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Trends in mandibular fractures in the USA: A 20-year retrospective analysis

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Abstract

Background/Aim: The mandible is one of the most fractured bones in the maxillofacial region. This study analyzes trends in mandibular fracture patterns, demographics, and mechanisms since the early 2000s.

Material and Methods: Mandibular fractures were reviewed from the 2007, 2011, and 2017 National Trauma Data Bank including 13,142, 17,057, and 20,391 patients by year, respectively. This database contains hundreds of thousands of patients annually and represents the largest trauma registry in the United States. Variables included number of fractures, sex, age, injury mechanism, and fracture location. Mechanism of injury included assault, motor vehicle crash, fall, motorcycle, bicycle, pedestrian, and firearm. Anatomic locations based on ICD-9/10 codes included symphysis, ramus, condyle, condylar process, body, angle, and coronoid process. Frequencies were compared using Chi-square tests of homogeneity with effect sizes estimated using Cramer's V.

Results: Mandibular fractures represent 2%–2.5% of all traumas reported in the database from 2001 to 2017. The proportion of patients sustaining a single reported mandibular fracture decreased from 82% in 2007 to 63% in 2017. Males consistently experienced 78%–80% of fractures. Eighteen to 54-year-olds experienced the largest percentages of fractures throughout the 21st century, while median age of fracture shifted from 28 to 32 between 2007 and 2017. The most common fracture mechanisms were assault (42% [2001–2005]–37% [2017]), motor vehicle crash (31%–22%) followed by falls (15%–20%). From 2001–2005 to 2017, a decrease was observed in assaults (−5%) and motor vehicle crash (−9%) and an increase in falls (+5%), particularly among elderly females. The mandibular body, condyle, angle, and symphysis represent approximately two-thirds of all fractures without a consistent temporal trend among them.

Conclusions: The temporal trends observed can be linked to shifting age demographics nationally that may aid clinicians in diagnosis and inform public safety policies aimed at reducing these injuries, particularly among the growing elderly population.

KEYWORDS
age-related, epidemiology, mandible fractures, national trends

1 | INTRODUCTION

The mandible is one of the most fractured facial bones, representing an estimated 29% of facial fractures in the US from 2007 to 2015.[1] Facial fractures affect a diverse demographic cohort, ranging from pediatric through geriatric patients.[1,2] Mandibular fractures occur due to multiple different mechanisms that are not evenly distributed across ages.[2–9] Moreover, they demonstrate one of the highest rates of necessary repair among facial fractures and can incur significant medical costs with lengthy hospitalization.[1] Allareddy et al. reported 6 days as the average length of hospitalization with an average cost of $62,000 per patient.[10]

The life expectancy of the population in the United States (US) has increased in recent years; similarly, trauma centers have reported rises in geriatric trauma patients.[11–14]

While local and regional surveys of mandibular fracture patterns stretch back decades, the advent of national databases cataloging trauma, such as the National Trauma Data Bank (NTDB) created in 1989, has fostered the ability to examine trauma demographics at a national scale.[15–17] To date, Afrooz et al. (2015) examined mandibular fractures from the early 2000s and Wasicek et al. (2019) summarized mandibular fractures from 2007 to 2015 using the NTDB.

The aim of the study was to expand on these previous reports and further examine cultural shifts in mandibular fractures in the United States throughout the 21st century.

2 | MATERIALS AND METHODS

To answer the proposed research question, a retrospective exploratory study using a secondary dataset was approved by The Northeast Ohio Medical University Institutional Review Board (IRB# 20-010). The Trauma Quality Program (TQP) Participant Use File (PUF) was identified as a comprehensive dataset having ample variables to investigate trauma patients with mandibular fractures. The PUF includes data from American College of Surgeons (ACS) verified trauma centers ranging from Level I to Level V for both adult and pediatric centers. The sample included patients who experienced mandibular fractures treated at ACS-verified trauma centers in the United States. Datasets obtained by the NTDB PUF included years 2007, 2011, and 2017. Patient consent was waived due to the use of a retrospective de-identified dataset.

De-identified datasets were obtained from the TQP PUF. Primary variables from the datasets included demographics, mechanism of injury (MOI), location of mandibular fracture, and number of fractures. Fracture data from 2001 to 2005, 2007, and 2011 were classified using ICD-9 open/closed mandibular fracture codes (802.2–802.39). The dataset from 2017 used the ICD-10 mandibular fracture code (S02.6).

Demographic variables included patient age and sex. Variable identification and descriptions closely followed Afrooz et al. to ensure comparability of demographic data.[2] Age was grouped to mirror age ranges reported in Afrooz et al.: 0–1, 2–4, 5–9, 10–14, 15–17, 18–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, and ≥85 years.[2] Fractures were assigned to MOI categories (assault, bicycle crash, fall, firearm-related, motorcycle collision, motor vehicle collision [MVC], and pedestrian), while the remaining fractures were categorized as other. Anatomical locations were taken from ICD9/10 injury codes including symphysis, ramus, condyle, condylar process, body, angle, and coronoid process.

Data were summarized with categorical variables representing counts and percentages. Frequencies were compared among 2007, 2011, and 2017 datasets using Chi-square tests of homogeneity ($\alpha = 0.05$). Large samples sizes often present bias toward significant but not necessarily meaningful results; therefore, the use of effect sizes using Cramer's V were reported.[18] This statistic ranges from 0 to 1 where values closer to 0 indicate smaller effect sizes. When available, quantitative data were included from 2001 to 2005 in these statistical assessments. Otherwise, qualitative comparisons were made with these earlier data to assess trends.

3 | RESULTS

Admissions recorded in the NTDB increased from 630,000 during 2001–2005 to 997,971 in 2017.[2] Total numbers of patients sustaining one or more mandibular fractures and their percentages of the total NTDB admissions were: 13,142 (2.1%) in 2001–2005, 12,527 (2.5%) in 2007, 17,057 (2.2%) in 2011 and 20,391 (2.0%) in 2017. While the chi-square test indicated significant differences in percentages across years ($p < .001$), the effect size of 0.01 (Cramer's V) indicates the variation among years has little explanatory power. Mandibular fractures consistently represent 2%–2.5% of the NTDB admissions throughout the 21st century.

The proportion of patients sustaining only one reported mandibular fracture decreased from 82.3% in 2007 to 62.7% in 2017. This matched a trend of doubling of percentages of admissions sustaining two or three mandibular fractures from 2007 (17.4%) to 2017 (35.6%). The chi-square test indicated a significant difference in fracture distribution among years matching these trends ($p < .001$). The Cramer's V of 0.13 indicates a small, but noteworthy effect of year. Males and females demonstrate similar trends.

Male patients represent four times the number of mandibular fracture admissions than females in the database (Figure 1). A slight decrease in the frequency of males was observed from 80% in the first decade of the 2000s to 78% by 2017 (Figure 2). While the significant chi-square test reflects that slight shift in frequency ($p < .001$), the Cramer's V value of 0.02 suggests only a minor change in sex frequency over the past 20 years.

Age-related trends in mandibular fractures changed subtly over the 20th century (Figure 2). At all four time points examined, 18–54-year-olds represent the largest percentages of fractures in the database with pediatric and elderly fractures exhibiting much smaller percentages. A slight shift was noted in 2017 with 25–34-year-olds being the age demographic with the highest

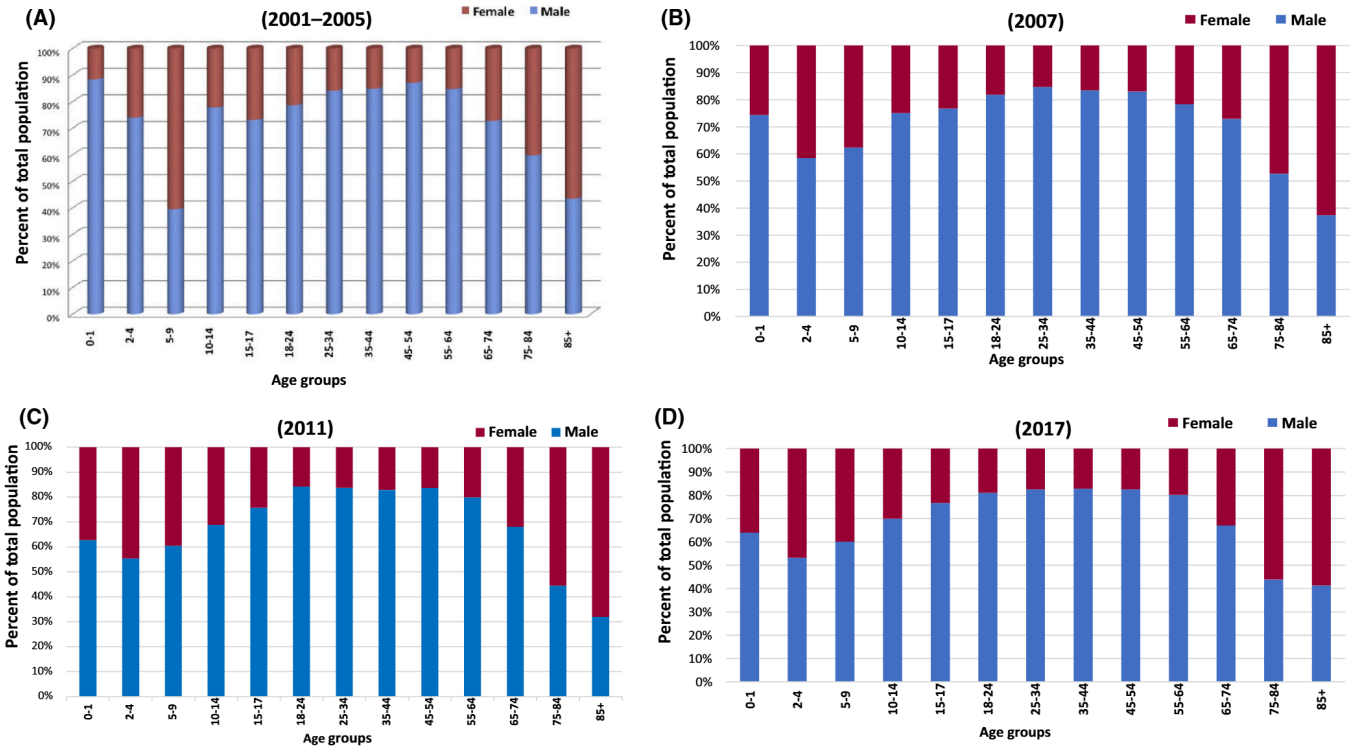


FIGURE 1 The male-to-female distribution across the various age groups for 2001–2005 (A), 2007 (B), 2011 (C), and 2017 (D). (A is recreated from Afrooz et al., 2015 with permission).

percentage of fractures as opposed to 18–24-year-olds for previous years. Fractures in older and elderly groups (beginning at 55 years) doubled in percentages from 2007 to 2017; although still smaller percentages than 18–54-year-olds (Figure 2). These observations are supported by a significant chi-square test ($p < .001$) and a Cramer's V of 0.1 indicating a small, but notable effect. Inspection of residual plots for males and females suggest that males are primarily responsible for the temporal increase in fractures among 55–64-year-olds, while females contribute more to the shift at older ages. Both sexes contribute to the downward trend in 18–24-year-olds from 2007 to 2017 (Figure 3).

Sex distribution varies considerably with age groups but remains largely consistent throughout the 20th century (Figure 1). Pediatric and juvenile fractures are male-dominated, but typically not to the four-fold difference seen by late adolescence through most of adulthood. By 75 years of age, male and female fractures typically show more equal distribution with females tending to be the dominant sex in the oldest age groups (Figure 1).

Assaults represent the most frequent mechanism of jaw fracture in the database (Figure 3). MVCs are the second most common injury mechanism followed by falls. The remaining four mechanisms, motorcycle, pedestrian, firearm, and bicycle, each represent less than 10% of injuries per year sampled (Figure 4). After an initial high of 42% in 2001–2005, assaults remained relatively constant at 37–38% throughout the past 15 years (Figure 4). MVAs have decreased from 31% in 2001–2005 to 22% in 2017. Alternatively, falls have increased from 15% in 2001–2005 to 20% by 2017. Among the less frequent injury mechanisms, firearms jumped from 2% in 2001–2005 to 8% by 2017. These annual shifts are reflected in a significant chi-square result ($p < .001$) and a small effect size of 0.09 based on Cramer's V.

Assault remains the most common mechanism for jaw fracture in males from 15 to 54 (Figure 5). Assaults as the most common mechanism extends to age 64 in males in 2017. While assaults are not the dominant injury mechanism in females (Figure 6), both sexes show a pattern of less frequent assaults in 15–24-year-olds with relative increases in 25–34 and 55–74-year-old groups from the early to later part of the 20th century (Figure 7A). This observation is supported by a significant chi-square ($p < .001$) and Cramer's V of 0.11. MVCs show a similar shift in demographics – declining in 15–24-year-old groups from 2007 to 2017, while increasing in frequency in elderly groups throughout the century (Figures 5–7B). Finally, falls tend to decrease in relative frequency until age 54 from 2007 compared to 2017. Falls then increase, particularly in females, from age 55+ from 2007 to 2017 (Figures 5–7C).

No consistent temporal trends were observed in frequency of breaks across anatomical locations (Table 1). The most frequently injured regions across all years sampled were the symphysis, body, angle, and condylar processes. The subcondylar process and ramus are less frequently injured and show some temporal shift throughout the years with a decrease in subcondylar fractures and increase in rami injuries (Table 1). Finally, alveolar and coronoid injuries remain comparatively infrequent throughout the 20th century (Table 1). Despite a significant chi-square test result ($p < .001$), the Cramer's V of 0.06 suggested that variation in year had limited effect on regional variation in fracture location.

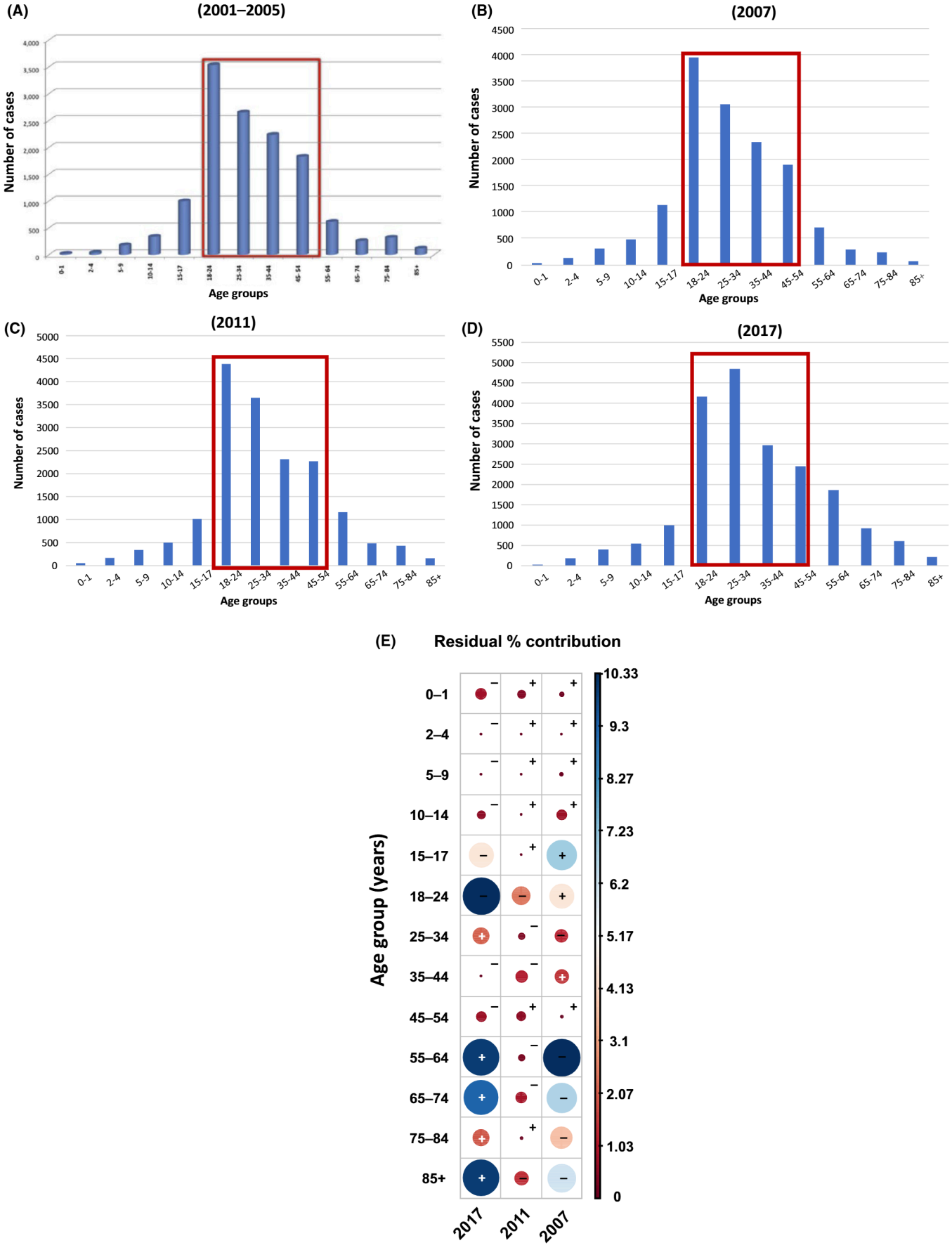
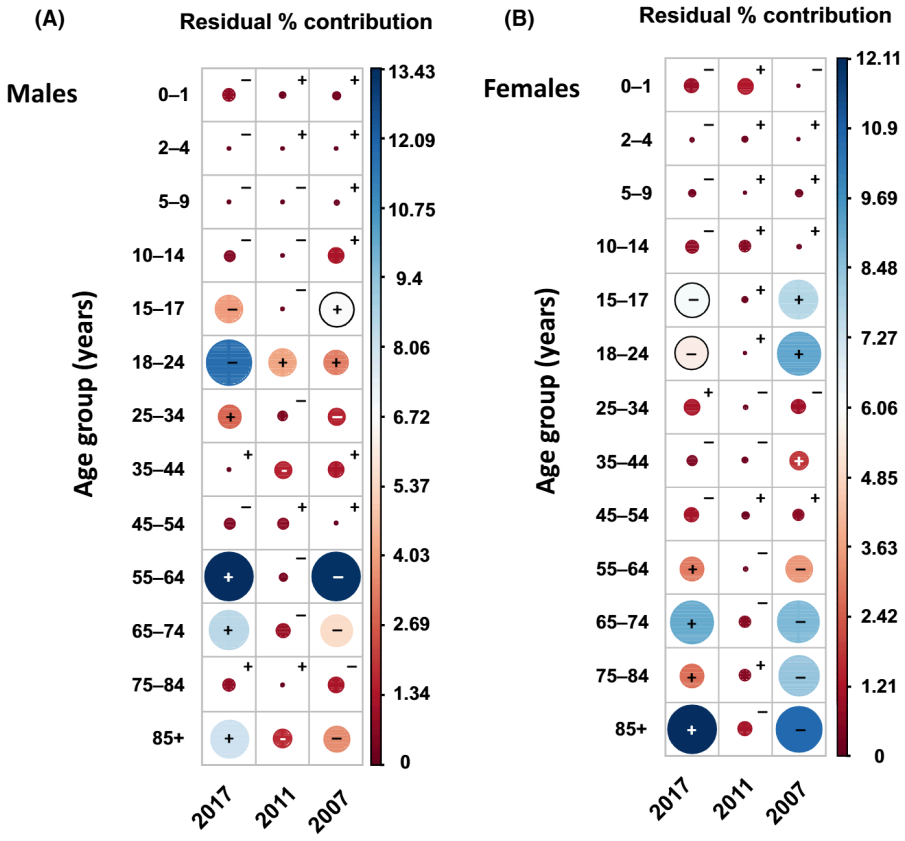


FIGURE 2 The number of individuals with at least one incidence of jaw fracture by age group for 2001–2005 (A), 2007 (B), 2011 (C), 2017 (D). Red boxes indicate the age range where most fractures occur. (E) Residual plot illustrating temporal shifts in mandibular fractures with age from 2017 to 2007. The *y*-axis represents age. Within each cell is indicated the Pearson residual (R) for that cell ((observed value-expected value/(expected value$^{\wedge 0.5}$)) scaled to chi-square statistic (R^2/chi-square statistic). The color legend maps to magnitude of the residual contribution. The "+" or "−" signifies whether the residual change is positive (+) or negative (−) for that cell. The position of the ± within or outside of the circle is for viewing convenience only. In this plot, 2017 showed relative increases in fractures among older and elderly (55–85+) and a relative decrease in 18–24 year olds compared to previous time periods. (A is recreated from Afrooz et al., 2015 with permission).

FIGURE 3 Residual plot illustrating temporal shifts in mandibular fractures with age for (A) males and (B) females from 2017 to 2007. See Figure 2E for explanation of residual % contribution and ± notation.



Finally, when anatomical locations are considered relative to the three most frequent injury mechanisms, differences exist in anatomical region injured for a specific MOI, but no clear temporal trends exist. (Figure 8). For example, mandibular angles tend to be more frequently injured in assaults, while condyles are more commonly injured in falls. These locational patterns persist across sample years (Figure 8).

4 | DISCUSSION

Trends in mandibular fractures across the 21st century were explored with respect to demographics, injury mechanisms, and anatomical locations using the National Trauma Data Bank (NTDB). To the extent that multicenter databases accurately reflect national trends, mandibular fractures consistently represent 2%–2.5% of US trauma admissions annually this century.[19,20] The apparent stability in frequency may be coincidental as both upward and downward trends in specific demographics and mechanisms were observed over this period.

The percentage increase in individuals experiencing multiple mandibular fractures from 2007 to 2017 (Figure 1) like has multiple explanations. One possibility is the shift from ICD-9 to ICD-10 codes may contribute to the 12% decrease in single fractures between 2011 and 2017.[21] For example, the additional coding for open/closed fracture, left/right sides in ICD-10 and removal of a multiple fracture code from ICD-9 may have increased coding for multiple fractures in ICD-10. However, the 7.5% decrease from 2007 to 2011 cannot be explained by changes in ICD coding (i.e., both years used ICD-9) and may reflect trends in mechanisms, diagnosis, and/or coding over the time period.

Despite changes in ICD coding, sex distribution largely remained consistent. Males experienced 80% of the mandibular fractures in 2007, which declined slightly to 78% in 2017. The frequency of mandibular fractures in males is markedly higher compared to all incidents in the NTDB. In 1999–2003, males experienced approximately 66% of all incidents.[22] This percentage declined to approximately 61% by 2015.[23] Following total incident trends in the NTDB, males are more likely to experience mandibular fractures and this likelihood has increased with time as females represent a

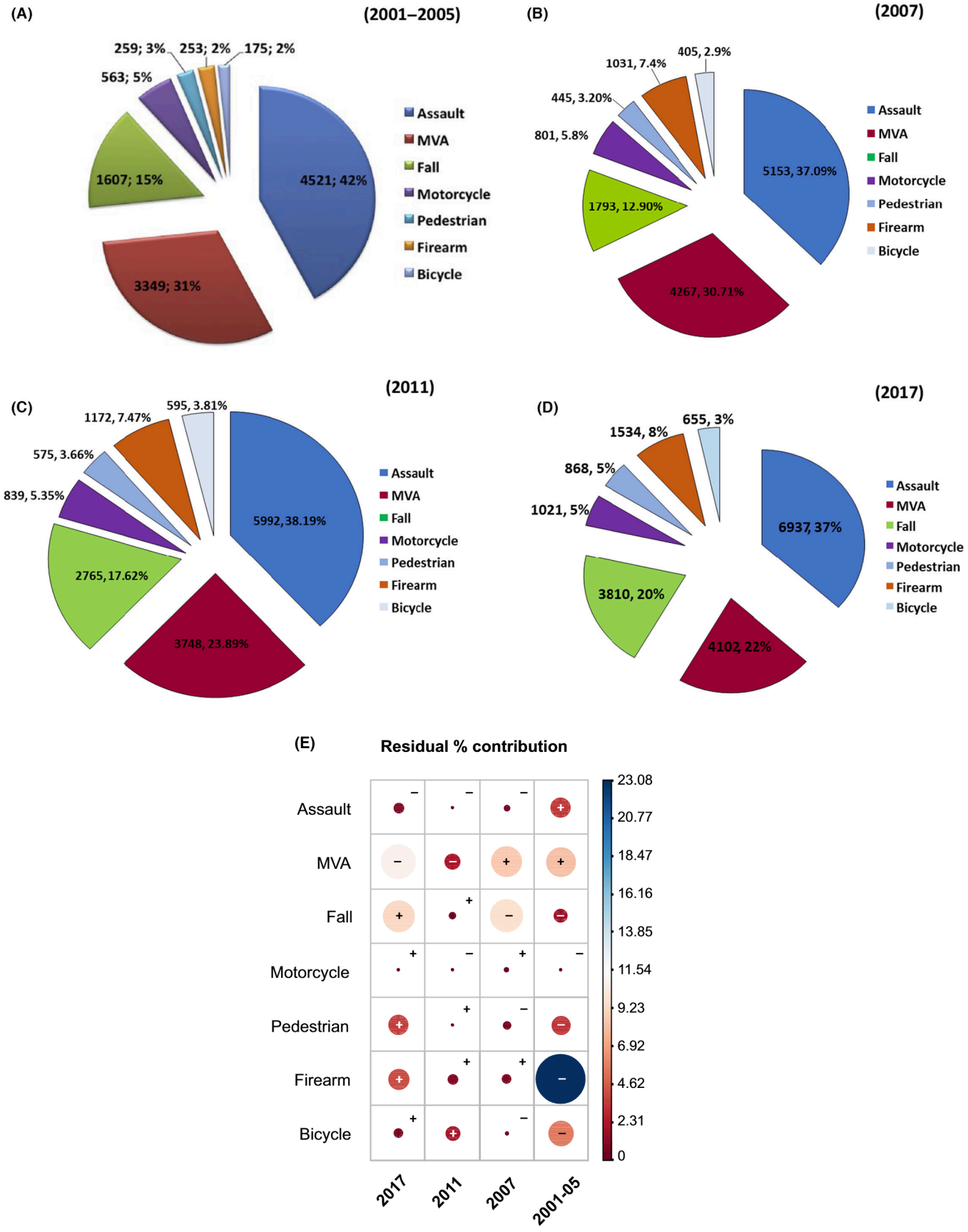


FIGURE 4 The number and percentage of reported fractures by mechanism of injury for 2001–2005 (A), 2007 (B), 2011 (C), and 2017 (D). (E) Residual plot illustrating temporal shifts in mandibular fracture mechanisms from 2017 to 2001–2005. See Figure 2E for explanation of residual % contribution and ± notation. (A is recreated from Afrooz et al., 2015 with permission).

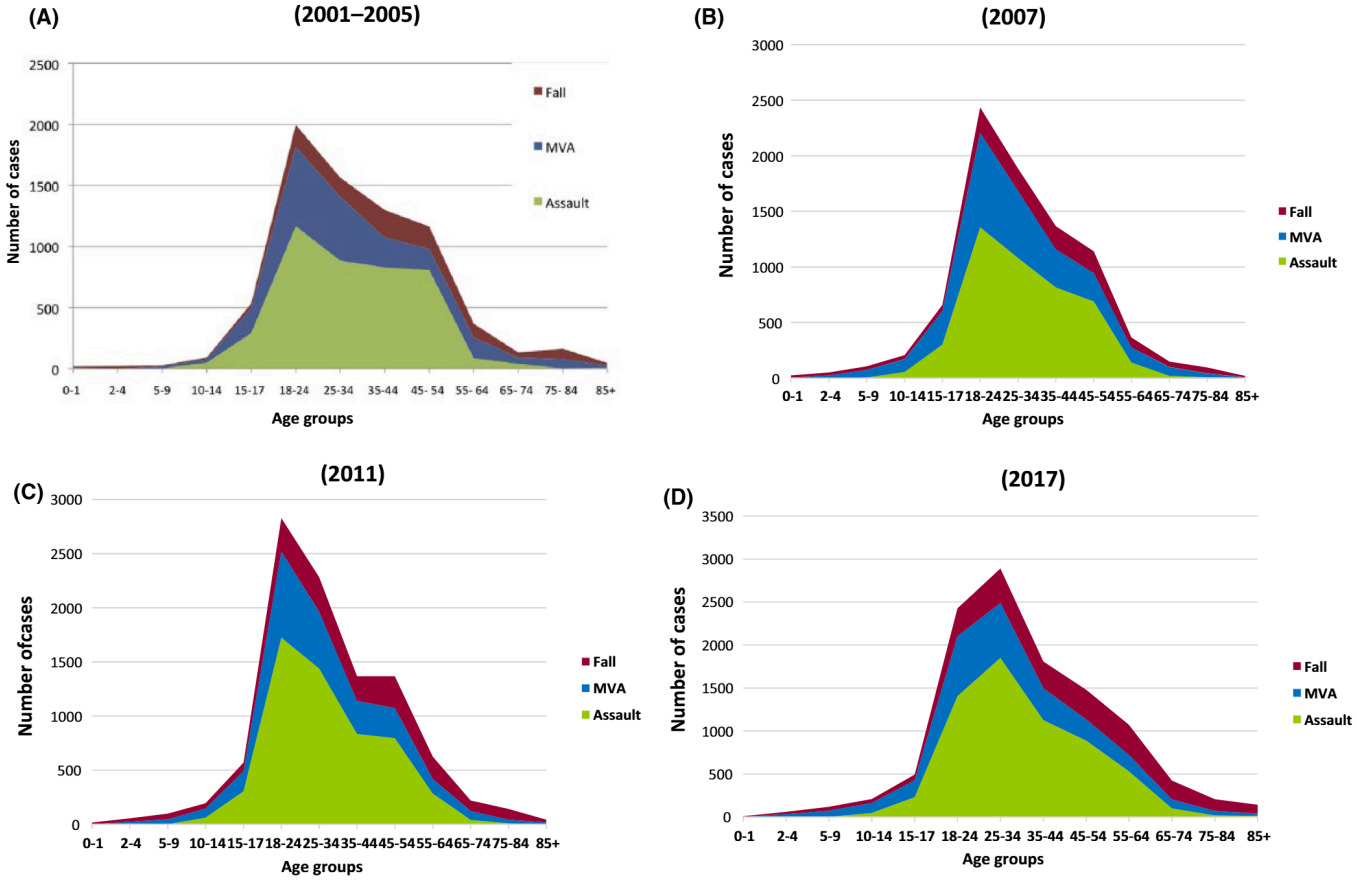


FIGURE 5 Stacked area chart showing the distributions of the three major mechanisms (Assault, MVA and Falls) across age groups for male patients in 2001–2005 (A), 2007 (B), 2011 (C), and 2017 (D). (A is recreated from Afrooz et al., 2015 with permission).

larger percentage of incidents more recently (Figure 1). Given that assaults on males represent approximately 33% of mandibular fracture incidents, this result is not surprising. Assaults, combined with the approximately three-fold higher representation of males with mandibular fractures in motorcycle collisions and by firearms, likely drive the higher frequency and relative stability of sex differences in mandibular fractures.

While mandibular fractures have remained a consistent percentage of overall incidents in the 21st century, there is a shift toward more older individuals of both sexes experiencing fractures. The median age of individuals with mandibular fractures increases from 28 years of age in 2007 to 32 in 2017. Comparison of cumulative percentages of fractures across ages show that at 18–24 years of age, there is a 10% drop in percentage fracture in 2017 compared to 2007 (Figure 9). This decrease among 18–24-year-olds is maintained until 45–54 years of age. European nations exhibit similar trends with 80% of the affected population being males with an average age of injury of 35 years old.[24,25]

This shift toward older individuals experiencing a larger percentage of mandibular fractures reflects in part the increasing age of the population as median age in the United States increased from 35.3 to 38.1 years from 2000 to 2017.[26] The percentage of elderly in the population are expected to continue increasing in the first half of the 21st century both in the United States and worldwide.[27] Adding to this demographic shift toward a larger elderly population is the potential for increased activity in the elderly associated with lifestyle changes including extensive motor vehicle operation.[28,29] For example, from 2001 to 2010 in Maryland there was a general decline in statewide MVCs but a significant increase in mean age of injured motorists from 39 to 43 suggesting increased numbers of older motor vehicle occupants.[30] Overall, these trends suggest the potential for continued increase in mandibular fractures among the elderly and a greater representation of elderly among patients with fractures.

The ranking of the top three mechanisms of injury of assault, MVC, and fall, remained consistent throughout the 21st century. Boffano et al. reported the same top three mechanisms in Europe, with sports-related injury due to the popularity of soccer as the fourth most common mechanism.[31] An earlier report from Ellis et al. showed these three were predominant mechanisms for fractures from the mid-1970s to 80s potentially extending the time frame of their significance.[16] While still predominant, shifts could be seen in their percentages throughout the first part of the 21st century. Assaults and MVCs, the top two mechanisms, declined 5% and 9%, respectively (Figure 3). Alternatively, falls increased from 15% to 20% of fractures.

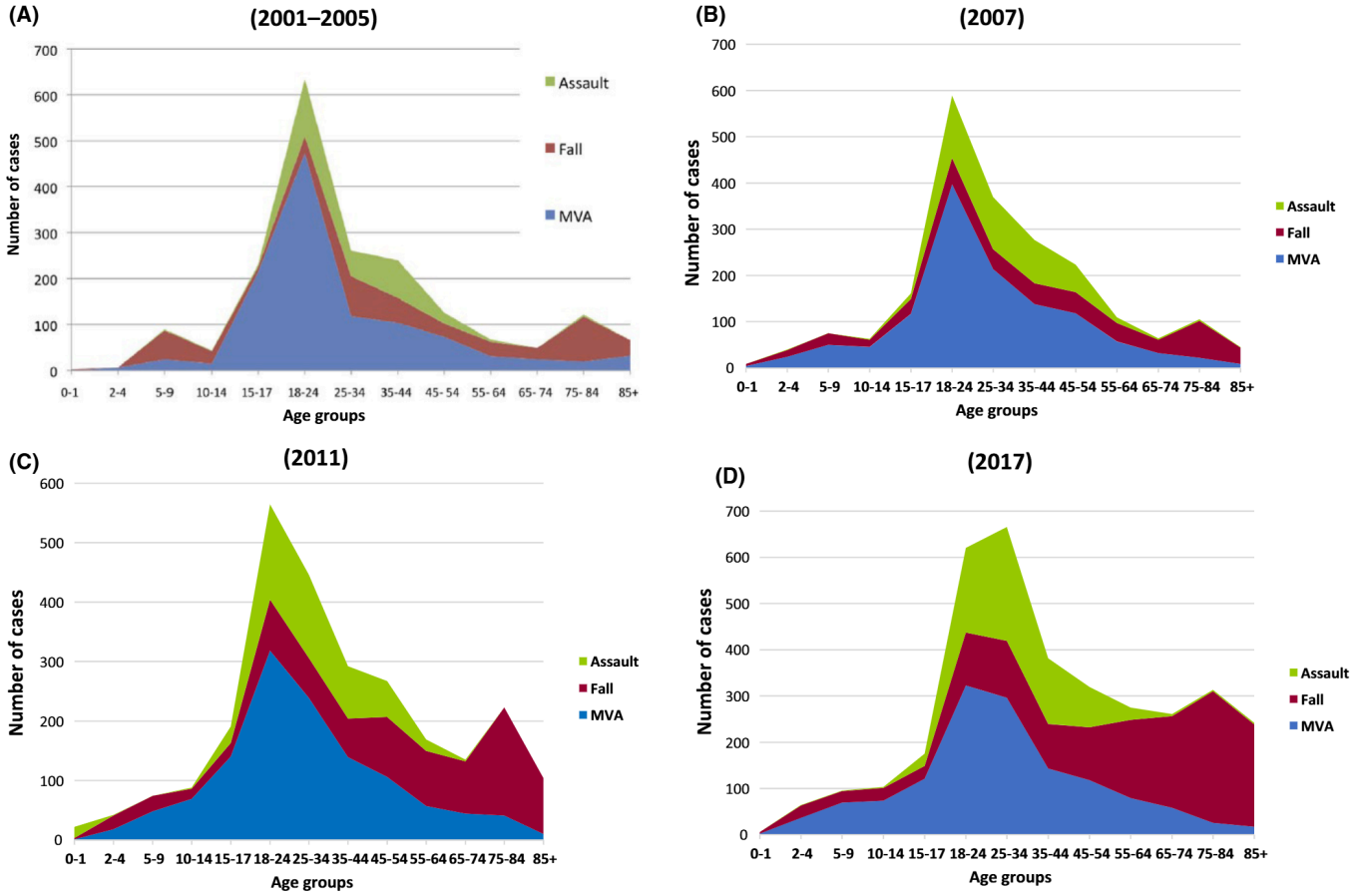


FIGURE 6 Stacked area chart showing the distributions of the three major mechanisms (Assault, MVA and Falls) across age groups for female patients in 2001–2005 (A), 2007 (B), 2011 (C), and 2017 (D). (A is recreated from Afrooz et al., 2015 with permission).

The decline in assaults as a mechanism of mandibular fracture appears to follow national injury and fatality trends for the 21st century. From 2003 to 2017, the death rate due to being "struck by" declined from 0.37 to 0.32 individuals per 100,000.[32] Similarly, being "struck by" represented 15.1% of nonfatal injuries recorded in the NEISS (National Electronic Injury Surveillance System) in 2003. This percentage dropped to 12.1% by 2017 demonstrating a general trend of declining assaults in the 21st century.

The decline in MVA-related fractures also largely follows national trends throughout the 21st century in MVCs. The reported national death rate due to MVA in 2003 was 15.5 individuals per 100,000 and 14.7 individuals per 100,000 in 2007.[32] These values dropped to 11.4 and 12.5 individuals per 100,000 in 2011 and 2017, respectively.[32] This decreasing trend is more apparent when fatality data are scaled by the number of miles traveled since travel has increased throughout the century. Deaths per million miles traveled decreased from 1.48 in 2003 to 1.17 in 2017.[33] The decrease by decade matches the observed drop in the frequency of mandibular fractures due to MVAs from the 2000s (i.e., ~31% in 2001–2005 and 2007) to the 2010s (i.e., 24%–22% in 2011 and 2017, respectively) (Figure 4). Nonfatal injury data for MVAs similarly drops from 10.4% of all reported injuries in 2003 to 8.2% in 2017.[32]

Cultural shifts emphasizing automobile safety and driving laws have also likely impacted the downward trend in MVC-related mandibular fractures. Motor vehicle safety has increased throughout the 21st century as more vehicles integrate both active and static safety measures.[34] Personal choice and more stringent legal enforcement likely also play a role in observed declines. Since 2003, there has been an approximate 60% drop in potential lives that could have been saved by wearing seatbelts suggesting increased seat belt use throughout the 21st century.[33] Similarly, driving under the influence (DUIs) decreased by 43.7% from 2002–2003 to 2016–2017 indicating changing cultural awareness of risks associated with impaired driving.[35] Clinically, these demographic changes may impact the patterns of injuries, both within the mandible and throughout the body, associated with MVAs. Boffano et al. examined etiology in Europe highlighting cultural factors, drinking habits, road standards, and variation in MVA laws among countries, which likely contribute to fractures patterns overseas.[31]

Falls become a major mechanism of mandibular fracture in the elderly. This is an increasing trend throughout the 21st century and is particularly true for females who experience increased falls from 2001–2005 to 2017 (Figure 5). Because of the aging of the US population, deaths due to falls have increased from 6.2 per 100,000 in 2003 to 11.6 per 100,000 in 2017.[32] When looking at

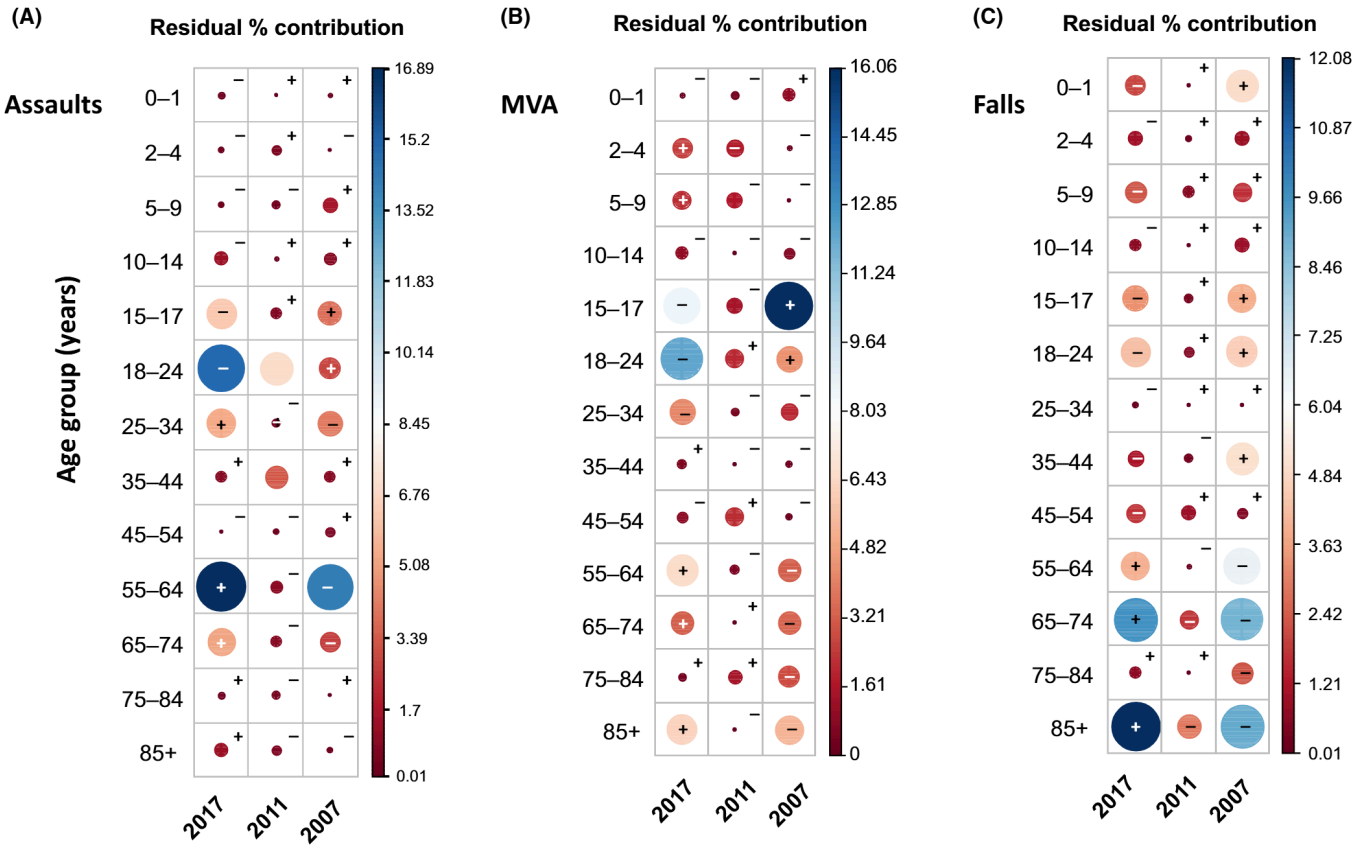


FIGURE 7 Residual plot illustrating temporal shifts in mandibular fractures with age from 2017 to 2007 for assaults (A), motor vehicle accidents (MVA) (B) and falls (C). See Figure 2E for explanation of residual % contribution and ± notation.

TABLE 1 Percentages of mandibular fractures for each anatomical region by years. (Percentages are based on 13,142 patients for 2001–2005; 15,063 patients for 2007; 22,002 patients for 2011; 29,923 patients for 2017).

Percentage of fractures by anatomic region per year				
	2001–2005	2007	2011	2017
Symphysis	19.20%	15.18%	17.73%	17.15%
Body	18.10%	15.49%	14.82%	19.20%
Angle	16.20%	14.31%	16.28%	17.55%
Condylar process	14.80%	11.68%	13.65%	17.57%
Subcondylar process	12.60%	9.53%	9.13%	7.40%
Ramus	11.30%	10.08%	11.44%	14.59%
Alveolus	4.50%	4.07%	3.96%	3.17%
Coronoid	3.30%	1.91%	2.67%	3.35%

just the frequency of injuries and not considering population increase, the percentage of injuries among 65+ attributable to falls has remained constant at ~63% throughout the 21st century.[32] Taken together, these data suggest the increased number of mandibular fractures treated in elderly patients throughout the 21st century largely reflects the changing and aging US population. Previous explanations focused on osteopenia and other degenerative diseases likely still explain the proximate reasons for individual patient fractures.[1,2] An analysis of the elderly European population demonstrates similar trends with a female-to-male ratio of 0.81:1 for patients over 70 and falls as the most common mechanism.[36]

Afrooz et al. observed the most common anatomical locations of mandibular fractures focused on the symphysis, condyle, body, and angle.[2] While the frequencies of these locations have shifted slightly between years (Table 1), these sites remain the most common anatomical locations for injury throughout the century. There were clear trends in changing anatomical locations associated with fractures. Thus, specific mechanisms associated with tendencies to fracture specific portions of the mandible likely remain largely unchanged such as the well-documented location of a left/right hook in a punch naturally directing force across the body and angle with increased risk for associated contralateral condylar fracture.[37] With MVCs, the direct force of the front of the face into the steering wheel or airbag

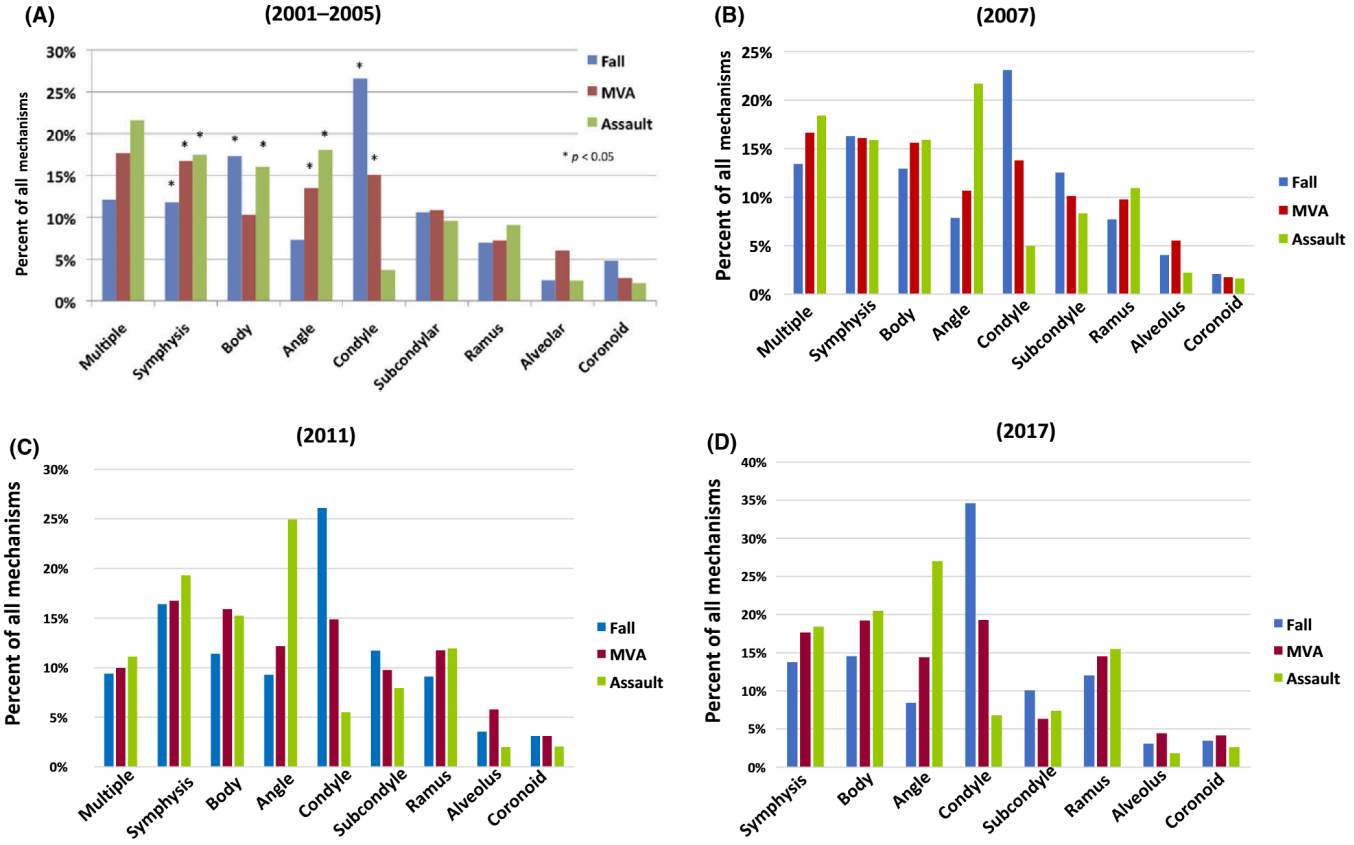


FIGURE 8 Percentage of fractures for each mandibular region attributable to Assault, MVA and Falls for 2001–2005 (A), 2007 (B), 2011 (C), and 2017 (D). Note *Y*-axis scales are not the same for a through D. (A is recreated from Afrooz et al., 2015 with permission).

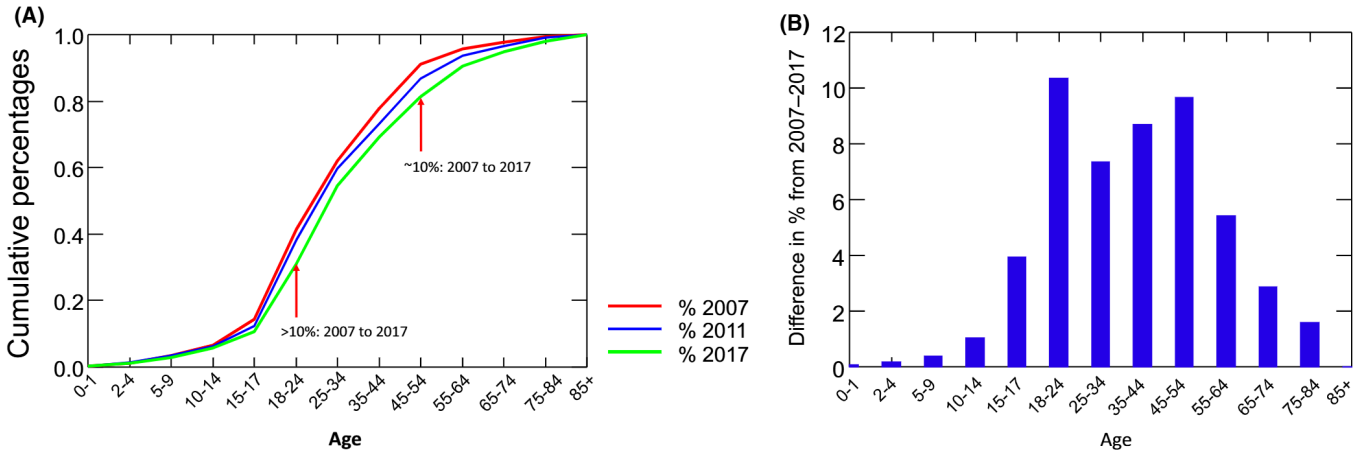


FIGURE 9 Cumulative distribution of individuals experiencing fractures in 2017, 2011 and 2007 (A) Arrows indicate where major shifts in percentage of population experiencing factures by a given age have occurred in 2017 compared to 2007. (B) Shifts in percentages with age between 2017 and 2007.

affects the symphysis and transfers force to the body.[38] Brucoli noticed similar breakage patterns in Europe.[39] With regards to falls, people falling onto their sides tend to injure the lateral aspects of the face and transmitting the force to break the condyle, a trend observed in the European elderly as well.[36]

As a retrospective study, there are inherent limitations as this work only documents large-scale trends rather than assessing cause-effect relationships.[20] Furthermore, data quality and selection bias linked to trauma level and/or socioeconomic factors impacting the registry may affect the observed trends.[19] Despite these limitations, the number of patients considered supports the observed overall stability, coupled with other moderate temporal changes in mandibular fractures throughout this first part of the 21st century.

AUTHOR CONTRIBUTIONS

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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