ABSTRACT: Comparison of preliminary data from magnetic resonance images (MRI) of 4 children with Down syndrome (DS) ages (mos;year) 0:10, 1:5, 3:2 and 8:10 and their age and percentile growth matched controls indicate that both groups have similar tongue length and area. However, children with DS have a smaller anterior oral cavity that does not accommodate a normal-sized tongue.

PURPOSE: Given the prevalence of speech sound errors (impaired or deviant articulation) in children with Down Syndrome (DS), the purpose of this study is to begin exploring the anatomic similarities and differences of the supralaryngeal speech apparatus in typically developing children and children with DS using Magnetic Resonance Imaging (MRI).

BACKGROUND: Some of the major physical features/characteristics of the head and neck for individuals with DS -- based mostly on observations -- that are considered to be of diagnostic significance include 1, 3, 5, 7, 11, 22:

• Head: Flattening the back of the head
• Flat facial profile, slanting eyelids, depressed nasal bridge, smaller mouth and ears
• Tongue: Macroglossia (60% relative macroglossia)
• Palate: High and narrow palatal arc
• Dentition: Malocclusion (mandibular overjet, posterior cross bite)
• Feeding: DS infants are prone to have feeding problems 15, and individuals with DS typically experience oral and pharyngeal dysphagia
• Airway: Obstruction (acute and chronic); small airway, large tonsils/adenoid causing sleep apnea.
• Muscle tone: Decreased muscle tone, hypotonia and ligamentous laxity.

METHODS & PROCEDURES: Subjects: Four children with Down Syndrome ages (mos;year) 0:10, 1:5, 3:2 and 8:10, and four age and percentile growth matched typically developing controls. Percentile growth was determined from growth charts specific for Trisomy 2119 using weight rather than height (See figure 1 and 2). All subjects received magnetic resonance imaging (MRI) at the University Hospital for medical reasons that were judged not affect growth and development.

RESULTS: Preliminary data/measurements are presented on grouped bar graphs. The standard deviation of measurement error for soft tissue structures was smaller (MSP-cm) = .20; n=79). Each figure -- bar graph -- is followed by a statement highlighting findings and where applicable followed by a statement comparing findings to reports by other researchers.

Figure 1. Growth curves for ages 0-36 months; dotted line represents DS growth curves, and dashed line typical growth curves for females (top) and males (bottom).

Figure 2. Growth curves for ages 2-20 years; dotted line represent DS growth curves, and dashed line typical growth curves for females (top) and males (bottom).

Procedures: Magnetic resonance images from children with Down Syndrome and their controls were measured using procedures we established in 1999 30. Using the specified anatomic landmarks (Figure 3), the following set of measurements were made in the head and neck region from midsagittal, parasagittal and axial slices.

- Head length: (MSP-cm; g-op): The maximum distance from the glabella (g) to the opisthocranion (op).
- Head height: (MSP-cm; n-v): The distance from the nasion (n) to the vertex (v).
- Upper Facial Height (MSP-cm; n-st): The distance from the nasion (n) to the stenion (st). Lower Facial Height (MSP-cm; st-o): The distance from the stenion (st) to the gonion (g).
- Facial Convexity (MSP-degrees): g-prn-pg or g-sn-pg: Triangular measure at the nose tip when the glabella (g) - pronasale (prn) - pogonion (pg) connect. ANB Angle (MSP-degrees; subnasale - subspinale): Assesses maxillary growth or the maxillary to mandibular anteroposterior facial parameters.
- Tongue Length (MSP-cm): The curvilinear distance along the dorsal superior contour of the tongue from tongue tip to valleculae.
- Hard Palate Length (MSP-cm): The curvilinear distance along the hard palate contour from the anterior point of the incisors or tooth bud to the beginning of the soft palate.

Figure 3. Anatomic landmarks. Defined in text. Midsagittal MRI slice of a male $^2$ (2,0)

Figure 4. MRI of S DS-F58 at age 10 mos

Figure 5. MRI of S F21 at age 9 mos

Figure 6 shows that head length (g-op) of the youngest DS subject DS-F58 is very similar to her control F21, however, head length differences are present at all other ages.

Farkas et al. 9,10,11 report DS head circumference (a measure that correlates highly with head length) to be only 28.6% within normal measurement (within 1 to 2 SD from normally developing subjects). This percentage, however, is based on group data from 127 DS patients ages 7 months to 36 years.

Farkas et al. 9,10,11 report DS head height to be a measure that is 85% within normal measurements (within 1 SD of typically developing Ss). This is based on group data from 127 DS patients ages 7 months to 36 years.
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orations, though contrary to descriptive physical characteristics of DS subjects, are supported by
some researchers but not others. Redman et al. 13 and Shapiro et al. 26, 27 state that this nonmetrical
expression of “narrow” and “high” palate is due to shelf-like palatal alveolar processes. Panchon-Ruiz et al. 28, however, report that the DS palate is not a reduced scale model of the typically developing palate. They report palatal morphology in DS to fit an elliptic paraboloid.

Uong et al. 29, who used MRI, report the mandible (mental spine-clivus distance in sagittal plane) to be
smaller in DS subjects. This measure captures our mandibular length and depth measures. They report
maxillary growth to be reduced in comparison to mandibular growth. Also, they report the measures of
maxillary arc (tragion-subnasale-tragion), and upper facial depth (tragion-nasion) to classify 99% DS
recognition. Their findings are based on group data from 199 subjects with DS ages 6 months to 61 years.

**CONCLUSIONS & DISCUSSION:**
- In general, our preliminary findings support other researchers’ findings. Imaging technology is adequate to study typical and atypical development of the supralaryngeal speech apparatus.
- To summarize, findings indicate:

  - **Head and face:** DS children have a shorter head length, longer head height, shorter upper face height and a flatter facial profile (larger facial convexity measures).
  - **Vocal tract structures:** DS children and their controls have similar tongue length and area, soft palate length, and maxillary length and width. DS children, however, have a shorter hard palate length, shorter mandibular length and depth, shorter oro-nasopharyngeal length, and shorter vocal tract length than their controls.
  - These findings, as supported by other researchers, indicate that the many of the physical features/characteristics of the head and neck that are used for diagnostic purposes are based on observations that are not supported by qualitative or metrical research findings. For example, findings do NOT support the clinical impression of:
    - General macroGLOSSIA, but rather relative macroGLOSSIA i.e. tongue appears bigger because the anterior oral cavity is smaller. Also, since the airway is smaller in DS subjects, the tongue may be positioned forward to open up the airway. 12, 29
    - Narrower palate -Findings indicate maxillary width to appear to be narrower because of its shape. Thus, there is a need to examine the palate in 3D.
    - Airway obstruction due to enlarged tonsils – instead, findings indicate a smaller airway (due to skeletal abnormalities i.e. smaller midface and lower face skeleton) with smaller adenoid and tonsil volumes. 12, 29
- Studies on palatal plate therapy (after Castillo-Morales device) along with speech physiology report long term effects on oral motor function (including inactive open mouth, inactive tongue protrusion) as well as speech improvements. 8, 6, 20, 22, 25. Prospective studies examining the anatomic and physiologic changes that accompany such improvements in speech are indicated.
- Are improvements due to improved muscle tone of the tongue? Or are there changes in oral anatomy due to the intra-oral forces applied by palatal plate therapy and oral-motor exercises?
- The methodology used to examine anatomic differences between DS subjects and their controls should take into account age. Farkas et al. (2002) report that in early childhood (ages 1-5) patients with DS generally displayed more normal than abnormal craniofacial proportions. This corresponds to reports that there are substantial similarities, rather than differences, between the vocalizations of infants with DS and typically developing children. 1, 13, 24. Thus, anatomic, physiologic and acoustic studies that examine the age at which more differences than similarities between DS subjects and their controls emerge are indicated.

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SELECT REFERENCES: Addendum to poster

MRI Comparison of Children's Vocal Tract Anatomy: Normal vs Down Syndrome - Preliminary data.
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