

The hyoid bone at birth consists of three parts that gradually fuse into a horseshoe shaped bone.

Questions:

1. What is the developmental pattern of hyoid bone fusion?
2. Are there age and sex differences in hyoid bone density?

BACKGROUND: The hyoid bone:

- Is a small U-shaped bone located in the neck that anchors the tongue and larynx.
- Consists of three parts that fuse after a protracted period.
- Is the only free-floating bone in the body.

Knowledge on the development of the hyoid bone is important for:

- Speech
- Swallowing
- Forensic Studies

Hyoid Fusion: The exact time of fusion is debated. Previous studies cite fusion occurring:

- In "middle life" and "later decades" (Harjeet et al. 2010).
- Between 40 and 60 years of age, sometimes as young as 30 to 40 years (Gupta et al. 2008).

Bone Density: Although many studies have examined the developmental trend of bone density, to our knowledge there are no studies that have focused on the density of the hyoid bone.

- Studies on the hip and heel bones found:
 - o Bone density decreases with age (Furrer et al. 2014).
- Studies on osteoporosis in the hip bones and lumbar spine found:
 - o Men have higher bone density than women, with the exception of the lumbar spine in women under 40 years of age. (Lee et al. 2013).

METHODS:

Modeling: Three-dimensional (3D) models were created from 106 anonymized head and neck Computed Tomography (CT) scans taken at UW Hospital and Clinics. Models of the hyoid bone were made using image visualization and analysis software Analyze 11.0® (AnalyzeDirect®, Overland Park, KS). This software "stacks" 2D CT scans onto each other, forming a 3D image. Subsequent thresholding (see Figure 2) allows for the removal of tissue based on intensity (which correlates with bone density). Tissues of higher density (e.g., bone, cartilage) appear brighter than tissues of lower density (e.g., skin, muscle, air).

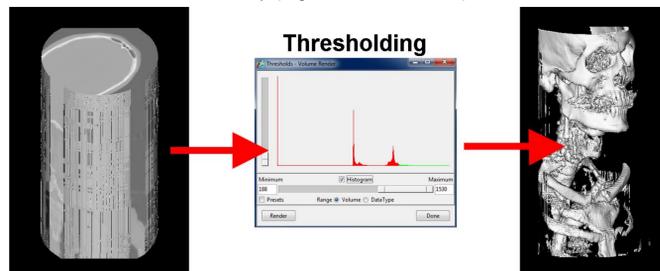


Figure 2. Thresholding process used in Analyze 11.0® software.

3D hyoid models were created using the Volume Edit tool in Analyze 11.0®. Figure 3 shows axial, sagittal, and coronal views, which are used to ensure accuracy while modeling.

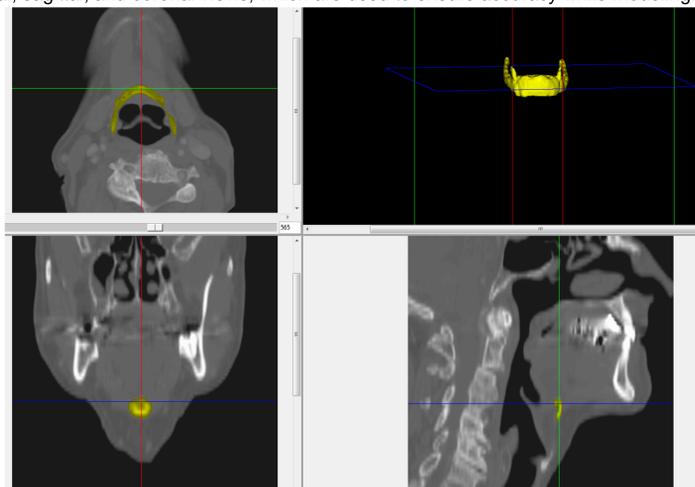


Figure 3. Axial (top left), Coronal (bottom left), and Sagittal (bottom right) views in Analyze 11.0®

For this study, 106 models were created and placed into four cohorts defined as:

- Pediatric: Ages 0-20 years (n=46, 23 males, 23 females)
- Young Adults: Ages 20-30 years (n=20, 10 males, 10 females)
- Middle Adults: Ages 45-55 years (n=20, 10 males, 10 females)
- Older Adults: Ages 70-100 years (n=20, 10 males, 10 females)

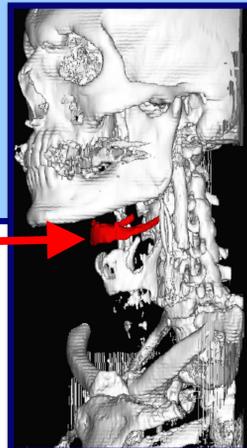


Figure 1. Hyoid bone location (shown in red).

FUSION:

Fusion Classification: Using methods adapted from (Harjeet et al. 2010), CT scans were visually inspected and both left and right sides were given a numeric ranking of fusion (1-3). (See Figure 4) For the purposes of this study, any hyoid bone with fusion on only one side (unilateral fusion) was given a ranking of "2".

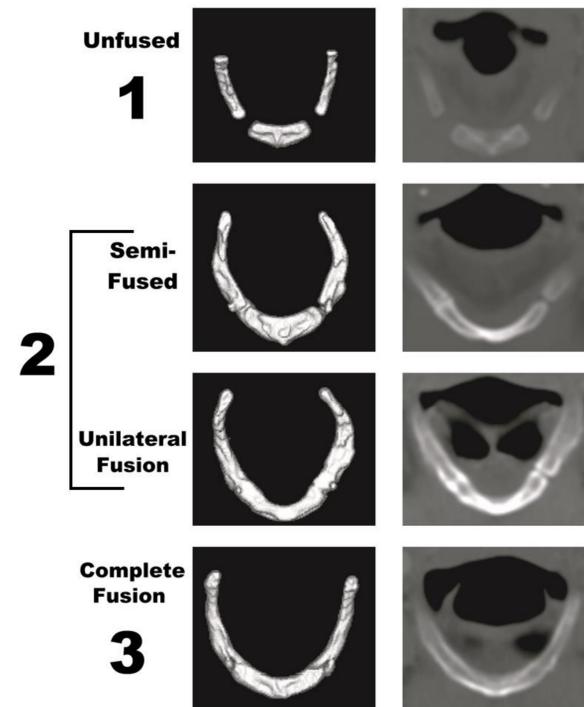


Figure 4. Fusion classifications.

BONE DENSITY:

Using the Region of Interest tool in Analyze 11.0®, the mean intensity of the overall 3D model was recorded (See Figure 5). Bone density cannot be directly measured but it can be inferred from the CT scan intensity statistics.

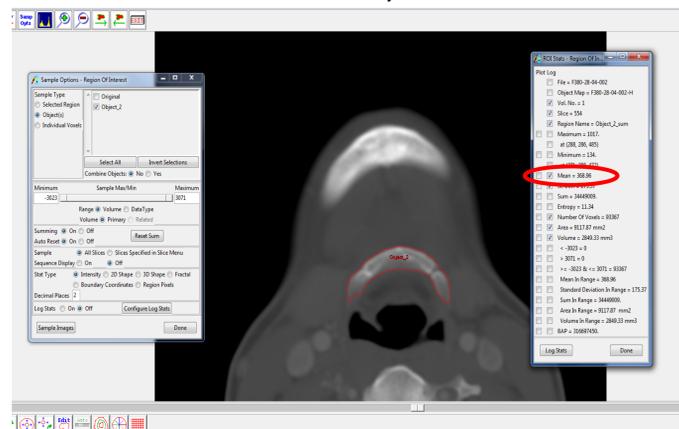


Figure 5. Mean density measurement (circled in red) in Analyze 11.0® software.

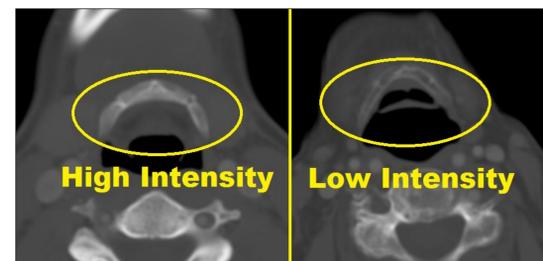


Figure 6. 28 year-old female (High Intensity) and 85 year-old female (Low Intensity)

References:

1. Furrer, R., van Schoor, N., de Haan, A., Lips, P., de Jongh, R. (2014). *Calcif. Tissue. Int.*, 1-9.
2. Gupta, A., Kohli, A., Kumar Aggarwal, N., Banerjee, K.K. (2008). *Legal Medicine*, 10, 253-256.
3. Harjeet, K., Singh, S., Kaur, G., Aggarwal, A., Wahe, P. (2010) *Legal Medicine*, 12, 223-227.
4. Lee, J., Lee, S., Jang, S., Hyun Ryu, O. (2013). *Endocrinol. Metab.*, 28, 180-191.

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RESULTS:

FUSION: Figure 7 shows:

- No hyoid bone fusion before age 20.
- Complete fusion may be present in individuals as young as 22 years old but may not always be achieved even by older adults.
- Unfused and Semi-Fused hyoids are seen in all age groups over 20 years old, with the oldest unfused hyoid found at 89 years of age.

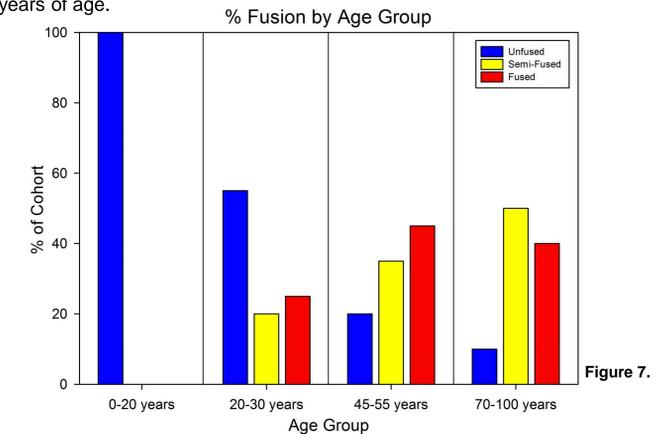


Figure 7.

BONE DENSITY: Figure 8 shows:

- Bone density of the hyoid decreased with age after 20 years.
- Men had higher hyoid bone density than women after age 20.
- The young adult cohort (20-30 years old) displayed the highest average bone density.
- Lowest average bone density measures are found in the 0-20 year cohort for men and the 70-100 year cohort for women.

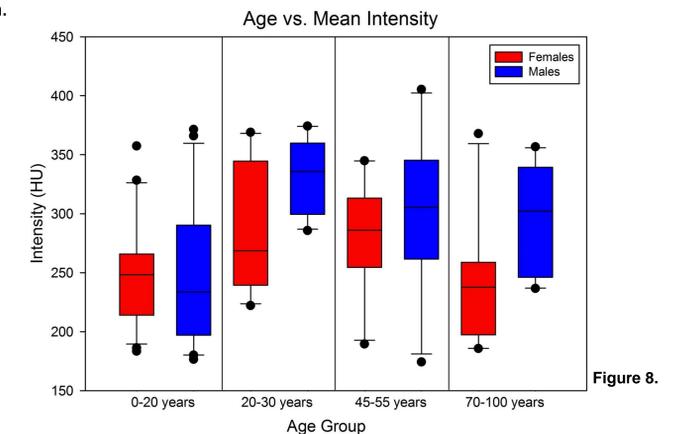


Figure 8.

DISCUSSION/CONCLUSION: The development of the hyoid bone varies greatly. These findings provide a baseline for understanding typical development with possible implications for atypical patients in Speech Pathology, Anatomy, and Forensics.

The results of this study show:

- Age and sex may factor into the developmental patterns of the hyoid bone.
- Fusion results support the research of Harjeet et al. (2010) and Gupta et al. (2008) in regards to timing of fusion; however a few novel items were found. Such as cases of complete fusion in the 20-30 year cohort, and unfused hyoids in all age groups.
- Bone density results support the research of Furrer et al. (2014) and Lee et al. (2013) with both age and sex affecting the density of the hyoid bone. After age 20, the hyoid bone becomes less dense with age, with males having higher bone density than females.

Future studies will explore:

- Sex differences in terms of the timing of fusion.
- The relationship between fusion and bone density.
- The differences in unilateral and bilateral fusion.
- And improve upon the methodology of this study by:
 - o Including a larger number of CT scans.
 - o Quantitatively measuring the distance of pre-fusion spacing.
 - o Improving measurements of bone density including calculating density at specific points on the hyoid bone, and looking at maximum and minimum density measurements.

Answers:

1. Despite great variations in hyoid bone growth, hyoid bone fusion can begin as early as 22 years of age and is typically completed by age 50.
2. Findings also show that during the third decade of life (20-30 years), hyoid bone density begins to decrease as age increases in both sexes with males having higher bone density than females.