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Paediatric maxillofacial fractures have increased in incidence and their nature and aetiology have changed during three decades

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The safety of children's living environment is affected by several factors. Safer living environments have been offered as one explanation to decreases in children's fractures. Earlier studies provide evidence of a decreasing trend in children's fractures in the past decades. The objective of this study was to investigate demographic and clinical features of paediatric maxillofacial fractures during three time periods. A retrospective cross-sectional single-centre study was designed. The study included 474 patients aged ≤15 years admitted to Helsinki University Hospital in Finland with maxillofacial fractures during 1980–1989, 1993–2002 and 2013–2018. Maxillofacial fractures increased by 25% during the study period. The increase was greater in boys (28%) than in girls (19%), and significant in age groups 0–5 years (71%) and 13–15 years (32%). Exclusively mandibular fractures decreased by 20%, while exclusively midfacial fractures increased more than four-fold and exclusively upper-third fractures five-fold. Being hit by object and falls from height increased more than two-fold. A temporary increase in assaults and decrease in bicycle accidents in the middle period of the study was observed. During the three decades, paediatric maxillofacial fractures have increased and both fracture type and underlying aetiology have changed. These findings reflect improvements in diagnostics, traffic safety, regulations and technology. The role of factors such as interpersonal violence and economic fluctuation on the incidence of childhood maxillofacial fractures is discussed.

Children's living environment and safety are modified by societal and technical development.

Paediatric fractures in Finland have been found to have peaked in 1983 and decreased until 2005. According to the same study, epidemiology and fracture patterns had changed, with an increase in fractures from low-energy trauma[1]. Similar findings have been made in Sweden[2,3]. There is a paucity of studies concerning the incidence and pattern of children's facial fractures over time. The present study investigated demographic and clinical features of paediatric maxillofacial fractures between 1980 and 2018.

Patients and methods

Study design and sample

To address the research aim, a retrospective cross-sectional study was designed. The data was collected at Töölö Trauma Centre, Helsinki University Hospital, a tertiary trauma centre with a population base of 2.2 million. We included patients ≤ 15 years old diagnosed with maxillofacial fractures at during two 10-year periods 1980–1989 and 1993–2002 and a six-year period 2013–2018. Patients with exclusively dentoalveolar fractures were excluded. The annual population size of 0–15-year-olds in the corresponding area was retrieved from Statistics Finland.

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Study variables

The patient records were reviewed recording sex, age, fracture type, and aetiology. Patients were categorized into four groups based on age at the time of injury. Dental development stages were used as the basis for the categories; ≤ 5 years, 6–9 years, 10–12 years, and 13–15 years. Fracture types were categorized into four groups according to injury location of the facial thirds as follows: exclusively mandibular fracture, exclusively midfacial fracture, exclusively upper third fracture (i.e., orbital roof and/or frontal sinus fracture), and combined fractures (i.e., any combinations of the aforementioned).

Data analysis

Descriptive statistics were calculated for all variables. The proportional distributions of sex, fracture type, and aetiology were calculated for all age groups in each period. Fracture incidences were calculated by dividing the number of patients during each study year by the number of children in the same age group in the corresponding geographic area as reported on December 31 for each year studied[4]. Incidences for each period were calculated as averages of annual incidences in the period in question. Incidences are given per 100,000 inhabitants. Chi-square tests were used to analyse statistical differences between the three periods. A 95% confidence interval was used, and the threshold of statistical significance was set to 0.05.

Ethical approval

The use of data from the period 1980–1989 was approved by the Internal Review Board of the Surgical Hospital, Helsinki University Hospital, Finland (64/1991). The use of data from the period 1993–2002 was approved by the Internal Review Board of the Division of Musculoskeletal Surgery, Helsinki University Hospital, Finland (14.6.2006). The use of data from the latest period was approved by the Internal Review Board of the Head and Neck Center, Helsinki University Hospital, Finland (HUS/356/2017). All methods were carried out in accordance with the Declaration of Helsinki. Due to the retrospective nature of the study, the need for obtaining informed consent was waived by the Internal Review Board of the Surgical Hospital, Helsinki University Hospital, Finland (1980–1989), the Internal Review Board of the Division of Musculoskeletal Surgery, Helsinki University Hospital, Finland (1993–2002), and the Internal Review Board of the Head and Neck Center, Helsinki University Hospital, Finland (2013–2018) upon approval of data use. All patient data were anonymised.

Results

Altogether 474 children met the inclusion criteria. The number of patients for the three time periods was 168 (1980–1989), 175 (1993–2002), and 131 (2013–2018). The average incidence per 100,000 for 0–15-year-olds was 4.2 in the first period and 4.1 in the middle period, increasing to 5.2 for the last period.

Descriptive statistics for all 474 patients during the entire study are presented in Table 1. The male-to-female ratio was 1.7:1. The number of patients increased with increasing age group with nearly half of the patients belonging to the oldest age group. Exclusively mandibular fractures were by far the most common, followed by exclusively midfacial fractures. Combined fractures and fractures exclusive to the upper facial third were infrequent. A bicycle accident was the most common aetiology.

Table 2 depicts the proportional distribution of patients according to sex, fracture type, and aetiology in each age group. There was a male preponderance in all groups, the male-to-female ratio being highest in the youngest group (2.4:1). Exclusively mandibular fractures were the most common fracture type in all age groups, showing a slight decrease with increasing age. Exclusively midfacial fractures were the second most common fracture type in all age groups, increasing with increasing age. Bicycle accidents were the most common aetiology in the three youngest age groups, peaking in the second youngest group and decreasing thereafter. Falls from height and on ground level were common in the youngest and second-oldest age groups. MVAs were less common in the youngest age group, increasing thereafter to being the second most common aetiology in the three older age groups. Assaults were rare in the youngest age groups only to become the most common aetiology in the oldest age group.

In Table 3 the proportional distribution of patients according to sex, age, aetiology and fracture type are shown for the three periods. Males predominated in each period. There was a change in the distribution according to fracture type ($p < 0.001$). Exclusively mandibular fractures remained the most common fracture type during all periods. Their proportion, however, continued to decrease during the study from 84% in the first period to 53% in the last ($p < 0.001$). While no change was found in combined fractures, there was a shift within different types of combined fractures ($p = 0.001$). Combined fractures of the mandible, mid-face and upper third were only found in the first period while fractures exclusive to the midface and upper third became more common in the last period. Distribution according to aetiology changed as well ($p < 0.001$). Bicycle accidents were the most common aetiology during all periods, with a decrease during the middle period ($p = 0.04$). No statistically significant change was found in the proportion of MVAs. A peak in assault-related accidents was observed during the middle period, with their proportion subsequently falling to levels below the first period ($p = 0.02$).

The incidence of facial fractures during the three periods is compared in Table 4. Incidence increased significantly from the first and middle periods to the last ($p = 0.0004$ and 0.0007, respectively). During all periods, incidence was higher for boys than girls. There was a significant increase from the first to the last period for boys ($p < 0.001$) and girls ($p = 0.03$). In terms of age group, there was an increase in the youngest and oldest age groups between the first and last period ($p = 0.005$ and $p = 0.007$, respectively). There was a significant decrease in the incidence of exclusively mandibular fractures between the first and last periods ($p = 0.005$). Exclusively midfacial and exclusively upper third fractures both increased in incidence between the first and last periods ($p < 0.0001$ and $p = 0.008$, respectively). A more than three-fold increase was observed in the incidence of being

		% of 474
Sex		
Male	299	63
Female	175	37
Age (years)		
Average age 11,5		
0–5	52	11
6–9	96	20
10–12	110	23
13–15	216	46
Fracture type		
Exclusively mandibular	329	69
Exclusively midfacial	108	23
Combined	30	6.3
Exclusively upper third	7	1.5
Aetiology		
Bicycle	141	30
MVA	85	18
Fall on ground level	55	12
Hit by object	52	11
Fall from height	51	11
Assault	50	11
Horse kick	21	4.4
Collision with person / object	17	3.6
Gun shot	1	0.2
Fireworks	1	0.2

Table 1. Descriptive statistics of 474 children with maxillofacial fractures.

	≤5 years (n = 52)		6–9 years (n = 96)		10–12 years (n = 110)		13–15 years (n = 216)	
		%		%		%		%
Sex								
Male	37	71	57	59.4	66	60	139	64
Female	15	29	39	40.6	44	40	77	36
Fracture type								
Exclusively mandibular	41	79	69	72	80	73	139	64
Exclusively midfacial	7	13	18	19	20	18	63	29
Exclusively upper third	1	1.9	1	1.0	2	1.8	3	1.4
Combined	3	5.8	8	8.3	8	7.3	11	5.1
Aetiology								
Bicycle	21	40	45	47	32	29	43	20
Fall from height	12	23	10	10	16	15	13	6.0
Fall on ground level	8	15	10	10	17	15	20	9.3
MVA	5	9.6	17	18	18	16	45	21
Hit by object	2	3.8	8	8.3	15	14	27	13
Collision with person /object	2	3.8	5	5.2	2	1.8	8	3.7
Assault	1	1.9	1	1.0	1	0.9	47	22
Horse kick	1	1.9	0	0.0	8	7.3	12	5.6
Gun shot	0	0.0	0	0.0	1	0.9	0	0.0
Fireworks	0	0.0	0	0.0	0	0.0	1	0.5

Table 2. Proportional distributions of sex, fracture type and aetiology by age group.

	1980–1989 (n = 168)		1993–2002 (n = 175)		2013–2018 (n = 131)		
		% of n		% of n		% of n	*p* value
Sex							0.2
Male	110	65	101	57.7	88	67	
Female	58	35	74	42.3	43	33	
Average age	11.3		12.1		11.1		
Age group (years)							0.1
0–5	17	10	17	9.7	18	14	
6–9	40	24	27	15	29	22	
10–12	44	26	37	21	29	22	
13–15	67	40	94	54	55	42	
Fracture type							< 0.001
Exclusively mandibular	141	84	118	67	70	53	< 0.001
Exclusively midfacial	13	7.7	49	28	46	35	< 0.001
Exclusively upper third	1	0.6	3	1.7	3	2.3	0.5
Combined	13	7.7	5	2.9	12	9.2	0.05
Type of combined fracture							0.001
Mandibular + midfacial	7	4.2	2	1.1	2	1.5	0.1
Midfacial + upper third	2	1.2	3	1.7	10	7.6	0.003
Mandibular + midfacial + upper third	4	2.4	0	0.0	0	0.0	0.03
Aetiology							< 0.001
Bicycle	59	35	40	23	42	32	0.04
MVA	36	21	30	17	19	15	0.3
Fall on ground level	20	12	21	12	14	11	0.9
Assault	16	9.5	27	15	7	5.3	0.02
Hit by object	12	7.1	14	8.0	26	20	0.001
Fall from height	10	6.0	22	13	19	15	0.04
Horse kick	10	6.0	8	4.6	3	2.3	0.3
Collision with person / object	4	2.4	12	6.9	1	0.8	0.01
Gun shot	1	0.6	0	0.0	0	0.0	0.4
Fireworks	0	0.0	1	0.6	0	0.0	0.4

Table 3. Distribution of patients according to sex, age, fracture type and aetiology by study periods. *P*-values based on chi square tests between study period and variables.

hit by an object ($p < 0.0001$) and falls from height ($p < 0.0001$) between the first and last periods. In the middle period, there were some statistically significant changes differing from the observed long-term development.

Figure 1 depicts the change in distribution according to fracture type for aetiologies MVAs and assaults. The annual average of facial fractures resulting from MVAs remained largely unchanged, but the associated fracture type changed during the study. In the first two periods, roughly two-thirds of patients had exclusively mandibular fractures, and by the third period, the proportion had decreased to one-third. Exclusively midfacial and combined fractures became more common increasing from one-tenth in the first period to one-third in the second and further to one-half in the third period. Similarly, the most common resulting fracture type for assaults changed from exclusively mandibular in the first period to exclusively mid-facial in the last two periods.

Discussion

Both prevention and diagnosis of facial fractures have improved markedly during the last decades[5]. In this study, patients under the age of five represented a tenth of all patients. While this is a positive finding, it poses challenges for the clinician regarding diagnostics and treatment. It is known that there are challenges in the diagnostics of facial fractures in young children with up to a third of mandibular fractures going undiagnosed at first health-care contact[6]. Our study shows, that while trauma mechanisms and fracture types have changed during the last decades, the incidence of paediatric facial fractures has increased. This is an interesting finding considering the opposite has been found in paediatric fractures in general[1–3].

Male predomination in all age groups throughout the study is a finding consistent with earlier studies[7,8]. The development of the child and related anatomical features are reflected both in fracture type and aetiology. Falls from height were common in the youngest age group. For small children, these are often related to falls during play or from furniture. Improved agility and coordination explain the decreasing role of bicycle accidents in the older age groups.

The changes in incidence relative to sex and age group can to some extent be tied to the changes in incidence according to aetiology. The second youngest group is most represented in bicycle accidents, and as they decreased,

	1980–1989	1993–2002	2013–2018	1980–1989 to 1993–2002		1993–2002 to 2013–2018		1980–1989 to 2013–2018	
	IR (95% CI)	IR (95% CI)	IR (95% CI)	IR change (95% CI)	*p* value	IR change (95% CI)	*p* value	IR change (95% CI)	*p* value
All patients	4.2 (3.8 to 4.6)	4.1 (3.7 to 4.5)	5.2 (4.8 to 5.7)	−0.10 (−0.06 to 0.05)	0.9	1.1 (0.49 to 1.7)	0.0004	1.0 (0.44 to 1.6)	0.0007
Sex									
Boys	5.3 (4.9 to 5.8)	4.7 (4.2 to 0.51)	6.8 (6.3 to 7.4)	−0.60 (−0.06 to −1.2)	0.03	2.1 (1.5 to 2.9)	< 0.0001	1.5 (0.83 to 2.2)	< 0.0001
Girls	2.9 (2.6 to 3.3)	3.6 (3.2 to 3.9)	3.5 (3.1 to 3.9)	0.70 (0.11 to 1.1)	0.02	−0.10 (−0.57 to 0.47)	0.9	0.60 (0.06 to 1.1)	0.03
Age group (years)									
0–5	0.42 (0.30 to 0.57)	0.40 (0.28 to 0.54)	0.72 (0.53 to 0.91)	−0.02 (−0.20 to 0.16)	0.8	0.32 (0.01 to 0.53)	0.003	0.30 (0.09 to 0.51)	0.005
6–9	0.99 (0.80 to 1.21)	0.63 (0.48 to 0.80)	1.2 (0.95 to 1.4)	−0.36 (−0.61 to −0.11)	0.005	0.57 (0.26 to 0.78)	0.0001	0.21 (−0.13 to 0.45)	0.3
10–12	1.1 (0.90 to 1.3)	0.87 (0.70 to 1.1)	1.2 (0.95 to 1.4)	−0.23 (−0.49 to 0.05)	0.1	0.33 (0.001 to 0.56)	0.05	0.10 (−0.23 to 0.35)	0.7
13–15	1.7 (1.4 to 1.9	2.2 (1.9 to 2.5)	2.2 (1.9 to 2.5)	0.50 (0.16 to 0.94)	0.005	0.0 (−0.43 to 0.39)	0.9	0.50 (0.15 to 0.91)	0.007
Fracture type									
Exclusively mandibular	3.5 (3.1 to 3.9)	2.8 (2.5 to 3.1)	2.8 (2.5 to 3.1)	−0.70 (−1.2 to −0.23)	0.004	0.0 (−0.45 to 0.47)	1	−0.70 (−1.2 to −0.22)	0.005
Exclusively midfacial	0.32 (0.22 to 0.45)	1.2 (0.95 to 1.4)	1.8 (1.6 to 2.1)	0.88 (0.06 to 1.1)	< 0.0001	0.60 (0.34 to 1.0)	0.0001	1.5 (1.2 to 1.8)	< 0.0001
Exclusively upper third	0.02 (0.002 to 0.07)	0.07 (0.03 to 0.14)	0.12 (0.06 to 0.21)	0.05 (−0.01 to 0.11)	0.1	0.05 (−0.04 to 0.14)	0.3	0.10 (0.03 to 0.17)	0.008
Combined	0.32 (0.22 to 0.45)	0.12 (0.06 to 0.21)	0.48 (0.35 to 0.64)	−0.20 (−0.33 to −0.07)	0.003	0.36 (0.21 to 0.51)	< 0.0001	0.16 (−0.02 to 0.34)	0.07
Aetiology									
Bicycle	1.5 (1.2 to 1.7)	0.94 (0.76 to 1.2)	1.7 (1.4 to 1.9)	−0.56 (−0.82 to −0.22)	0.0008	0.76 (0.41 to 1.1)	< 0.0001	0.20 (0.14 to 0.56)	0.2
MVA	0.89 (0.71 to 1.1)	0.70 (0.55 to 0.88)	0.76 (0.60 to 0.95)	−0.19 (−0.44 to 0.06)	0.1	0.06 (−0.17 to 0.26)	0.6	−0.13 (−0.38 to 0.12)	0.3
Fall on ground level	0.50 (0.37 to 0.66)	0.49 (0.36 to 0.65)	0.56 (0.42 to 0.73)	−0.01 (−0.21 to 0.19)	0.9	0.07 (−0.13 to 0.27)	0.5	0.06 (−0.14 to 0.26)	0.6
Assault	0.40 (0.29 to 0.54)	0.63 (0.48 to 0.81)	0.28 (0.19 to 0.40)	0.23 (0.03 to 0.43)	0.02	−0.35 (−0.54 to −0.16)	0.0002	−0.12 (−0.28 to 0.04)	0.1
Hit by object	0.30 (0.20 to 0.43)	0.33 (0.23 to 0.46)	1.0 (0.84 to 1.3)	0.03 (−0.13 to 0.19)	0.7	0.67 (0.47 to 0.93)	< 0.0001	0.70 (0.50 to 0.96)	< 0.0001
Fall from height	0.25 (0.16 to 0.37)	0.52 (0.39 to 0.68)	0.76 (0.60 to 0.95)	0.27 (0.09 to 0.44)	0.002	0.24 (0.02 to 0.46)	0.03	0.51 (0.31 to 0.71)	< 0.0001
Horse kick	0.25 (0.16 to 0.37)	0.19 (0.11 to 0.30)	0.12 (0.06 to 0.21)	−0.06 (−0.19 to 0.07)	0.4	−0.07 (−0.18 to 0.04)	0.2	−0.13 (−0.25 to −0.01)	0.03
Collision with person/object	0.10 (0.05 to 0.18)	0.28 (0.19 to 0.40)	0.04 (0.01 to 0.10)	0.18 (0.06 to 0.30)	0.004	−0.24 (−0.35 to 0.13)	< 0.0001	−0.06 (−0.10 to 0.01)	0.1
Gun shot	0.02 (0.002 to 0.07)	NA	NA	NA	NA	NA	NA	NA	NA
Fireworks	NA	0.02 (0.002 to 0.07)	NA	NA	NA	NA	NA	NA	NA

Table 4. Incidence rate (IR) of maxillofacial fractures per 100,000 in each period and change in IR between study periods. *P*-values based on chi square tests on the difference between incidence rates.

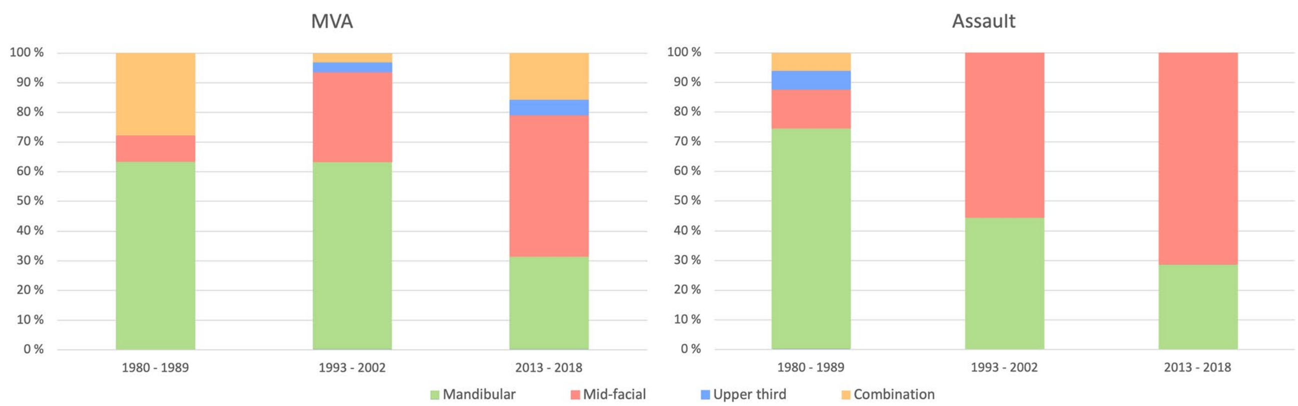

Fig. 1. Distribution according to fracture type for aetiologies MVA and assault.

so did the age group. Similarly, as boys predominated in this study, their proportional decrease in the middle study period may also be explained by the simultaneous decrease in bicycle accidents.

The increase in midfacial fractures can partly be explained by diagnostics improvement. Conventional radiographs are not ideal for the diagnosis of such fractures. Improvements in the availability and technical development of cross-sectional imaging have been remarkable between the 1980s and 2020s. Better access, iterative reconstruction, image thickness, faster imaging speed, and lower radiation exposure have all contributed to a lower threshold for using cross-sectional imaging and improvement in detecting facial fractures. In particular, the diagnosis of fractures in the midfacial region, with multiple overlapping small bony structures, has benefitted from improved imaging. While improvements in imaging may play an important role, there may be other explanatory factors for the increase in the incidence of facial fractures. The observed increase in facial fractures during the study is largely explained by the nearly six-fold increase in midfacial fractures from the first to the last period. Midfacial fractures thus also explain the proportional changes according to fracture type.

While the annual average of facial fractures resulting from MVAs has remained largely unchanged during the study, the associated fracture type has changed. The introduction of the airbag may play a role in the shift in fracture type from predominantly exclusively mandibular fractures to a relatively even distribution between exclusively mandibular versus combined or exclusively midfacial fractures. Airbags have been proven to prevent fatal fractures and enable patients with less severe fractures to survive[9]. This study included only patients admitted to hospital and on-site fatalities were not included. Therefore, airbags may in part explain the observed increase in exclusively midfacial fractures. In Finland, seatbelt use in the back seat became mandatory in 1987. Airbags were introduced in European cars in the early 1990s when the first European car manufacturers began fitting them. While not mandated by law in the European Union, airbags have been fitted in most new cars since the turn of the century. Laws and regulations concerning booster seats and children's car seats have tightened between the last two periods of the study, adding to child safety in vehicles. Car turnover varies between countries, contributing to the adoption of safety technology. Finland has an older-than-average vehicle fleet, with a third of passenger cars older than 20 years[10].

Bicycle accidents remained the most important underlying aetiology for facial fractures throughout the study. Considering improved helmet use and vehicle safety features designed to protect pedestrians and cyclists, the increase in facial fractures resulting from bicycle accidents speaks of poorer traffic safety for this age group. Sadly, the improvements in safety regulations and technology are yet to have a positive effect on the occurrence of traffic-related children's facial fractures. A recent European Commission report found Finland's road safety to be improving less favourably than the EU average when looking at trends from 2010–2012 to 2018–2020. They also discovered an upward trend (+ 19%) in fatal bicycle accidents in Finland, while the EU trend is decreasing (− 3%)[10].

Changes in the fracture type resulting from assault speak of the hardening nature of violence in assaults on teenagers. Assaults decreasing and bicycle accidents and being hit by an object increasing in proportion may reflect positive changes in children's habits, as the latter two are associated with physical activity and hobbies. Nevertheless, the fact that assault is present at all in such a young population is disconcerting. The steady increase in falls from height is unfortunate and the underlying factors merit further investigation.

Although the periods were not equally long and neither were the gaps between periods (3 vs. 10 years), the data covers 67% of the years between the first and last study year, providing an adequate sample of the population. Two of the periods in this study were preceded by financial turmoil. The Finnish Great Depression 1990–1993 and the resulting heavy socioeconomic burden on families and children coincided with the middle period. The aftermath of the global financial crisis of 2008 extended well into the first years of the last period. Bicycle accidents decreased and assaults increased in the middle period. In the last period, these aetiologies returned to levels closer to those of the first period. Similar results have been reported concerning the Greek economic depression of 2010[11]. When looking at the entire data, these changes in the middle period appear temporary seeming not to have affected trendlines.

The proportional changes in the distribution of facial fractures are of epidemiological interest. Changes in incidence, however, can be thought to reflect societal factors and trends of interest for policymakers and in the fields of sociology and health economics.

The findings of our study raise two disconcerting issues; children's facial fractures have increased in incidence and assaults have not decreased. The study spans three decades of strong economic growth and technological advancement, both generally thought to improve social well-being and safety in urban areas. As bicycle accidents remain the most common aetiology, improving the technical safety of surroundings for children is important. Nonetheless, it only goes so far in preventing and mitigating children's facial fractures. Based on our results there is a need for preventive measures targeted at changes in behaviour both in traffic and interpersonal encounters. Bearing in mind the age distribution of the focus group, the earlier the better.

Data availability

The datasets generated during and/or analysed during the current study are not publicly available due to Finnish legislation on patient data but are available from the corresponding author on reasonable request.

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Author contributions
T.P. and J.S. collected the data. H.T. and A.K. conceived and designed the analysis. All authors took part in refining the final format of the design. A.K. wrote the main manuscript text and prepared figures and tables. T.P., J.S. and H.T. reviewed the manuscript during the process. A.S. and A.K. performed statistical tests and analysis. All authors reviewed the final manuscript.

Competing interests
The authors declare no competing interests.

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