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## Introduction

The human bony labyrinth is an inner ear structure located inside the pyramid of the temporal bone. Thanks to the great resistance and the resulting high preservation rate of the pyramid in skeletal remains, even those in fragmentary, poorly preserved or cremated conditions, the bony labyrinth is often uncovered intact. Yet, its accessibility is problematic and restricted mostly to irreversible invasive techniques. The application of non-invasive imaging techniques represents a modern non-destructive way allowing a complex three-dimensional analysis (e.g., Spoor, Zonneveld 1995; Gunz et al. 2012). However, due to the complicated morphology, the morphological variations of the bony labyrinth have not been fully described and many questions are yet to be answered.

## Objectives

The present study aims to propose novel methods for morphometric examination of human bony labyrinth using standardized X-ray images and a PC-aided approach employing three-dimensional virtual models generated from CT scans. It aims to employ the proposed techniques on a set of human temporal bones in order to evaluate side-specific, sex-related and age differences.

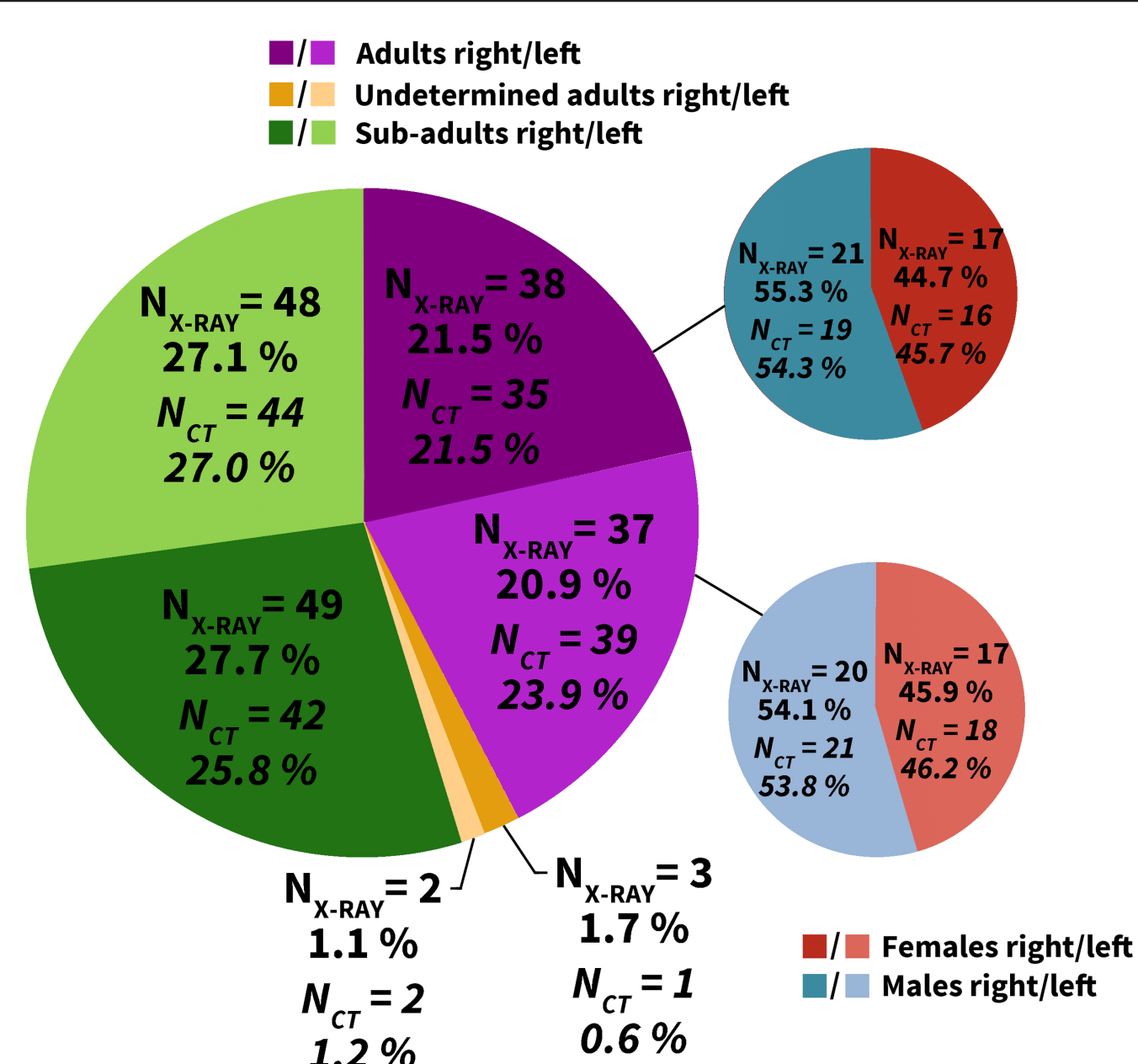
## Key words

human temporal bone  
 inner ear  
 bony labyrinth  
 non-invasive imaging techniques  
 X-ray and CT imaging  
 3D digital model  
 morphometrics  
 computer-aided measurements  
 sexual dimorphism  
 age differences

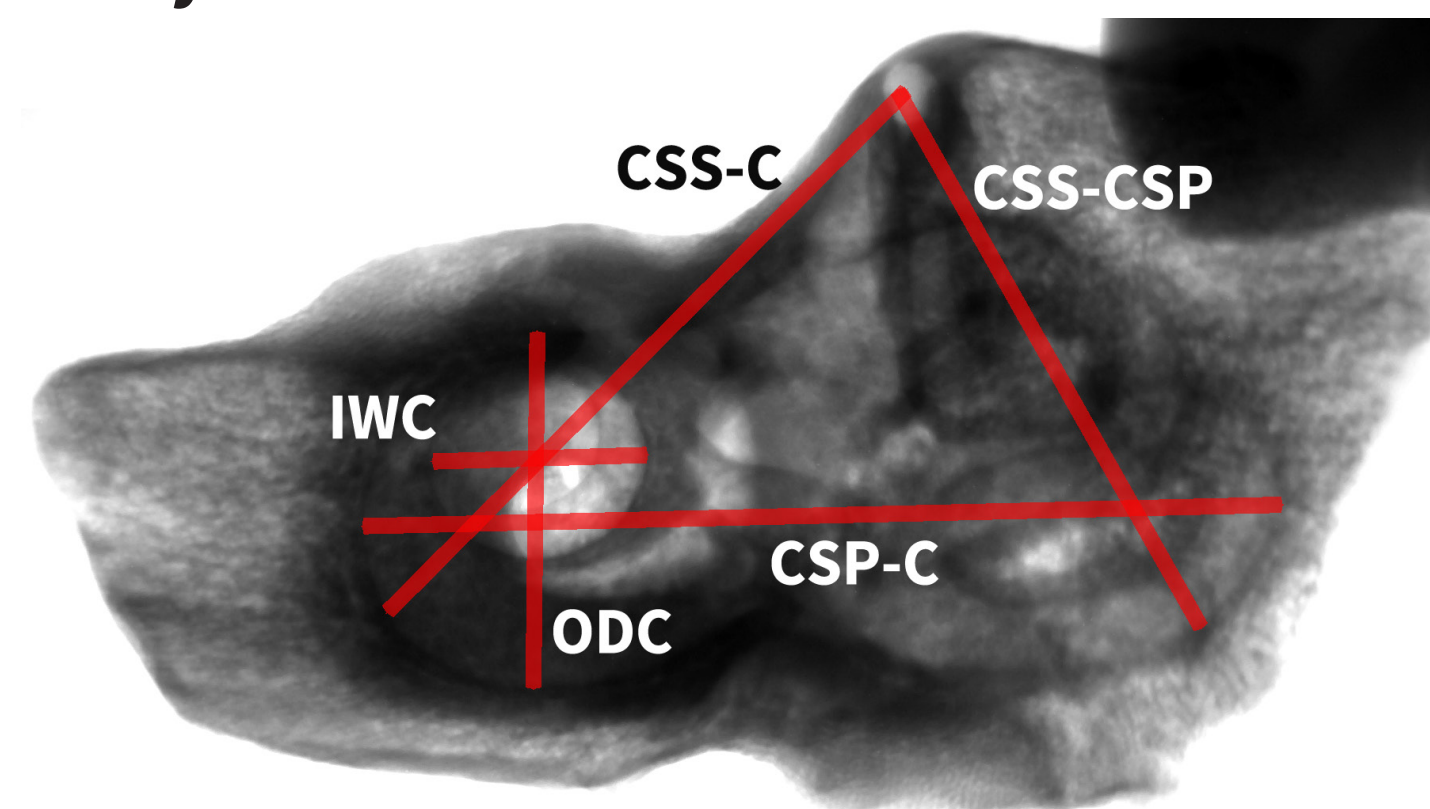
## Material and methods

### Material

The studied sample of pyramids originated from early medieval archaeological site (1000's – 1100's A.D.) Dětkovice – Za zahradama, Czech Republic. The burial site consisted of 134 graves, while the temporal bones of 93 individuals (177 bones, 84 pairs) were used for an X-ray examination and of 92 individuals (163 bones, 71 pairs) for 3D modelling. The studied individuals were classified into age groups from infants to old adults (0 to 60+ years).



### X-ray examination



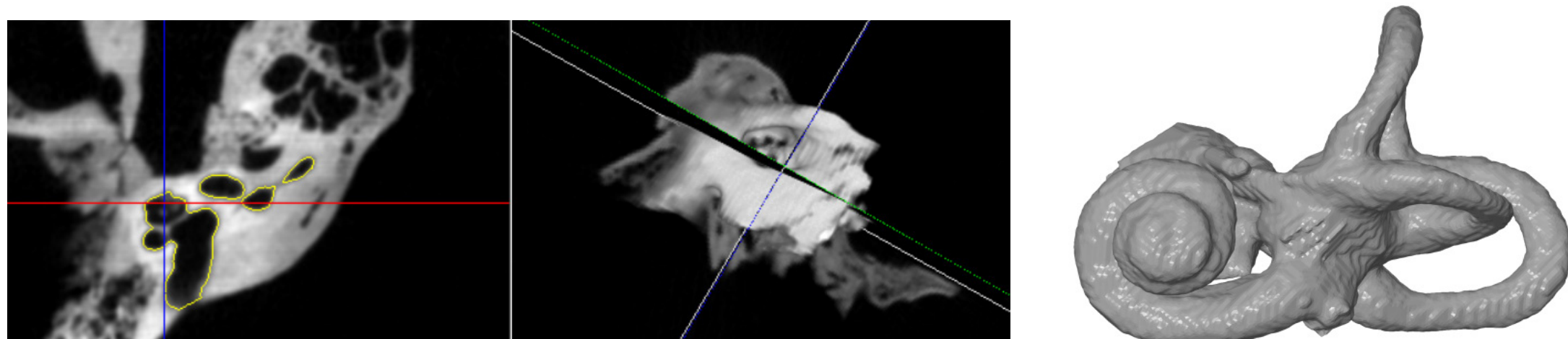
**CSS-C:** distance from the centre of the small oval brightening representing upper flexure of the *canalis semicircularis superior* (CSS) to the farthest (most distant) external circumference of the bony cochlea (C)  
**CSS-CSP:** distance from the centre of the small oval brightening representing upper flexure of the *canalis semicircularis superior* (CSS) to the farthest (most distant) point on the posterior arc of the *canalis semicircularis posterior* (CSP)  
**CSP-C:** the maximum distance between a point on the lateral edge of the *canalis semicircularis posterior* (CSP) and medial point on the circumference of the bony cochlea (C)  
**ODC:** width/diameter of the largest thread of the cochlea measured in the direction perpendicular to the longitudinal axis of the pyramid  
**IWC:** width/diameter of the second thread of the cochlea measured parallel with the longitudinal axis of the pyramid

- Radiography with an X-ray Carestream Xtreme device - standardized position - the posterior side of the pyramid (*facies posterior pyramidis*) in horizontal plane and the *porus acusticus internus* located at the centre of the flat panel detector
- Raw radiographs intensity and contrast adjusted manually - better visualization of the bony labyrinth structures
- Measurements (in mm) - ImageJ program 1.46r - five linear distances of the semicircular canals and cochlea

### CT-aided approach

#### Data processing

- Medical imaging - cone-beam CT unit – iCAT - resolution 0.125 mm
- DICOM data processing - AMIRA 5.3.2 program - MagicWand tool, threshold: 120
- Three-dimensional modelling - AMIRA 5.3.2. program - Display Isosurface function

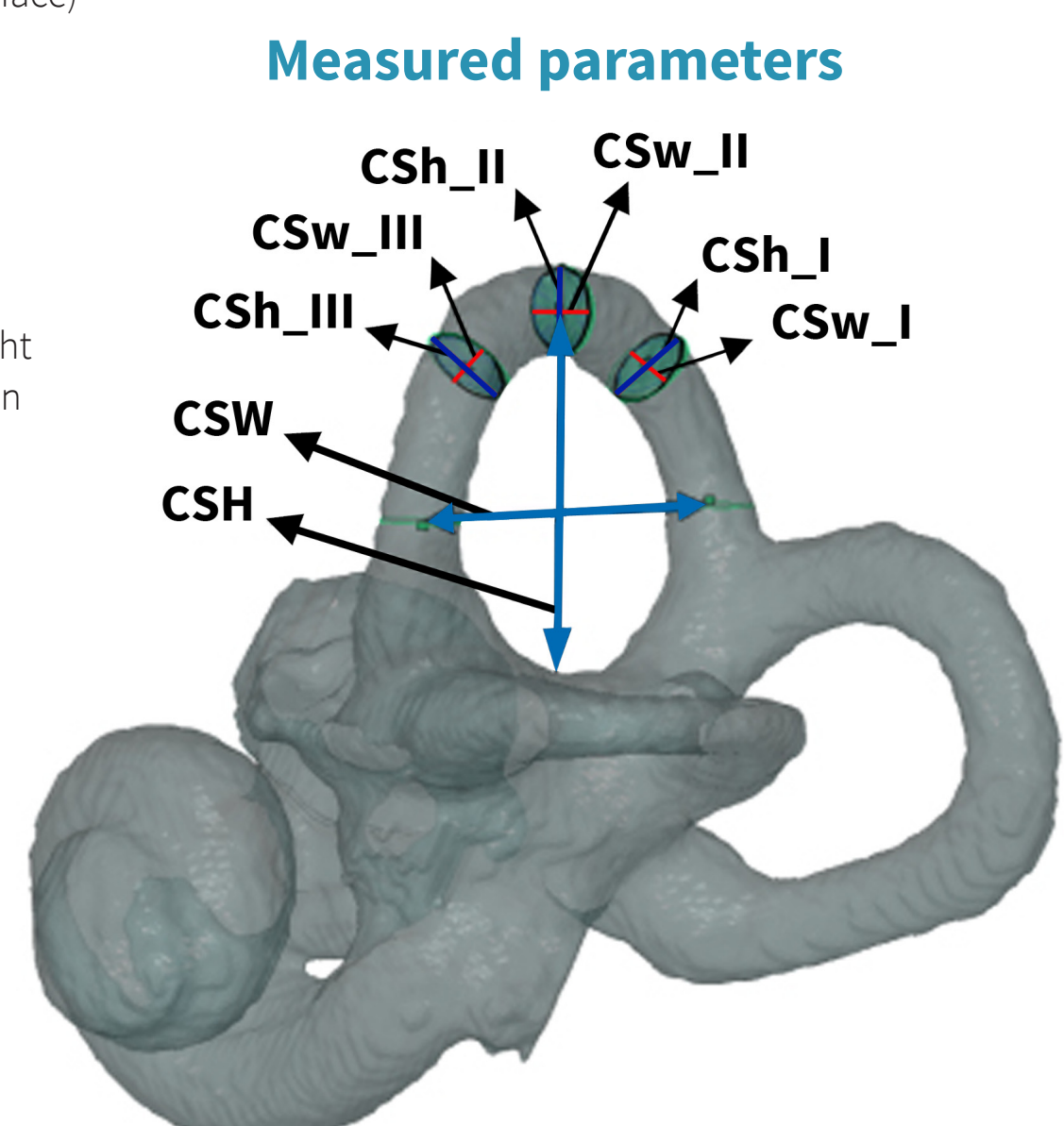


#### Measurements

- conducted in GOM Inspect program (GOM mBH 2013)
- Canal area selection (function Select/Deselect Through Surface)
- „Fitting circle“ construction (function Fitting Circle)
- Cross-sections construction (function Multisection Radial)
- Inscribed circles construction (function Fitting Circle – Maximum inscribed element)
- Circumscribed circles construction (function Fitting Circle – Minimum circumscribed element)
- Construction of a point located in the maximum canal height on the edge of the vestibule (function Construct Intersection (Normal) With Curve, Section)
- Automatic measurement of the dimensions (functions 2-Point Distance, Check Dimensions – Diameter)

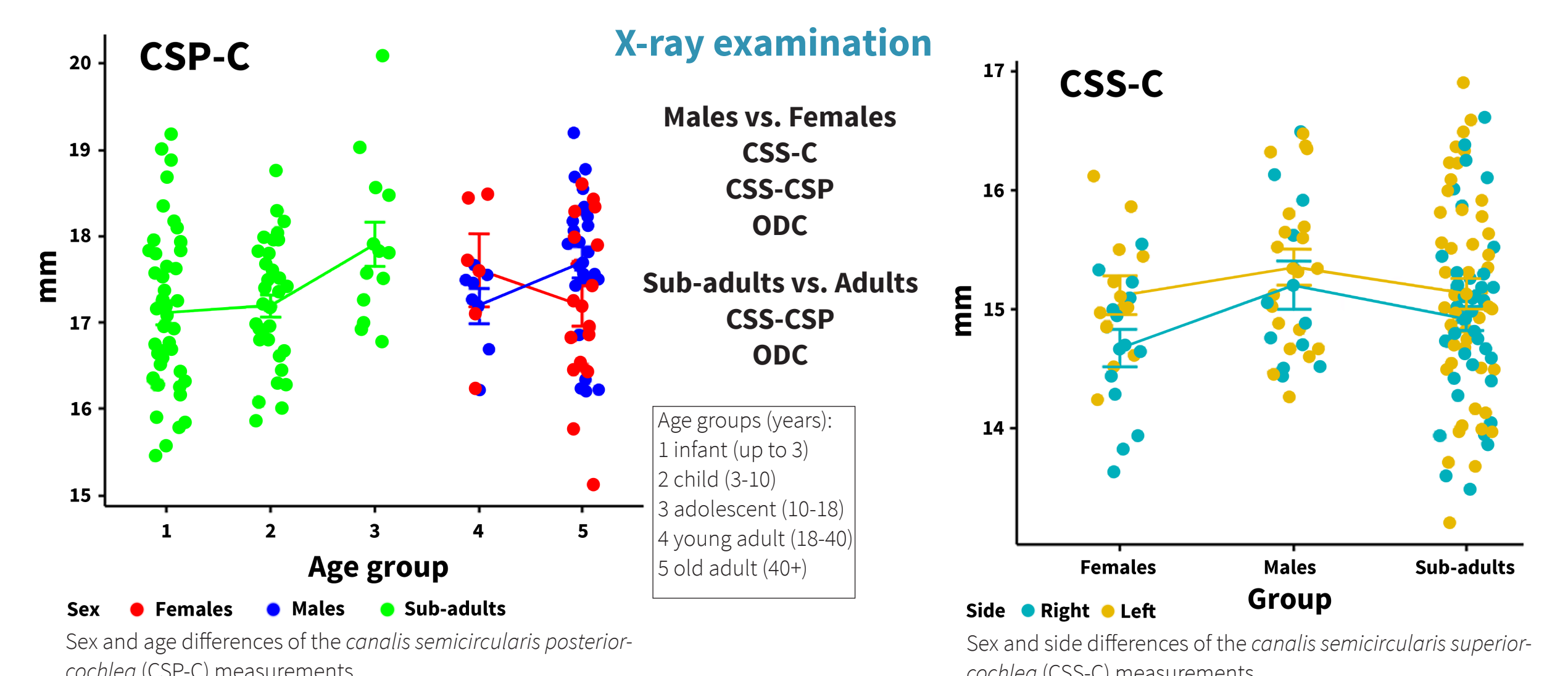
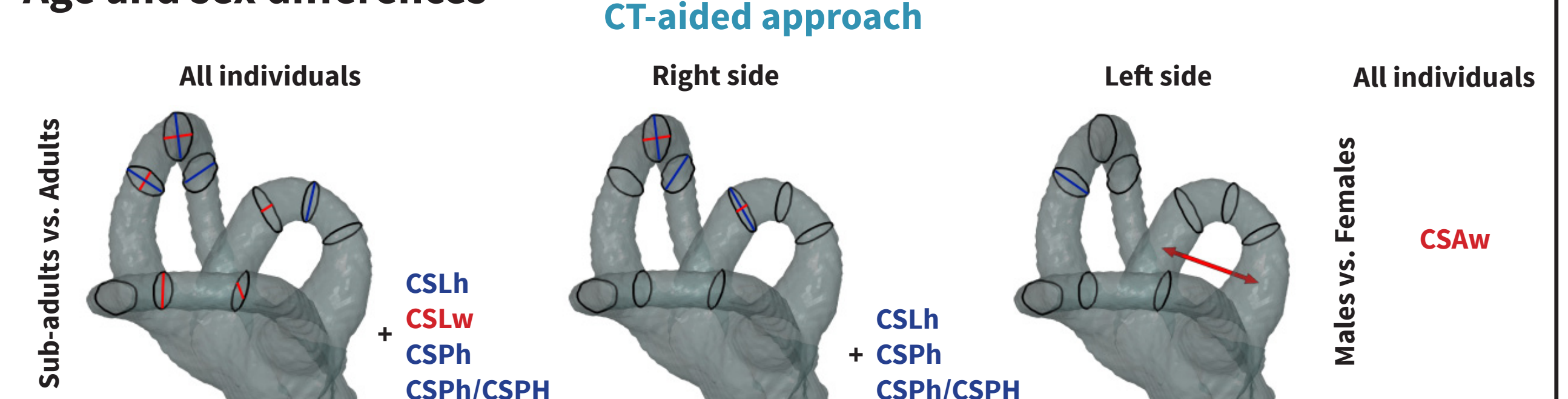
#### Derived parameters

**CSW/CSH:** the ratio of the maximum width and the maximum height of the whole arc  
**CSw:** the mean width of canal lumen (computed as average of widths of canal lumen measured in three positions – CSw\_I-III)  
**CSh:** the mean height of canal lumen (computed as average of heights of canal lumen measured in three positions – CSh\_I-III)  
**CSw/CSh:** the ratio of the mean width and the mean height of the canal lumen  
**Csh/CSH:** the ratio of the mean height of the canal lumen and the height of the whole arc

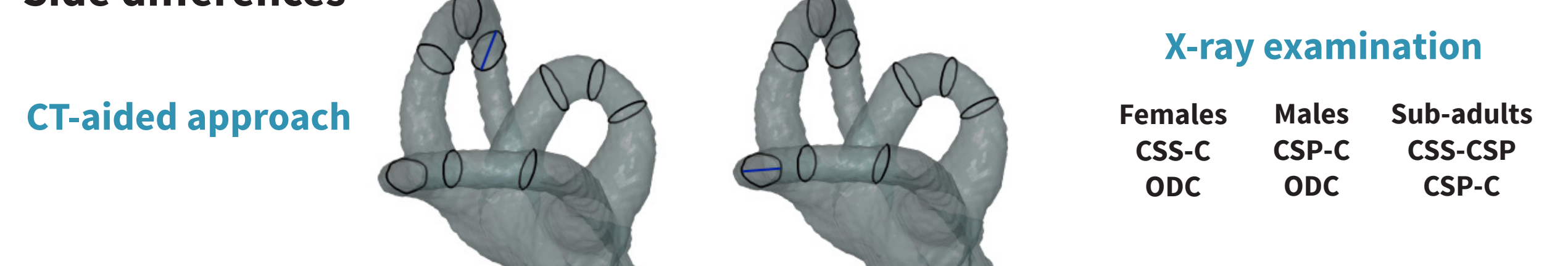


## Results

### Age and sex differences



### Side differences



## Conclusion

Based on the results acquired by X-ray examination it can be concluded that to a certain degree side, sex and also age-related differences were presented. This was, however, contradicted by the results obtained for the CT-aided approach, which showed that the semicircular canals exhibited mostly no sex-related and body-side specific differences. In addition, age-related differences were demonstrated between sub-adults and adults to an extent, particularly in the dimensions characterizing the lumen of the lateral and posterior canal. Despite the ambiguity of the acquired results, both employed methods proved their potentials for the morphometric examination of small osseous components with difficult accessibility.

### References

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