

## Background

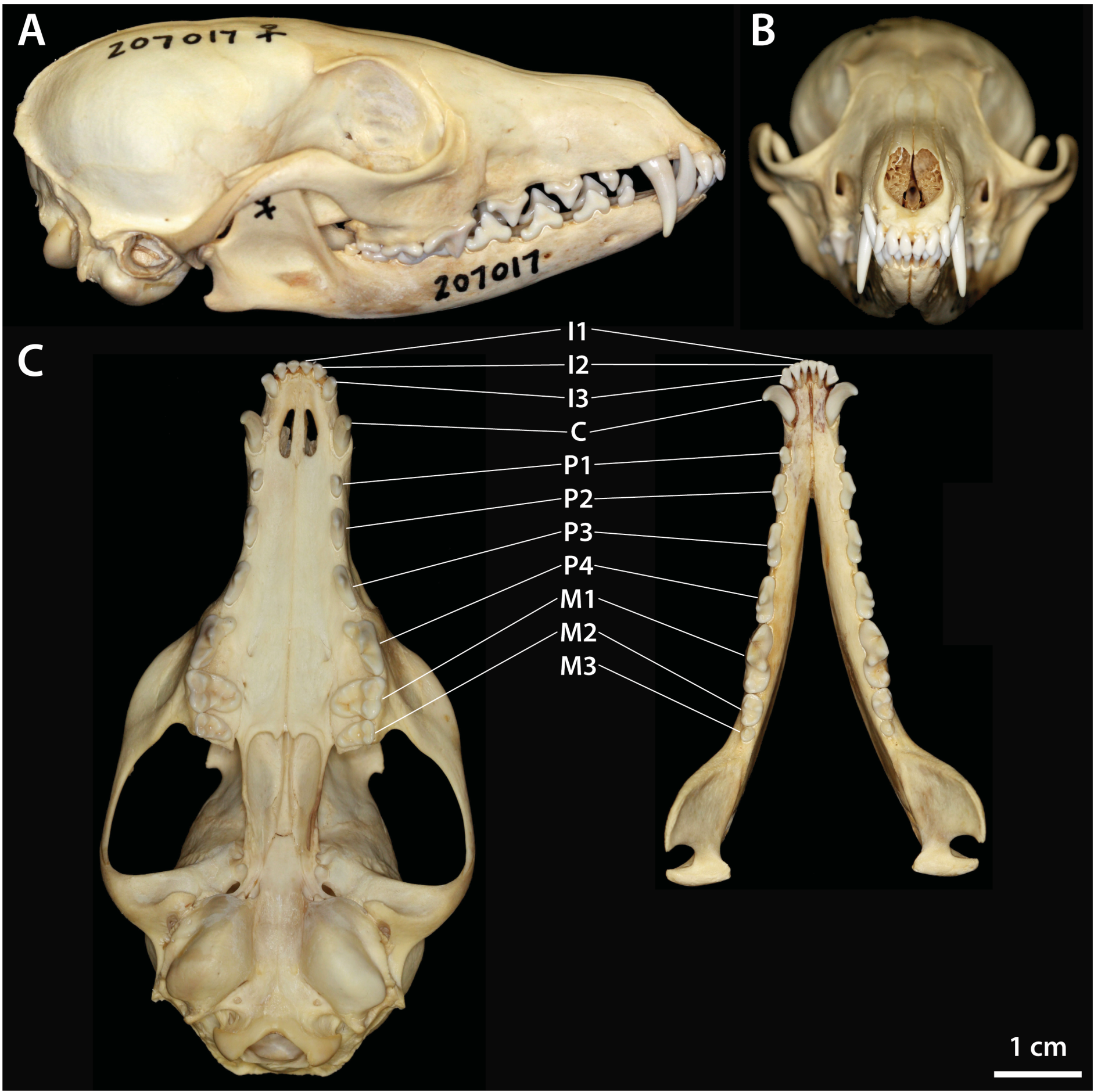
- The kit fox (*Vulpes macrotis*) is the smallest canid found in North America<sup>1</sup>
  - Geographical location: deserts of southwestern United States and northern to central Mexico<sup>1</sup>
  - Diet: primarily small mammals (kangaroo rats, ground squirrels); also ground-nesting birds and reptiles<sup>2</sup>
- International Union for Conservation of Nature status: least concern<sup>3</sup>
  - San Joaquin kit fox (*V. m. mutica*) listed as “endangered” by U.S. Fish & Wildlife, and “threatened” by California<sup>4</sup>
  - Importance: ‘umbrella species’ for the recovery of the San Joaquin Valley <sup>4</sup>
  - Threats to survival: urbanization, vehicular accidents, predation<sup>4</sup>
- Dental formula: I 3/3, C 1/1, P 4/4, M 2/3

## Hypothesis

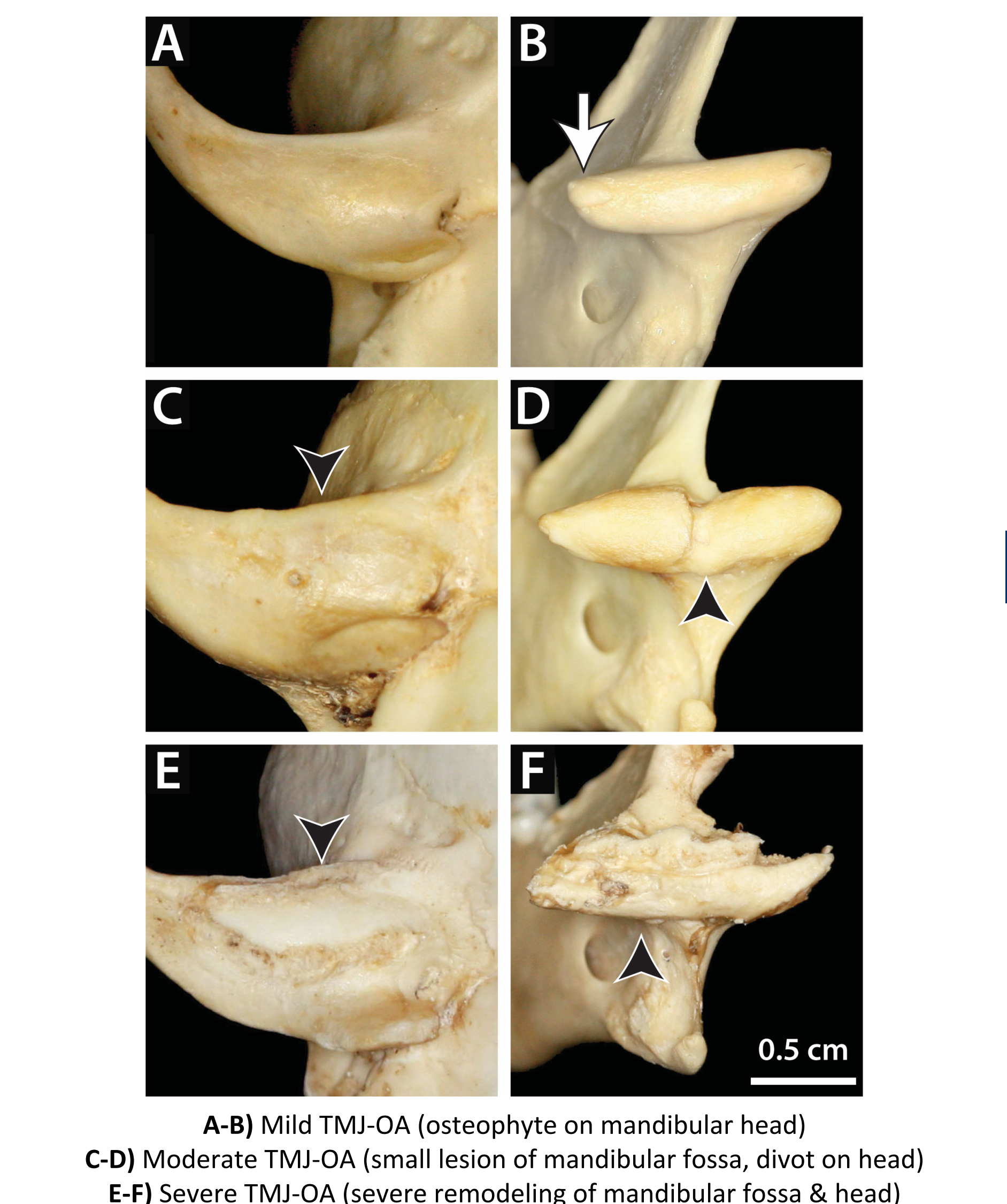
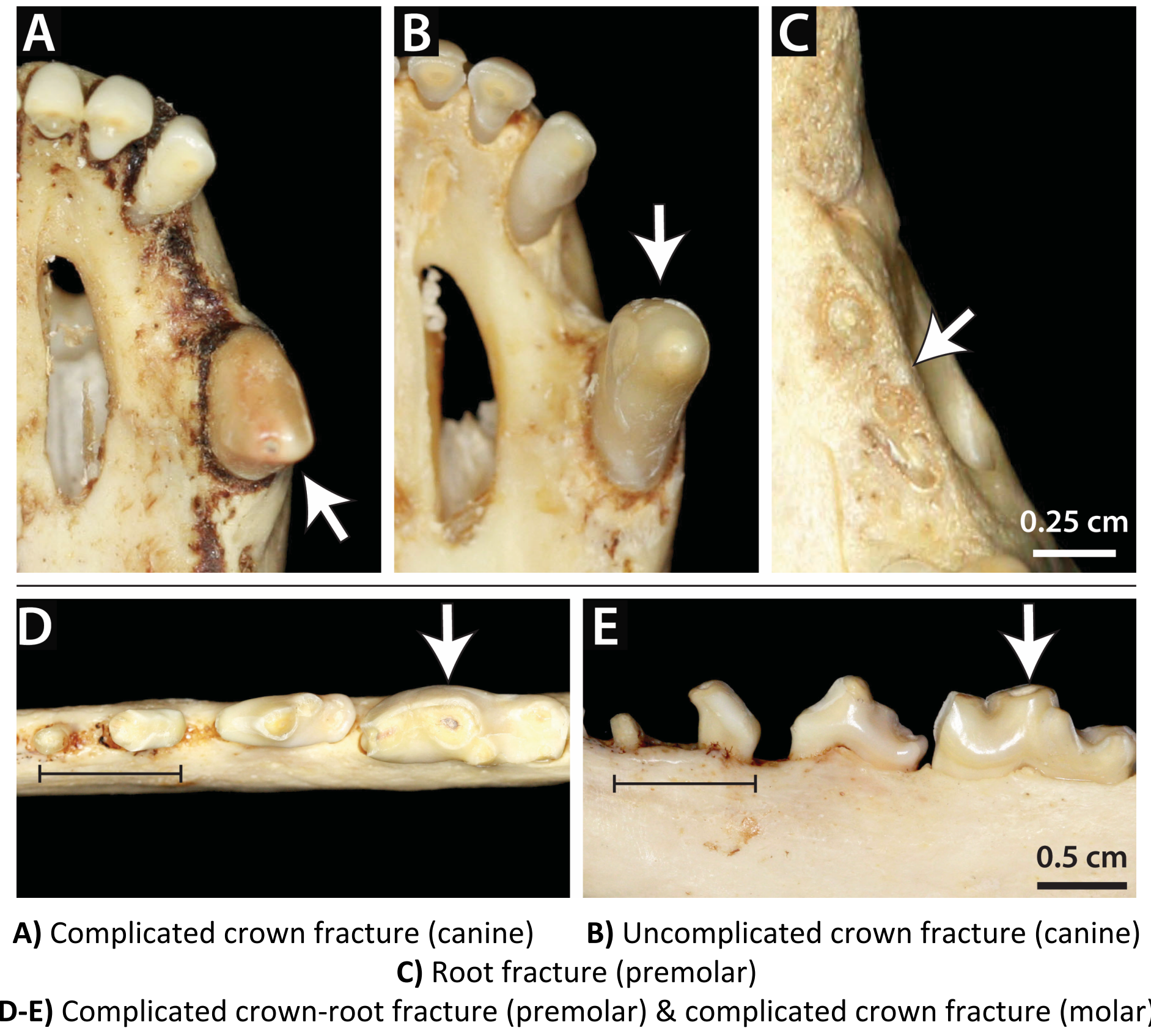
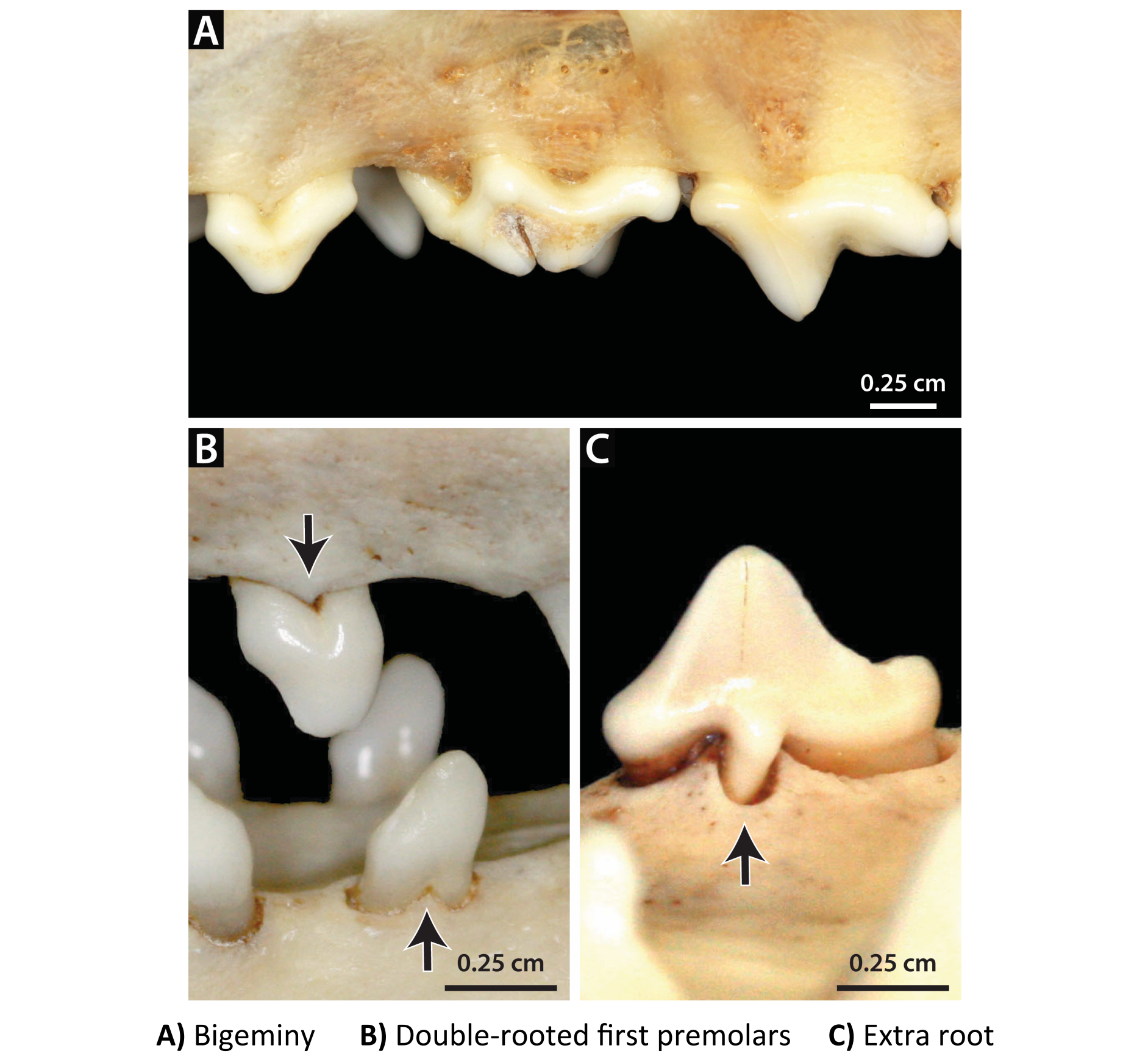
The aim of this study was to evaluate dental pathology in *V. macrotis*, determining what diseases occur in this species and in what frequency. It is hypothesized that *V. macrotis* will share similar dental pathology to that of the grey fox (*Urocyon cinereoargenteus*), another North American fox species, in which acquired legions such as attrition/abrasion, fractures, and periodontitis were commonplace.<sup>5</sup>

## Results

Pathology	Prevalence	Data
Presence	- 78 foxes had all teeth (13.6%) - 21,883 teeth present (93.2%)	<ul style="list-style-type: none"><li>Artefactual loss: 1,145 teeth in 440 skulls</li><li>Acquired loss: 405 teeth in 182 skulls</li><li>Congenital absence: 45 teeth in 34 skulls</li><li>Mandibular third molar teeth most frequently congenitally absent</li><li>Adults had significantly higher prevalence of acquired loss</li></ul>
Supernumerary Teeth	- 7 foxes (1.3%) - 8 teeth (0.04%)	<ul style="list-style-type: none"><li>Most commonly associated with maxillary third premolar teeth</li><li>1 specimen with bilateral supernumerary maxillary fourth premolar teeth</li></ul>
Malformed teeth	- 12 foxes (2.1%) - 13 teeth (0.06%)	<ul style="list-style-type: none"><li>2 exhibited bigeminy</li><li>3 microdonts, 1 macrodont</li><li>1 odontodysplastic tooth</li></ul>
Root Number Variation	- 218 foxes (39%) - 417 teeth (1.9%)	<ul style="list-style-type: none"><li>403 first premolar teeth with pseudo-double roots; more commonly found in <i>V.m.macrotis</i> than <i>V.m.mutica</i></li><li>14 triple-rooted second &amp; third premolar teeth</li></ul>
Enamel Hypoplasia	- 11 foxes (2.0%) - 12 teeth (0.05%)	<ul style="list-style-type: none"><li>≤1mm focal lesions</li><li>1 tooth with multifocal lesions</li></ul>
Fenestration	- 77 foxes (13.8%) - 109 teeth (0.5%)	<ul style="list-style-type: none"><li>Affected the maxillary fourth premolar teeth (n=80) and first molar teeth (n=29)</li><li>Most commonly at the mesiobuccal root</li><li>Males more affected than females</li></ul>
Periodontitis	- 400 foxes (71.6%) - 2,824 teeth (12.9%)	<ul style="list-style-type: none"><li>Stage 2 = 74.2%, Stage 3 = 20.3%, Stage 4 = 5.4% of cases</li><li>Highest prevalence in incisor teeth (27.6% of incisors affected)</li><li>Adult foxes had significantly higher prevalence than young adults</li></ul>
Attrition/ Abrasion	- 506 foxes (90.5%) - 11,379 teeth (52.0%)	<ul style="list-style-type: none"><li>Stage 1 = 17.9%, Stage 2 = 51.5%, Stage 3 = 29.6%, Stage 4 = 1.0% of cases</li><li>Adult foxes had significantly higher prevalence than young adults</li><li>Females more affected than males</li></ul>
Fractures	- 314 foxes (56.2%) - 958 teeth (4.4%)	<ul style="list-style-type: none"><li>41.8% were complicated crown fractures</li><li>Canine teeth had the highest prevalence (22.0% of present canines fractured)</li><li>Adult foxes had significantly higher prevalence than young adults</li></ul>
Periapical Lesions	- 52 foxes (9.3%) - 66 lesions	<ul style="list-style-type: none"><li>Prevalence was significantly higher in adults compared to young adults</li></ul>
TMJ Osteoarthritis	- 33 foxes (5.9%) - 40 joints (3.7%)	<ul style="list-style-type: none"><li>82.5% of cases were mild</li><li>1 fox with severe TMJ-OA had multiple lesions throughout skeleton, consistent with septic arthritis</li><li>7 foxes had bilateral TMJ-OA</li><li>Adult foxes significantly more affected</li></ul>



Representative dentition of a young adult kit fox



## Methods

- Macroscopic examination of 836 specimens from the Museum of Vertebrate Zoology (University of California, Berkeley) was performed; 559 specimens were included in this study
- Partial specimens and juveniles (mixed deciduous and permanent dentition) were excluded from the study
- Systematic evaluation of all teeth and surrounding bone was conducted using predefined criteria:
  - Presence of teeth was logged; missing teeth were categorized as artefactual, acquired loss, or congenital absence
  - Congenital/developmental abnormalities: persistent deciduous teeth, supernumerary teeth, tooth malformation, root number variation, and enamel hypoplasia
  - Acquired lesions: periodontitis, attrition/abrasion, fractures, periapical lesions, temporomandibular joint osteoarthritis (TMJ-OA)
- Prevalence of congenital absences, acquired losses, periodontitis, fractures, and attrition/abrasion among tooth types was analyzed using mixed effects logistic regression
- Prevalence of abnormalities was compared between age (young adult vs. adult), sex (female vs. male), subspecies (*V. m. mutica* vs. *V. m. macrotis*), and decade of collection (1900s-2010s) using logistic regression

## Discussion

- Dental pathology of the kit fox similar to that of the grey fox; acquired legions more prevalent than congenital abnormalities
- Most common lesions: attrition/abrasion (90.5% of foxes), periodontitis (71.6% of foxes), and fractures (56.2% of foxes)
- Fenestrations were common among the maxillary fourth premolar teeth and first molar teeth (13.8% of foxes)
  - 91.7% of these lesions were at the mesiobuccal root, with only 5 lesions at the distobuccal root, and 4 at both the mesiobuccal & distobuccal roots of the same tooth
- Many first premolar teeth had ‘pseudo-double roots’ (20.3% of all present first premolar teeth)
  - V. m. macrotis* were 2.7 times more likely than *V. m. mutica* to have this abnormality (95% CI [1.6, 4.6]); suggests etiology is likely genetic
- 1930s had higher rates of periodontitis and attrition/abrasion; 2000s had higher rates of attrition/abrasion and fenestrations
  - Possible environmental stressors increasing prevalence of acquired diseases during these decades
- Majority of TMJ-OA cases were mild (82.5%), with only 5 moderate cases and 2 severe cases
  - 7 joints with osteochondritis dissecans-type lesions
  - Right and left joints equally affected; only 7 foxes with bilateral TMJ-OA
- Traumatic skull injuries found in 37.7% of specimens
  - Only 12 specimens showed evidence of healing
  - Small body size likely increases threat of predation by red foxes, coyotes, and hawks; urbanization increases risk of vehicular accidents
- Limitations of this study include:
  - Lack of soft tissue to diagnose early signs of disease (i.e. periodontitis stage 1, which is defined as gingivitis only)
  - Specimen preparation introduces artifactual lesions that must be differentiated from true *ante mortem* pathology
  - Small skull size may tend towards under-diagnosis

## Acknowledgements

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References:  
1. Clark, J H O (2011) The history of arid-land fox discoveries in North America. *Archives of Natural History*, **38**, 2, 300-312.  
2. Meaney C A, Reed-Eckert M, Beauvais G P (2006) Kit Fox (*Vulpes macrotis*): A Technical conservation Assessment. [Online]. USDA Forest Service, Rocky Mountain Region.  
3. Cypher, B & List, R (2014) *Vulpes macrotis*. *The IUCN Red List of Threatened Species* 2014: e.T41587A62259374. <http://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T41587A62259374.en>.  
4. U.S. Fish and Wildlife Service (1998) Recovery plan for upland species of the San Joaquin Valley, California. Portland, OR, USA.  
5. Evenhuis J V, Zisman I, Kass P H, Verstraete F J M (2018) Dental Pathology of the Grey Fox (*Urocyon cinereoargenteus*). *Journal of Comparative Pathology*, **158**, 29-50.