicycle accident, where age, alcohol use, and comorbidities were added as covariates, for maxillofacial fractures, dental injury, and severe maxillofacial fractures.

Results: In total, 311 patients were included (73 e-bikers and 238 conventional cyclists). Sex distribution was equal in both groups (45% male vs 55% female). The e-bike group was older (66 vs 53 median age in years, $P < .001$) and had more comorbidities (0 vs 1, $P < .001$), while alcohol use was higher in the conventional bicycle group (32% vs 16%, $P = .008$). e-Bikers sustained midfacial fractures more frequently (47% vs 34%, $P = .04$), whereas conventional cyclists more often had mandibular fractures (1% vs 11%, $P = .01$). Although median Maximum Abbreviated Injury Scale and FISS scores did not differ between e-bike and conventional bicycle accidents, severe maxillofacial fractures (FISS score $\geq$ 2) were observed

*MD, PhD Student, Research Physician, Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands.

†Research Physician, Department of Trauma Surgery, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; Consultant Trauma Surgeon, Department of Surgery, Medical Center Leeuwarden, Leeuwarden, The Netherlands.

‡Consultant Oral and Maxillofacial Surgeon, Department of Oral and Maxillofacial Surgery, Isala hospital, Zwolle, The Netherlands.

§Chef de Clinique Consultant Oral and Maxillofacial Surgeon, Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands.

||Senior scientist, Principal investigator, Department of Trauma Surgery, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands; Senior scientist, Emergency Care Network Northern Netherlands (AZNN), Northern Netherlands Trauma Registry, The Netherlands.

P.D.v.d.Z. and R.R. contributed equally to the work.

Conflict of Interest Disclosures: None of the authors have any relevant financial relationship(s) with a commercial interest.

Address correspondence and reprint requests to Dr van der Zaag: Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, University of Groningen, Hanzeplein 1, 9700 RB Groningen, The Netherlands; e-mail: p.d.van.der.zaag@umcg.nl

*A list of authors and their affiliations to the REDUCTION study group.

Received December 21 2021

Accepted March 31 2022

0278-2391/22/00257-9

https://doi.org/10.1016/j.joms.2022.03.020

more often in the conventional cyclists (45% vs 25%, $P = .04$). No significant differences in risk of midfacial, mandibular, and severe maxillofacial fractures were found between e-bikers and conventional cyclists irrespective of their age, alcohol use, and comorbidities.

Conclusion: Both the distribution and the severe maxillofacial fractures differed between the e-bike and conventional bicycle accident patients. Patient-specific characteristics, such as age, alcohol use, and comorbidities, may have a greater influence on sustaining maxillofacial fractures than the type of bicycle ridden.

J Oral Maxillofac Surg 80:1361-1370, 2022

Bicycles are becoming an increasingly popular means of transport. Electric bicycles or "e-bikes" have been categorized as assisted physical pedaling with electric power, with the capacity to travel at higher speeds of up to 25 km/h or 15 mph. With the increased use of both conventional bicycles and e-bikes on Dutch cycling paths, the number and proportion of bicycle-related injuries have increased accordingly.[1,2]

Bicycle-related accidents are frequently associated with head and facial injuries. Facial injuries have been seen in 34% of the injured cyclists admitted to the emergency department (ED).[3] E-bike accidents frequently also lead to facial injuries.[4,5] A study comparing both types of bicycle-related accidents reported that 31% of the e-bikers suffered facial injury compared with 38% of the conventional cyclists, with equal severity.[6] Another study focusing on e-bike-related maxillofacial injuries showed that zygomaticomaxillary complex fracture was the most frequent observed injury followed by soft-tissue injuries.[5] Consequently, several studies suggested that helmet use can decrease the risk of, or even prevent, facial injury in bicycle accidents.[7,8] As bicycle-related accidents are considered one of the major causes of maxillofacial fractures, recommendations have been made to make wearing a helmet mandatory for cyclists.[9] With the increased presentation of patients at the ED after bicycle accidents, research focusing on the epidemiologic factors of the sustained maxillofacial injury is becoming increasingly more important.

However, there is a lack of epidemiologic data on maxillofacial injuries following e-bike and conventional bicycle accidents as well as evidence of the differences in the types and severity of maxillofacial injuries between these bicycle types. Therefore, the purpose of this study was twofold. First, to determine whether there is a difference in the incidence of maxillofacial fractures between e-bike- and conventional bicycle-related accidents. Second, to assess if there is a difference in the severity of maxillofacial injury between e-bike- and conventional bicycle-related accidents. It was hypothesized that e-bike accidents result more frequently in maxillofacial fractures and more severe maxillofacial injuries than conventional bicycle accidents. The aim of the study was, first, to assist ED personnel when assessing maxillofacial injuries due to conventional bicycle and e-bike accidents. Moreover, it is unusual to wear a bicycle helmet when cycling in the Netherlands.[10,11] Therefore, the second aim of this study was to provide new data for advice about helmet use for cyclists and e-bikers.

Material and Methods

STUDY DESIGN

A retrospective cohort study was conducted with patients selected from our research group's database containing patients with midfacial or mandibular injuries attending the ED of 4 hospitals in the north of the Netherlands between May 2018 and October 2019.[12] The Institutional Review Board of the University Medical Centre Groningen (Groningen, the Netherlands) confirmed that the Medical Research Involving Human Subjects Act does not apply (METc code 2017/249), and local feasibility was approved by all the hospitals.

PATIENT POPULATION

All the patients aged 18 years or older presenting with midfacial or mandibular injuries at the ED following a conventional bicycle or an e-bike accident were included. Patients suffering maxillofacial injuries due to other types of bicycles (eg, speed pedelecs, racing bicycles, or mountain bikes) were excluded. Patients who declined access to their electronic patient files were also excluded.

DATA EXTRACTION

Data were collected from the electronic patient files and the Dutch Trauma Registry. The Dutch Trauma Registry is based on the Major Trauma Outcome Study and includes patient characteristics, vital signs on admission, injury mechanism, anatomical injury characteristics, and outcome.[13] The patient characteristics

Table 1. PATIENT CHARACTERISTICS, INJURY CHARACTERISTICS, ADMISSION, AND MORTALITY AFTER CONVENTIONAL BICYCLE OR E-BIKE ACCIDENTS

	Total	Conventional Bicycle	e-Bike	*P* Value
Patients (n)	311	237	74	
Male sex, n (%)	141 (45)	108 (46)	33 (45)	.88
Age in years, median (IQR)	56 (35)	53 (38)	66 (18)	<.001*
FCI				
Comorbidities present, n (%)	123 (40)	80 (34)	43 (58)	<.001*
Comorbidities number, median (IQR)	0 (1)	0 (1)	1 (2)	<.001*
Alcohol use, n (%)	88 (28)	76 (32)	12 (16)	.008*
ISS				
Score, median (IQR)	5 (7)	4 (4)	6 (10)	.001*
Severe multitrauma, n (%)†	14 (5)	11 (5)	3 (4)	1
Discharge destination				
Hospital, n (%)	123 (40)	81 (34)	42 (57)	.001*
Admission duration in days, median (IQR)	2 (2)	2 (1)	3 (4)	.01*
ICU, n (%)	8 (3)	4 (2)	4 (5)	.1
Admission duration in days, median (IQR)	3 (6)	3.5 (8)	3 (6)	.76
Thirty-day mortality, n (%)	1 (0)	1 (0)	0 (0)	1

Abbreviations: IQR, interquartile range; FCI, Functional Comorbidity Index; ICU, intensive care unit; ISS, Injury Severity Score.
* $P < .05$.
† ISS score >15 is considered severe multitrauma.

van der Zaag et al. Maxillofacial Fractures in Bicycle Accidents. J Oral Maxillofac Surg 2022.

included age, sex, alcohol use, comorbidities, and 30-day mortality. The injury characteristics collected from the electronic patient files and radiographs consisted of the presence and classification of midfacial and mandibular fractures, dental injury, skull fractures, treatment decisions, concomitant injuries diagnosed at the ED, discharge destination after the ED, and days hospitalized.

OUTCOME MEASURES

The primary outcome was the incidence of midfacial and mandibular fractures and the severity of maxillofacial injury. Midfacial fractures were categorised as the frontal sinus, orbital, maxillary sinus, zygomaticomaxillary complex, nasoorbitoethmoid, nasal, Le Fort-type fractures, and dentoalveolar fractures of the maxilla.[14] Mandibular fractures were categorised as symphyseal and parasymphyseal, corpus, angular, ramus, coronoid, condyle, and dentoalveolar.[15] The severity of the maxillofacial injury was assessed using the Maximum Abbreviated Injury Scale (MAIS) of the facial region.[16] The MAIS is the Abbreviated Injury Scale (AIS) score of the most severe injury sustained. The AIS is an anatomically based injury severity scoring system that classifies each injury according to body region on a 6-point scale, with higher scores indicating higher injury severity. The maxillofacial AIS scores go from 1 to 4. The MAIS facial region score was used as a representation of the overall severity of the maxillofacial injury. Maxillofacial fracture severity was scored using the Facial Injury Severity Scale (FISS), on which each maxillofacial fracture subtype has a score of 1 to 6 points.[17] The FISS score is the summation of the points of the

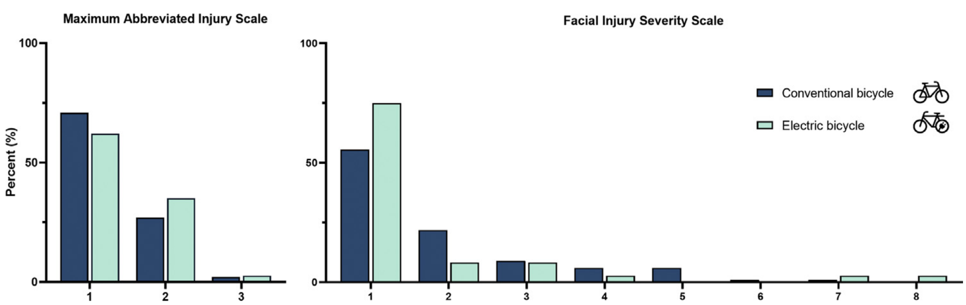

FIGURE 1. Maxillofacial injury severity after e-bike and conventional bicycle accidents.

van der Zaag et al. Maxillofacial Fractures in Bicycle Accidents. J Oral Maxillofac Surg 2022.

observed maxillofacial fractures. FISS scores were categorised into minor (FISS score = 1) or severe maxillofacial fractures (FISS score ≥ 2). Patients without a maxillofacial fracture (FISS score = 0) were excluded from the analyses regarding maxillofacial fractures. The overall injury severity was measured according to the Injury Severity Score (ISS), which is the sum of the squares of the 3 highest AIS scores of the studied body regions.[18] Severe multitrauma is defined as an ISS > 15. Dental injury involved (sub)luxation, avulsion, or a fracture of the teeth or tooth. Skull fractures were defined as frontal, temporal, parietal or occipital, or skull base fracture. Alcohol usage was scored as either yes (alcohol use, irrespective of the number of alcohol units) or no (no alcohol use or alcohol use was not noted in the electronic patient file). The Functional Comorbidity Index (FCI) was used to score the presence of 18 comorbid conditions, resulting in a total score between 0 and 18. A higher FCI score implies greater comorbidity and correlates with reduced physical function.[19]

STATISTICAL ANALYSIS

The Statistical Package for the Social Sciences was employed for the data analysis (IBM Corp. Released 2015, IBM SPSS Statistics for Windows, Version 23.0). The categorical variables were presented as frequencies and percentages. Regarding the continuous variables, the normally distributed variables were displayed as means with the standard deviation, and the nonnormally distributed variables were represented as the median with the interquartile range. Pearson's χ^2 test or Fischer's exact test was used to test the differences in both the subgroup analyses for the patient characteristics per maxillofacial fractures and maxillofacial injury severity scores, irrespective of type of bicycle, and in the maxillofacial fractures and maxillofacial injury severity scores between the conventional bicycle group and the e-bike group. The Mann-Whitney U test was used to test differences in the nonnormally distributed data. A binary logistic regression analysis was applied to assess differences in the risk of maxillofacial fractures, dental injury, and for severe maxillofacial fractures between conventional bicycle group and the e-bike group. Analyses were conducted for the midfacial fractures, mandibular fractures, skull fractures, dental injury, and maxillofacial fractures with a FISS score ≥ 2 (ie, severe maxillofacial fractures). Patient characteristics such as age, alcohol use, and FCI score were added to the analyses as potential cofounders. The FCI score was dichotomized for these analyses; the patients either had no or 1 comorbidity (FCI ≤ 1) or 2 or more comorbidities (FCI ≥ 2). Age was categorised into 18-54, 55-74, and 75+ years. A P value of ≤0.05 was used to indicate statistical significance.

Results

PATIENT CHARACTERISTICS

The details of the patient characteristics are presented in Table 1. Between May 2018 and October 2019, a total of 993 consecutive patients with maxillofacial injuries visited the EDs. Of these, 311 patients (32%) had a bicycle accident. Of those, 238 patients had suffered a conventional bicycle accident (77%), and 73 had an e-bike-related accident (23%). The e-bike group was statistically significantly older with a median age of 66 years compared to the conventional bicycle group's median age of 53 ($P < .001$). Sex distribution was equal in both groups. The presence of comorbidities ($P < .001$), and the total number of comorbidities ($P < .001$) was found to be statistically significantly higher for e-bikers than for conventional cyclists. Alcohol use frequency was statistically significantly higher in the conventional bicycle group (32%) than that in the e-bike group (16%) ($P = .008$).

MAXILLOFACIAL FRACTURES AND INJURY SEVERITY OUTCOME

Maxillofacial fractures and the severity of maxillofacial injuries are presented in Figure 1 (Table 2 and 3). Midfacial fractures (median age 62 years, $P < .001$), skull fractures (median age 63.5, $P = .03$), and maxillofacial injury with a MAIS score of 3 (median age 73 years, $P = .02$) were all statisticallly significantly associated with a higher age. Mandibula fractures and dental injury were statistically significantly associated with a lower age (median age of 28.5 and 44, respectively, $P < .001$ and $P = .001$), low number of comorbidities (median of 0 and 0, respectively, $P < .001$ and $P = .04$), and alcohol use (54% and 42%, respectively, $P = .003$ and $P = .03$). Midfacial fractures were observed statistically significantly more often in the e-bike group (47% vs 33%, $P = .03$). Mandibular fractures were observed statistically significantly more often in the conventional bicycle group (11% vs 1%, $P = .01$). There were no statistically significant differences in the median MAIS and FISS scores between the 2 groups. The severe maxillofacial fractures (FISS score ≥ 2) were found statistically significantly more often in the conventional bicycle group (45% vs 25%, $P = .04$).

FRACTURE TYPES

The midfacial and mandibular fracture outcomes are presented in Table 4. Zygomaticomaxillary complex fractures (19%) were the most frequently observed maxillofacial fracture type, followed by orbital

Table 2. PATIENT CHARACTERISTICS RELATED TO MAXILLOFACIAL FRACTURES AND THE MAXILLOFACIAL INJURY SEVERITY SCORES

Characteristics	Midfacial Fracture Subgroup	Mandibular Fracture Subgroup	Dental Injury Subgroup	Skull Fracture Subgroup	MAIS Score = 1	MAIS Score = 2	MAIS Score = 3	FISS Score = 1	FISS Score ≥ 2
Male sex, n (%)	54 (47)	14 (54)	19 (40)	15 (50)	91 (43)	46 (51)	4 (57)	37 (45)	30 (56)
P value	0.58	0.36	0.38	0.59	0.14	0.19	0.71	0.21	
Age in yr, median (IQR)	62 (21)	28.5 (17)	44 (33)	63.5 (24)	55 (40)	58.5 (30)	73 (25)	60 (29)	55 (37)
P value	<0.001*	<0.001*	0.001*	0.03*	0.13	0.41	0.02*	0.28	
FCI									
Comorbidities present, n (%)	49 (43)	0 (0)	14 (29)	13 (43)	86 (40)	34 (39)	3 (43)	37 (45)	12 (22)
Comorbidities number, median (IQR)	0 (1)	N/A	0 (1)	0 (1)	0 (1)	0 (1)	0 (2)	0 (1)	0 (0)
P value	0.45	<0.001*	0.04*	0.87	0.64	0.55	0.74	0.11	
Alcohol use, n (%)	32 (28)	14 (54)	20 (42)	4 (13)	57 (27)	31 (34)	0 (0)	32 (39)	15 (28)
P value	0.95	0.003*	0.03*	0.06	0.33	0.12	0.20	0.19	

Abbreviations: FCI, Functional Comorbidity Index; FISS, Facial Injury Severity Scale; IQR, interquartile range; MAIS, Maximum Abbreviated Injury Scale; N/A, not applicable.
* $P < .05$.

van der Zaag et al. Maxillofacial Fractures in Bicycle Accidents. J Oral Maxillofac Surg 2022.

fractures (10%) and nasal fractures (9%). Regarding the conventional bicycle-related accidents, the most reported fractures were zygomaticomaxillary complex (19%), nasal (9%), orbital floor and rim (8%), and condyle process and head fractures (8%). In the e-bike group, the most reported fractures were zygomaticomaxillary complex (20%), orbital floor and rim (19%), and nasal fractures (8%). More symphyseal fractures were found in the conventional bicycle group (P = .03), while more orbital (P = .005) and Le Fort II (P = .04) fractures were seen in the e-bike group, the differences of which are statistically significant.

LOGISTIC REGRESSION ANALYSIS

The logistic regression analyses results are presented in Table 5. After correcting for relevant confounding factors, there were no statistically significant differences in the risk of sustaining midfacial fractures, mandibular fractures, skull fractures, dental injury, and severe maxillofacial fractures between the e-bikers and conventional cyclists.

Discussion

Bicycle-related accidents often result in maxillofacial injury.[9] With the increased use of e-bikes, there is a need to study the epidemiologic characteristics of the maxillofacial injuries in order to guide the diagnostic process at the ED department and to give input in discussions about the use of helmets. This study showed that midfacial fractures were found more frequently in e-bike accidents while mandibular fractures were observed more in conventional bicycle accidents. Maxillofacial injuries and fracture severity did not differ between both groups. However, the severe maxillofacial fractures were found more often in the conventional bicycle group.

Although both the median score and the differences in maxillofacial injury severity were not statistically significant, the MAIS indicated that the maxillofacial injuries due to e-bike accidents appeared more severe than on conventional cyclists. A trend was observed that e-bikers suffered fewer minor (MAIS 1) but more moderate maxillofacial injuries (MAIS 2) than conventional cyclists. The potential factors involved could be the higher speed of an e-bike or that the e-bike group was significantly older. In accordance with this study, previous research stated that elderly cyclists have a higher chance of more severe injuries.[20] However, the severe (MAIS 3) and serious maxillofacial injuries (MAIS 4) were rare and equally prevalent in both groups. Overall, there was no statistically significant difference in median maxillofacial fracture severity even though the e-bike-related accidents resulted in a higher FISS score than the conventional bicycle group. However, after a distinction was made between minor

Table 3. MAXILLOFACIAL FRACTURES AND THE MAXILLOFACIAL INJURY SEVERITY SCORES AFTER E-BIKE AND CONVENTIONAL BICYCLE ACCIDENTS

Maxillofacial Fractures and Maxillofacial Injury Severity Scores	Total	Conventional Bicycle	e-Bike	*P* Value
Midfacial fractures				
Patients, n (%)	114 (37)	79 (33)	35 (47)	.03*
Conservative treatment, n (%)	95 (83)	64 (81)	31 (87)	.32
Active treatment, n (%)	19 (17)	15 (19)	4 (11)	
Closed	12 (11)	11 (14)	1 (3)	
Surgical	7 (6)	4 (5)	3 (9)	
Mandibular fractures				
Patients, n (%)	26 (8)	25 (11)	1 (1)	.01*
Conservative treatment, n (%)	12 (46)	11 (44)	1 (100)	.46
Active treatment, n (%)	14 (54)	14 (56)	0 (0)	
Closed	4 (15)	4 (16)	0 (0)	
Surgical	10 (39)	10 (40)	0 (0)	
Dental injury, n (%)	48 (15)	43 (18)	5 (7)	.02*
Skull fractures, n (%)	30 (10)	19 (8)	11 (15)	.08
MAIS Face				
Score, median (IQR)	1 (1)	1 (1)	1 (1)	.16
MAIS score of 1, n (%)	214 (69)	168 (71)	46 (62)	.16
MAIS score of 2, n (%)	90 (29)	64 (27)	26 (35)	.18
MAIS score of 3, n (%)	7 (2)	5 (2)	2 (3)	.76
FISS				
Score, median (IQR)	1 (1)	1 (1)	1 (1)	.07
FISS score = 1, n (%)	83 (61)	56 (55)	27 (75)	.04*
FISS score ≥ 2, n (%)	54 (39)	45 (45)	9 (25)	

Abbreviations: FISS, Facial Injury Severity Scale; MAIS, Maximum Abbreviated Injury Scale.
* $P < .05$.

van der Zaag et al. Maxillofacial Fractures in Bicycle Accidents. J Oral Maxillofac Surg 2022.

(FISS = 1) and severe maxillofacial fractures (FISS ≥ 2), we saw that the incidence of severe maxillofacial fractures was significantly higher among the conventional cyclists. In other words, the e-bikers' maxillofacial fractures were less severe but were sustained more frequently, whereas the conventional cyclists sustained maxillofacial fractures less frequently, but, if they did, the fractures were more severe. A study focusing on patients hospitalized due to electric-powered bike accidents reported that the majority of oral- and maxillofacial-related injuries were moderate (MAIS 2) followed by minor (MAIS 1).[21] Two studies on patients who sustained maxillofacial fractures due to conventional bicycle accidents reported a mean FISS score, as a representation of severity, of 1.9 and 2.0, respectively.[22,23] Our study reports a median FISS of 1 for both conventional bicycle- and e-bike-related accidents. In general, maxillofacial injury severity seems to be comparable between the 2 types of cyclists. Both sustained minor maxillofacial injuries more frequently, followed by moderate maxillofacial injuries. In addition, both groups of cyclists had more maxillofacial fractures with a FISS score of 1 followed by maxillofacial fractures with an FISS score of 2. This seems to be in line with the results of a study where the e-bike accident injury patterns were more comparable with conventional bicycle accidents than with motorcycle accidents.[24] The mechanisms that are frequently involved in bicycle accidents and injury are loss of balance, falling while mounting or dismounting, or getting spooked by other traffic. The cycling velocity in such cases tends to be low, and the resulting fall takes place on a level surface, thus rarely leading to severe maxillofacial injuries.[23] These low-energy falls are known to frequently lead to soft-tissue injuries, such as abrasions, hematoma's, and lacerations, all of which are minor maxillofacial injuries.[25-27]

This study showed that the most frequent fractures seen in both groups were zygomaticomaxillary complex fractures, orbital fractures, and nasal fractures. Mandibular fractures were observed less frequently, and remarkably, only 1 mandibular fracture was reported in the e-bike group. The results of the present study are in line with previous studies that reported zygomaticomaxillary complex fractures and orbital fractures as the most frequently seen midfacial fractures following conventional bicycle accidents.[22,23,28,29]

Table 4. INCIDENCE OF MIDFACIAL AND MANDIBULAR FRACTURES AFTER E-BIKE AND CONVENTIONAL BICYCLE ACCIDENTS

Maxillofacial Fractures	Total	Conventional Bicycle	e-Bike	*P* Value
Midfacial fractures, n (%)				
Frontal sinus	5 (2)	5 (2)	0 (0)	.60
Orbital floor and rim	32 (10)	18 (8)	14 (19)	.005*
Zygomaticomaxillary complex	58 (19)	43 (18)	15 (20)	.68
Nasoorbitoethmoid	5 (2)	3 (1)	2 (3)	.34
Maxillary sinus	8 (3)	6 (3)	2 (3)	1
Nasal	28 (9)	22 (9)	6 (8)	.76
Le Fort I	5 (2)	3 (1)	2 (3)	.34
Le Fort II	4 (1)	1 (0)	3 (4)	.04*
Le Fort III	1 (0)	0 (0)	1 (1)	.24
Dentoalveolar process	8 (3)	8 (3)	0 (0)	.21
Mandibular fractures, n (%)				
Symphyseal and parasymphyseal	14 (5)	14 (6)	0 (0)	.03*
Corpus	6 (2)	6 (3)	0 (0)	.34
Angular	1 (0)	1 (0)	0 (0)	1
Ramus	3 (1)	3 (1)	0 (0)	1
Coronoid	1 (0)	1 (0)	0 (0)	1
Condyle process and head	19 (6)	18 (8)	1 (1)	.05
Dentoalveolar process	0 (0)	0 (0)	0 (0)	N/A

Abbreviation: N/A, not applicable.

* $P < .05$.

van der Zaag et al. Maxillofacial Fractures in Bicycle Accidents. J Oral Maxillofac Surg 2022.

The incidence of mandibular fractures in our study is also in accordance with that seen by previous studies whereby conventional bicycle accidents frequently lead to mandibular fractures, with condyle fractures being the most common subtype.[22,23,28,29] Two studies presented zygomaticomaxillary complex fractures as the most frequent midfacial fracture due to e-bike accidents.[5,21] There could be various reasons for the higher incidence of midfacial fractures and a lower incidence of mandibular fractures among the e-bikers. A potential influence could be the heavier weight of an e-bike, with more chance of falling sideways than toppling over the handlebar with low-speed accidents. In addition, the e-bike cohort was significantly older, and low-speed injury mechanisms, such as sudden stops and losing balance, are already common among elderly cyclists.[30,31] A study showed that the majority of the midface fractures due to conventional bicycle accidents were situated in the lateral region.[29] However, if e-bikers are more likely to fall sideways than conventional cyclists, then the lateral structures will be more frequently affected, possibly resulting in more midfacial fractures and fewer mandibular fractures among e-bikers. In contrast, toppling over the handlebar leads to a frontal impact on the chin, which can result in fractures in the symphyseal region and indirect fractures of the condyles, a common sequel to falling off a bicycle.[22,28] This is also reflected in the mandible fractures seen among our group of conventional cyclists, with the most reported subtypes being condyle and symphysis fractures. A notable aspect in these fractures, as well as in the dental injuries, is the high level of alcohol use. It is presumable that the alcohol use caused reduced stability and reaction capacity to avert the frontal impact.

A main finding of this study was that the logistic regression analysis showed that after correction for several relevant patient characteristics, both the e-bike and the conventional bicycle were not statistically significantly associated with an increased risk of the various maxillofacial fractures, dental injury, and the severe maxillofacial fractures. These findings suggest that it is not the type of bicycle ridden but the patient characteristics that play a crucial role in maxillofacial fractures following a bicycle accident. The use of a helmet for conventional cyclists has been proven to reduce head injury and has a protective effect on facial injuries and fractures.[8] However, in Dutch cycling culture, it is highly unusual to cycle with a helmet nor is it mandatory when cycling on an e-bike. Similarly, in this study, only a few of the participants were reported to wear a helmet. This limited helmet use is in line with a report on helmet use in the Netherlands.[11] Hence, helmet use was not included in the analyses and was sparse to draw conclusions from

Table 5. ANALYSIS OF DIFFERENCES IN THE RISK OF MAXILLOFACIAL INJURY BETWEEN E-BIKERS AND CONVENTIONAL CYCLISTS

Outcome	B	SE	*P*	OR	95% CI
Midfacial fractures*	0.27	0.29	.35	1.31	0.740-2.30
Mandibular fractures†,‡	−1.17	1.08	.28	0.31	0.04-2.54
Skull fractures*	0.47	0.43	.28	1.60	0.69-3.74
Dental injury*	−0.73	0.52	.16	0.48	0.18-1.34
Severe maxillofacial fractures (FISS ≥ 2)*	−0.83	0.48	.08	0.48	0.17-1.11

Conventional cyclists were used as the reference group.

Abbreviations: B, logistic regression coefficients; CI, confidence interval; FCI, Functional Comorbidity Index; FISS, Facial Injury Severity Score; OR, odds ratio; SE, standard error.

* Corrected for age, alcohol use, and comorbidities (FCI).

† Corrected for age and alcohol use.

‡ FCI was not a relevant cofounder.

van der Zaag et al. Maxillofacial Fractures in Bicycle Accidents. J Oral Maxillofac Surg 2022.

its possible effect on the risk of maxillofacial injuries in this study. A study also showed more severe brain injuries among e-bikers than among conventional cyclists.[6] In addition, considering that e-bikers more frequently suffered fractures to the skull and that cyclist characteristics strongly influence the maxillofacial injury, the advice for e-bikers as well as vulnerable and elderly cyclists is to wear a helmet.

STRENGTHS OF THIS RESEARCH

The primary strength of this study is the use of data from a large multicentre cohort and reporting on both the incidence and the severity of maxillofacial injuries sustained in e-bike-related accidents compared to conventional bicycle-related accidents. The participating hospital EDs cover a range of hospital trauma levels (level 1-3), populations, and geographic differences, thereby reducing forms of selection bias. The second strength of this study is that by correcting for differences in patient characteristics between the e-bikers and conventional cyclists, the actual risk involved with riding an e-bike or a conventional bicycle on maxillofacial fractures could be established.

LIMITATIONS OF THIS RESEARCH

This study has a number of limitations. First, a retrospective design was used, which is associated with some limitations such as the availability of data. For example, the number of used alcohol units was often not quantified. Therefore, alcohol usage was scored as binary, including patients in whom it was evident from the anamnesis that alcohol use could have had an effect on their cycling ability. As helmet use for e-bikers and conventional cyclists is rare in the Netherlands, helmet use was also seldom documented in the electronic patient files. Moreover, not wearing a helmet was consequently also rarely documented. Therefore, the decision was made to not include helmet use as a covariate. Also, the distribution among the 2 bicycle groups was disproportionate as the number of patients with e-bike-related accident was limited. Another limitation is that the outcome measures are only a limited representation of severity. The AIS for maxillofacial injury only goes from 1 to 4, and the 3 and 4 scores were uncommon in both groups. In other words, the AIS offers only a limited degree of distinction for facial injuries. The FISS is unable to assess minor maxillofacial injuries as it consists almost exclusively of maxillofacial fractures. Nevertheless, both scales were used side by side to assess the injuries as thoroughly as possible. Moreover, instead of a quantitative method, a binary registration of facial fractures was used, which may have overrepresented or underrepresented several fracture types. However, the FISS does take the number of fractures into consideration, minimizing the overrepresentation and underrepresentation when assessing the severity of these fractures.

STUDY RECOMMENDATIONS

Future research on maxillofacial facial injuries after e-bike and conventional bicycle accidents should increase the sample size, especially after e-bike accidents. Increasing the sample size will make it possible to provide more data on injury differences between both bicycle types. Moreover, prospective research on maxillofacial injury after bicycle accidents could focus on specific influences such as helmet use, quantifying alcohol use, and the mechanism of injury. The advantages of a helmet as a protective measure for e-bikers, as well as for vulnerable and elderly cyclists, should be advocated and then investigated further given the fact that e-bikers suffered fractures to the skull more frequently and that cyclist characteristics could influence maxillofacial injury.

In conclusion, e-bikers suffered midfacial fractures significantly more often, and mandibular fractures less often, than conventional cyclists. There was no significant difference in the severity of maxillofacial injuries as well as the severity of maxillofacial fractures between both groups. However, severe maxillofacial fractures were found significantly more frequently among the conventional cyclists. Furthermore, this study indicates that the cyclist's characteristics, such as age and comorbidities, could have a major influence on sustaining maxillofacial fractures rather than the type of bicycle being ridden.

References

1. Ministry of Infrastructure and Water Management. Mobiliteitsbeeld 2019, 2019. https://www.kimnet.nl/publicaties/%0Ahttps://www.kimnet.nl/publicaties/rapporten/2019/11/12/mobiliteitsbeeld-2019-vooral-het-gebruik-van-de-trein-neemt-toe. Accessed April 22, 2020
2. Verstappen EMJ, Vy DT, Janzing HM, et al: Bicycle-related injuries in the emergency department: A comparison between E-bikes and conventional bicycles: A prospective observational study. Eur J Trauma Emerg Surg 47:1853–1860, 2021
3. Rivara FP, Thompson DC, Thompson RS: Epidemiology of bicycle injuries and risk factors for serious injury. Inj Prev 3:110–114. https://doi.org/10.1136/IP.3.2.110, 1997
4. Papoutsi S, Martinolli L, Braun CT, Exadaktylos AK: E-bike injuries: Experience from an urban emergency department-a retrospective study from Switzerland. Emerg Med Int 2014:1–5. https://doi.org/10.1155/2014/850236, 2014
5. Frenkel B, Bahouth H, Abu Shqara F, Rachmiel A: Craniofacial injuries seen among electric-Motorized bicycle Riders. J Craniofac Surg 31:2171–2174. https://doi.org/10.1097/SCS.0000000000006712, 2020
6. Poos HPAM, Lefarth TL, Harbers JS, et al: E-bikers are more often seriously injured in bicycle accidents: Results from the Groningen bicycle accident database. Ned Tijdschr Geneeskd 161, 2017 D1520. [Dutch]. PMID: 28537540
7. Hwang MJ, Dillon JK, Dodson TD: Helmets decrease risk of Bicyclist-related maxillofacial injuries but not severity. J Oral Maxillofac Surg 77:2055–2063. https://doi.org/10.1016/J.JOMS.2019.04.018, 2019
8. Fitzpatrick DG, Goh M, Howlett DC, Williams M: Bicycle helmets are protective against facial injuries, including facial fractures: A meta-analysis. Int J Oral Maxillofac Surg 47:1121–1125. https://doi.org/10.1016/J.IJOM.2018.03.005, 2018
9. Salentijn EG: Middengezichtsfracturen in een Amsterdamse populatie. Een epidemiologisch onderzoek. Ned Tijdschr Tandheelkd 125:287–290, 2018
10. Haworth N, Schramm A, Houtenbos M, Shinar D: International survey of bicycling exposure, crash involvement, behaviors and attitudes: Preliminary results, *in* International Cycling Safety Conference; 2015. 1-1
11. SWOV-factsheet, Fietshelmen, 2019. SWOV – Instituut voor Wetenschappelijk Onderzoek Verkeersveiligheid, Den Haag, 1-19.
12. Rozema R: REDucing Unnecessary Computed Tomography in MaxillOfacial injury studie, 2019. https://clinicaltrials.gov/ct2/show/NCT03314480. Accessed January 14, 2020
13. The Dutch trauma Registry, http://www.lnaz.nl. Accessed April 22, 2020
14. Kunz C, Audigé L, Cornelius CP, et al: The Comprehensive AOCMF classification system: Midface fractures - level 2 Tutorial. Craniomaxillofac Trauma Reconstr 7(Suppl 1):S059. https://doi.org/10.1055/S-0034-1389560, 2014
15. Reed O, Dingman AB: Surgery of facial fractures. Br J Surg 51: 560. https://doi.org/10.1002/BJS.1800510741, 1964
16. Petrucelli E, States JD, Hames LN: The abbreviated injury scale: Evolution, usage and future adaptability. Accid Anal Prev 13:29–35. https://doi.org/10.1016/0001-4575(81)90040-3, 1981
17. Bagheri SC, Dierks EJ, Kademani D, et al: Application of a facial injury severity scale in Craniomaxillofacial trauma. J Oral Maxillofac Surg 64:408–414. https://doi.org/10.1016/J.JOMS.2005.11.013, 2006
18. Baker SP, O'Neill B, Haddon W Jr, Long WB: The injury severity score: A method for describing patients with multiple injuries and evaluating emergency care. J Trauma 14:187–196, 1974
19. Groll DL, To T, Bombardier C, Wright JG: The development of a comorbidity index with physical function as the outcome. J Clin Epidemiol 58:595–602. https://doi.org/10.1016/J.JCLINEPI.2004.10.018, 2005
20. Kaplan S, Vavatsoulas K, Prato CG: Aggravating and mitigating factors associated with cyclist injury severity in Denmark. J Saf Res 50:75–82. https://doi.org/10.1016/J.JSR.2014.03.012, 2014
21. Lin S, Goldman S, Peleg K, Levin L: Dental and maxillofacial injuries associated with electric-powered bikes and scooters in Israel: A report for 2014-2019. Dent Traumatol 36:533–537. https://doi.org/10.1111/EDT.12562, 2020
22. Boffano P, Roccia F, Gallesio C, et al: Bicycle-related maxillofacial injuries: A double-center study. Oral Surg Oral Med Oral Pathol Oral Radiol 116:275–280. https://doi.org/10.1016/J.OOOO.2013.03.004, 2013
23. Yamamoto K, Matsusue Y, Horita S, et al: Maxillofacial fractures sustained in bicycle accidents. J Oral Maxillofac Surg 69:e155–e160. https://doi.org/10.1016/J.JOMS.2010.12.028, 2011
24. Spörri E, Halvachizadeh S, Gamble JG, et al: Clinical Medicine comparison of injury patterns between electric bicycle, bicycle and motorcycle accidents. J Clin Med 10:3359. https://doi.org/10.3390/jcm10153359, 2021
25. Einy S, Goldman S, Radomislensky I, et al: Maxillofacial trauma following road accidents—an 11-year multi-center study in Israel. Dent Traumatol 37:407–413. https://doi.org/10.1111/EDT.12639, 2021
26. Einy S, Abdel Rahman N, Siman-Tov M, et al: Maxillofacial trauma following road accidents and falls. J Craniofac Surg 27:857–861. https://doi.org/10.1097/SCS.0000000000002555, 2016
27. Acton CH, Nixon JW, Clark RC: Bicycle riding and oral/maxillofacial trauma in young children. Med J Aust 165: 249–251. https://doi.org/10.5694/J.1326-5377.1996.TB124957.X, 1996
28. Lee KH, Chou HJ: Facial fractures in road cyclists. Aust Dent J 53: 246–249. https://doi.org/10.1111/J.1834-7819.2008.00056.X, 2008
29. Lindqvist C, Sorsa S, Hyrkäs T, Santavirta S: Maxillofacial fractures sustained in bicycle accidents. Int J Oral Maxillofac Surg 15:12–18. https://doi.org/10.1016/S0300-9785(86)80005-9, 1986
30. Ormel W, Klein Wolt K: Enkelvoudige fietsongevallen: Een LIS-vervolgonderzoek - Rijkswaterstaat Rapportendatabank. In opdr. van Rijkswaterstaat Dienst Verkeer en Scheepvaart (RWS DVS), 2009. https://puc.overheid.nl/rijkswaterstaat/doc/PUC_133429_31/. Accessed May 5, 2020
31. Boele-Vos MJ, Van Duijvenvoorde K, Doumen MJA, et al: Crashes involving cyclists aged 50 and over in The Netherlands: An in-depth study. Accid Anal Prev 105:4–10. https://doi.org/10.1016/J.AAP.2016.07.016, 2017

Appendix

OTHER MEMBERS OF THE REDUCTION STUDY GROUP

Michiel H.J. Doff, MD, DMD, PhD, BEng[¶], Gysbert T. de Vries, MD[#], Mostafa El Moumni, MD, PhD[**], René Verbeek, MD[††], Bas W.J. Bens, MD[‡‡], Frederik K.L. Spijkervet, DMD, PhD[§§]

¶Research Physician, Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands; Consultant Oral and Maxillofacial Surgeon, Department of Oral and Maxillofacial Surgery, Nij Smellinghe Hospital, Drachten, the Netherlands. #Consultant Emergency Physician, Research Physician, Department of Emergency Medicine, Isala Hospital, Zwolle, the Netherlands. **Consultant Trauma Surgeon, Department of Trauma Surgery, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands. ††Consultant Emergency Physician, Research Physician, Department of Emergency Medicine, Nij Smellinghe Hospital, Drachten, the Netherlands. ‡‡Consultant Emergency Physician, Research Physician, Department of Emergency Medicine, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands. and §§Professor, Department Head Oral and Maxillofacial Surgeon, Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands