

# Dry bone and virtual modality interchangeability for the estimation of sex on the human pelvis and skull

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# Introduction: Identified osteological collections



Green: contemporary  
(born after 1920)

Purple: non-  
contemporary (born  
before 1920)

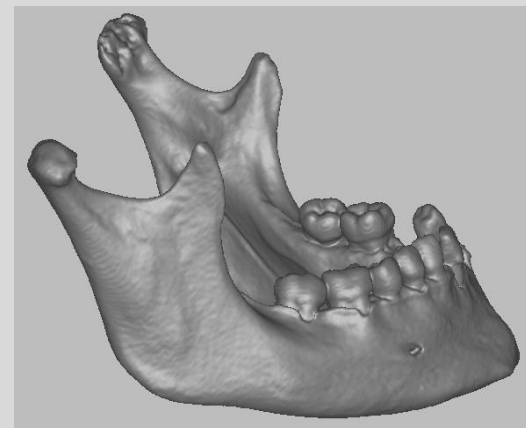
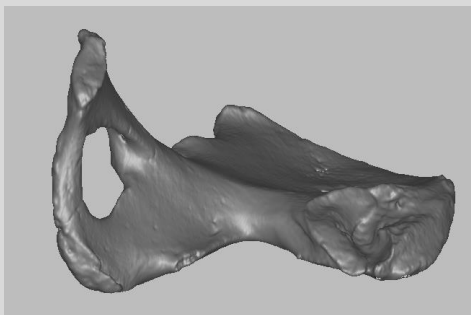
Orange: uncertain  
temporal status

Source: forensicanthropology.eu

# Introduction: Virtual osteological collections

- The New Mexico Decedent Image Database (NMDID, 1972) with 15'000+ individuals, Albuquerque (Edgar & Berry, 2019)
- Subadult Virtual Anthropology Database (SVAD, 2015) with ~5000 individuals, Reno (Stull & Corron, 2022)
- Bakeng se Afrika (BsA, 2019) based, among others, on the Pretoria Bone Collection (PBC) with ~1000 individuals, Pretoria (L'Abbé et al., 2021)

# Introduction: Visual-tactile vs visual-only sensation



Sources: Büren Chilchmatt 5293 (pelvis), Twann St. Petersinsel 3375 (mandible), photos: S. Braun

# Introduction: Published research

## Research on...

- ...virtual modalities without direct comparison with dry bones (Decker, Davy-Jow, Ford, & Hilbelink, 2011; Dereli et al., 2018; Grabherr et al., 2009; Ramsthaler, Kettner, Gehl, & Verhoff, 2010; Fahrni et al., 2017)
- ...modality comparison with sample sizes <100 (Abegg et al., 2021; Abegg, Hoxha et al. 2023; Chapman et al., 2014; Corron, Marchal, Condemi, Chaumoître, & Adalian, 2016; Colman et al., 2019)
- ...interchangeability with narrow anatomical focus (Braun, Ridel, L'Abbé, Theye, & Oettlé, 2022)

# Rationale and research question

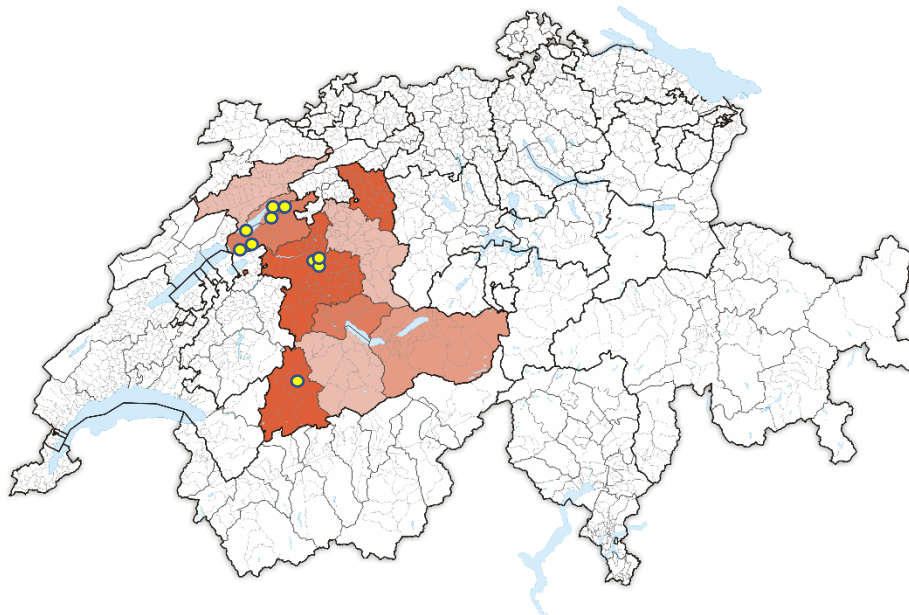
Summarizing rationale:

- Despite increased use of virtual modalities, no comprehensive study on interchangeability of analogous and virtual pelvis and skulls

Aim:

- Consistency of pelvic and cranial sex estimation traits on dry bone, CT and 3D surface scans

# Materials: 200 pelves and 223 skulls from archaeological sites in Switzerland

**Sites:**

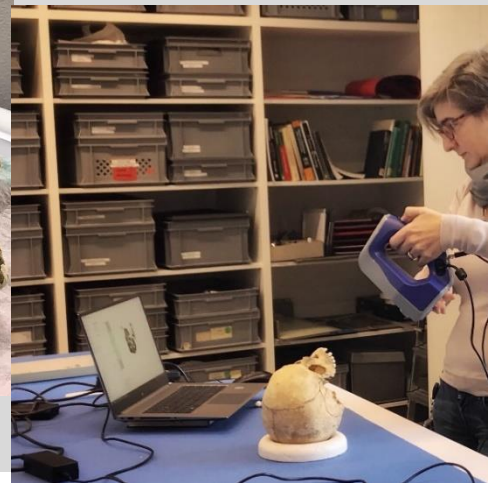
Bern franz. Kirche  
Bern Grosse Schanze  
Biel-Mett Kirche  
Büren aA Chilchmatt  
Ins Kirchgemeindehaus  
Kallnach Bergweg 95  
Köniz Kirche  
Nidau  
Twann St. Petersinsel  
Zweisimmen

# Materials: Dry bone (gold standard) / CT (n=200/223); 3D surface scans (n=39/50)

Dry bone (**B**), CT (**C**)



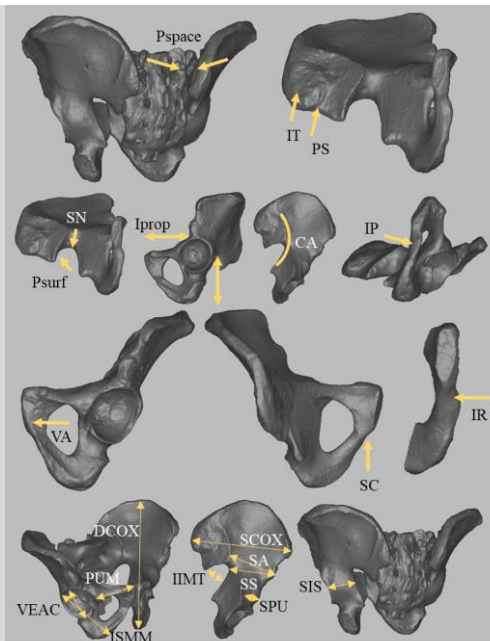
Artec 3D surface scans (**A**)



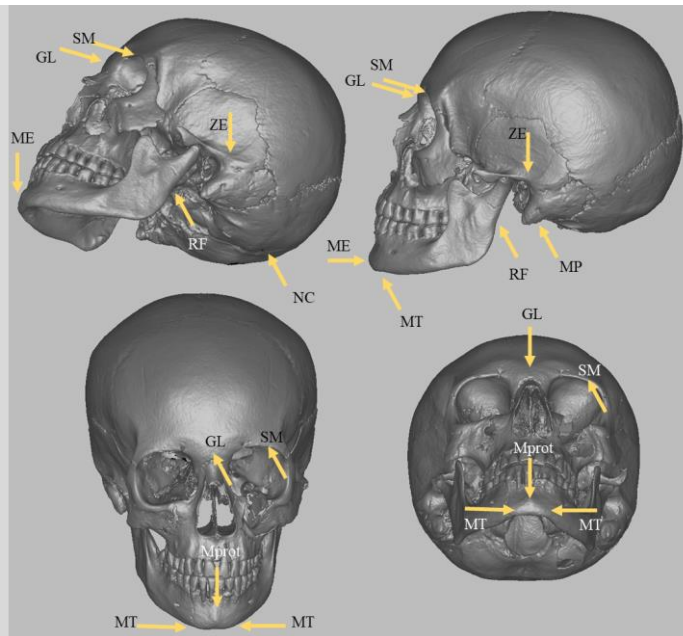
Photos: S Braun, J Ryan



# Methods: Sex estimation protocols



**Pelvic:**  
İşcan & Derrick 1984  
Bruzek 2002  
Klaes et al. 2012  
Bruzek et al. 2017

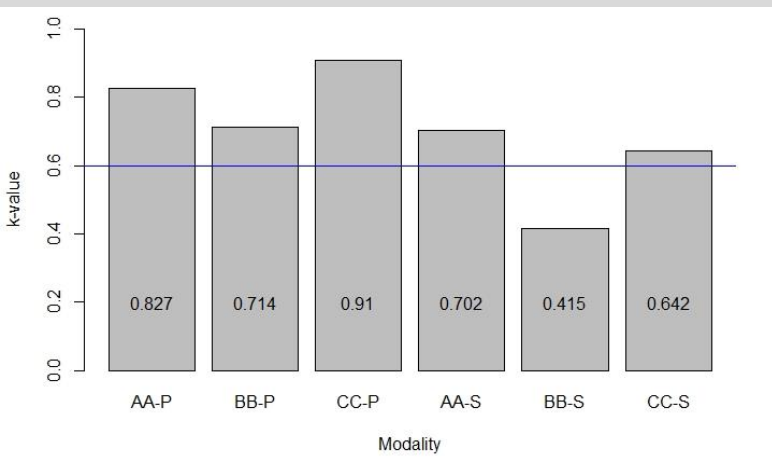


**Cranial:**  
Loth & Henneberg 1996  
Walker 2008  
Langley et al. 2018

# Methods: Statistical analyses

- Cohen's (weighted) kappa (Cohen, 1968)
  - $\kappa \geq 0.6$  acceptable agreement
- Relative technical error of measurement (metric) (Bruzek et al., 2017)
  - $rTEM \leq 5\%$  acceptable error
- R version 4.1.4 in RStudio

# Results: Intraobserver agreement



Legend:

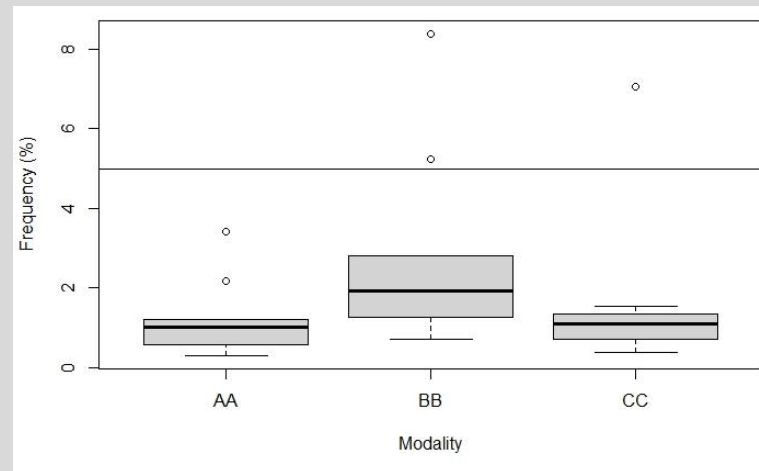
**A** = 3D surface scans

**B** = dry bone

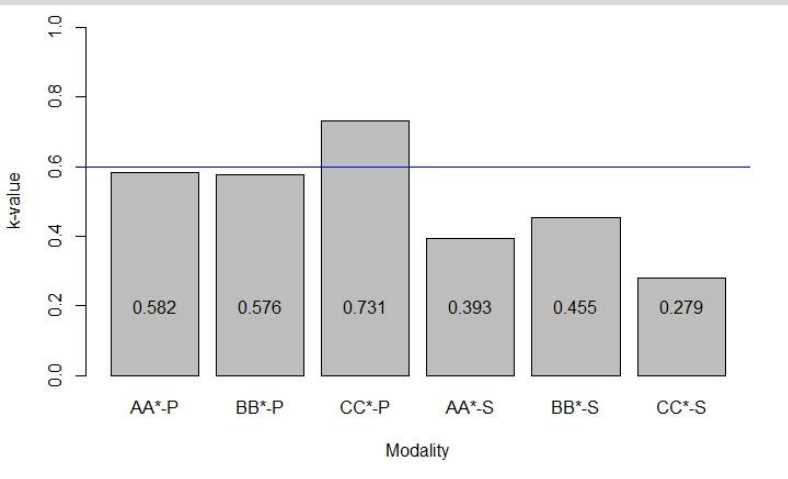
**C** = CT scans

**P** = pelvis

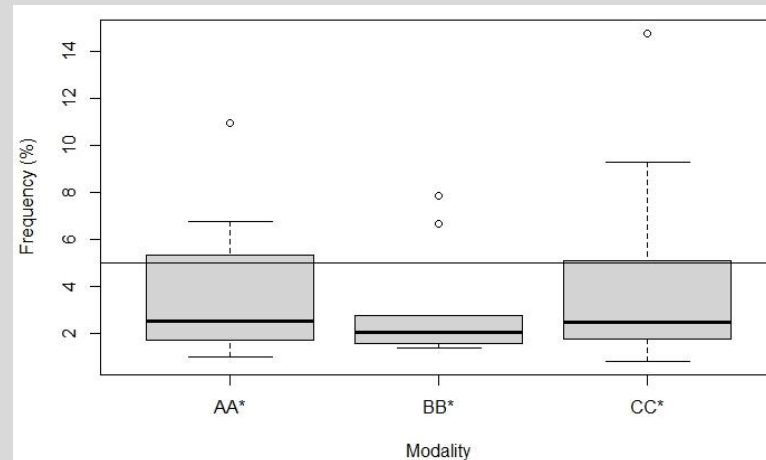
**S** = skull



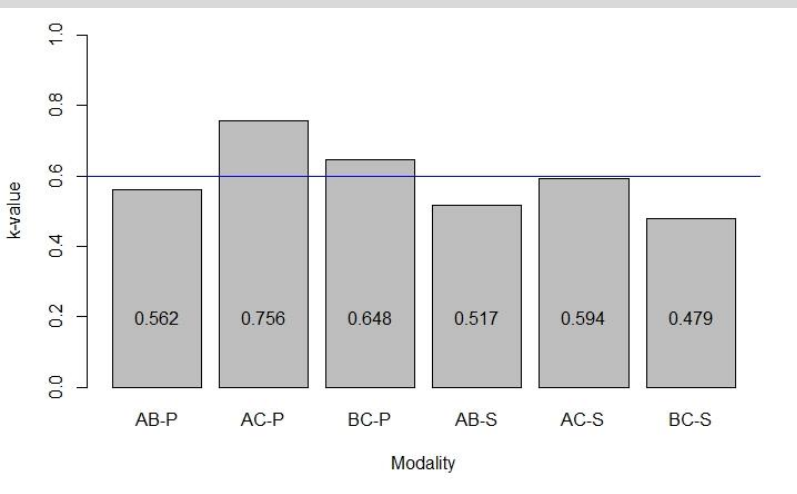
# Results: Interobserver agreement



Legend:  
**A** = 3D surface scans  
**B** = dry bone  
**C** = CT scans  
P = pelvis  
S = skull



# Results: Intermodality agreement



Legend:

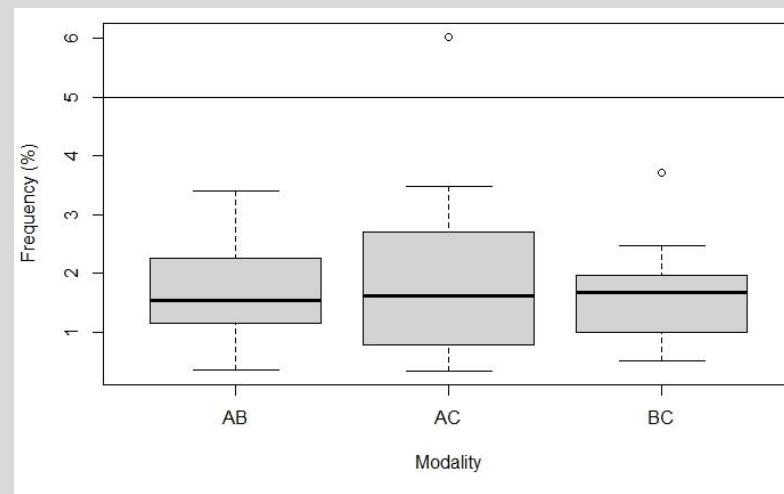
**A** = 3D surface scans

**B** = dry bone

**C** = CT scans

P = pelvis

S = skull

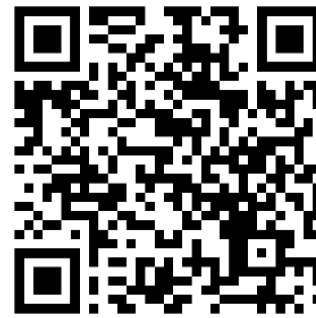


# Discussion & Conclusion

- Metric data more consistent than nonmetric data
- Pelvic sex estimation traits more consistent than cranial traits
- Modalities (**A**, **B**, **C**) are interchangeable for most of the analyzed sex estimation traits
- CT (**C**) and surface scans (**A**) yield better results than the combination with dry bone (**B**)

# Limitations

- CT and 3D surface scans only
- Pelvis and skull only
- Observers with previous imaging experience only
- Selection of sex estimation methods








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ORIGINAL ARTICLE

# What we see is what we touch? Sex estimation on the pelvis in virtual anthropology

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**Thank you for your attention!  
Any questions?**

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