AAOF Legacy Collection

Scaled Measurements from the AAOF Legacy Collection Images

Scaled Measurements

Introduction

In order to properly measure anatomic landmark locations or distances between landmarks on the AAOF Legacy Collection lateral cephalograms, the scale of the images must be known. This document describes several methods for deriving image scales, and explains some of the differences amongst the various Collections. Note that currently it is possible to measure only the lateral cephalograms from the AAOF Legacy Collection Website.

Lateral Cephalogram Sources

Source	Image Scale	Scaling Methods
Downloaded directly from the Website by right clicking on a image and saving it to a local computer	Varies across collections and within collections - images are resized to 400 horizontal pixels for Previews, and 800 horizontal pixels for larger images	Must use fiducials or embedded scale where available
Requesting “full size” images from the Website, to be supplied later after review	Images are generally 300 or 600 dpi. Always check a sample image in Photoshop to make sure.	Can use fiducials, embedded scales where available, or rely on the image resolution - see notes below

Fiducials are reference marks embedded in the digital images, usually one at each corner, although some images may have more. In this document, we will use only 4 fiducials called A, B, C, and D. They are normally labeled starting at the lower left corner of the image, and proceed in a clockwise direction. Because the fiducials are part of the image, and have known coordinate values, they can be used to compute the scale of the digital image, even if it has been expanded or reduced after scanning.

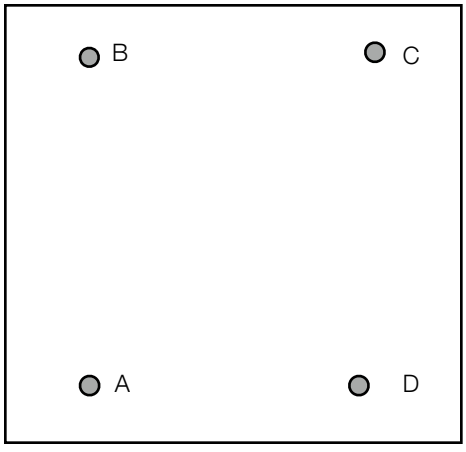


Figure 1 Default Fiducial Locations

Locating the Fiducials on an Image

The fiducials can sometimes be difficult to see on the digital images. They were placed on the original films by punching a small round hole in the emulsion. Therefore, they tend to be visible as small white circles in dark areas of the image. In light areas of the image, they may be visible as small light circles with slightly raised edges.

Some hints for locating the fiducials if they are difficult to see:

- View the image at 100% magnification and look in the general area of the 4 corners
- Each collection has a set of Subjects with anatomic landmarks and fiducials already digitized and recorded. You can locate these Subjects by choosing a collection on the website under Browse Images, then choose the Condensed Collection Inventory tab at the top of the page. Click on the Overlays column of the table until all of the Subjects with "Yes" are at the top, then choose one of them by clicking on the Subject Name in the Subject column. The Lateral Ceph will be displayed - click on the Overlay and Label buttons at the bottom of the image, and the landmarks and their labels will be displayed. By toggling the Overlays off and on, you can get a good idea of where the fiducials are located for this Collection.

Using the Fiducial Data

There are several ways that the fiducial data can be used to compute the scale factor for an individual image. First, though, it's important to understand why the fiducial data are needed:

- In the case of images downloaded directly from the website by right clicking on them and then saving to a local computer, each image can be a different scale. All images were resized to 800 horizontal pixels to fit on the web page, so depending on the original size of the image, they can all be different scales. Therefore, there is no way to make an accurate measurement on the website images without computing a scale.
- For the full size images requested on the website and later delivered via FTP, the task is a little easier. These images were scanned at known resolutions, and are usually delivered at a known resolution - 300 or 600 dpi. Therefore, it seems as if you can simply measure pixel distances in Photoshop or some other application, and convert to inches or millimeters using the fixed conversion factor. However, this does not take into account the possibility that the scanner had calibration or scale errors during scanning, and the digital image might be out of scale in one or both axes. Using the fiducial data will correct the digital image for any scanning scale errors.
- A further subtlety results if there is a ruled scale visible in the original image itself. If that ruler was placed at the mid-sagittal plane during exposure, it can be used to scale the image measurements by measuring its size in the digital image. However, that scale will not agree exactly with the scale computed from the fiducials. That's because the fiducial scale is the scale of the scanned film, not the mid-sagittal scale. All features on the skull are projected onto the film during exposure, Because of the long distance from the emitter relative to the skull and the film plane, the enlargement is small, but it is there. Objects closer to the emitter are enlarged more than objects closer to the film. The embedded scale provides an accurate scale for the mid-sagittal plane, whereas the fiducials provide a scale for the image as a whole.

With that said, here are several methods for utilizing the fiducials to compute an image scale:

1. The simplest method is to measure the distance between 2 fiducial marks in the digital image, and compare it to the distance between the same 2 fiducials, computed using the X and Y coordinates given later in this document. Dividing the 2 values will give a scale that can be applied to all measurements.
2. A more accurate method is to compute an average scale using the distances measured between 4 pairs of fiducials, comparing them to the 4 distances computed from the fiducial coordinates, and averaging the 4 scales to a single value.
3. The most accurate method is to use a least squares transformation between the digital image values and the known fiducial values, which results in independent X and Y axis scales plus any non-orthogonality between the scales. This method is probably overkill for most applications.

Fiducial Data for Each Collection

Iowa Growth

Fiducial Pattern: Standard pattern as shown in diagram on Page 1
Full Size Image Scale: 300 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	5.6	11.9	A-B 221.8
B	4.9	233.7	B-C 275.3
C	280.2	234.5	C-D 221.5
D	280.0	13.0	D-A 274.4

Mathews Growth

Fiducial Pattern: Standard pattern as shown in diagram on Page 1
Full Size Image Scale: 300 dpi
Special Note: Subject 001 Image 10 has incorrect fiducial identification on the website digital image
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	-0.4	-152.6	A-B 152.6
B	0.0	0.0	B-C 178.2
C	178.2	0.0	C-D 159.4
D	177.7	-159.4	D-A 178.2

Forsyth Twin

For the original Subjects (03-11 to 40-12) with pinpoint fiducials on the full size .tif images:
Fiducial Pattern: Standard pattern as shown in diagram on Page 1
Full Size Image Scale: 600 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	0.1	-152.6	A-B 152.6
B	0.0	0.0	B-C 177.0
C	177.0	0.0	C-D 159.8
D	176.7	-159.8	D-A 176.7

For the remaining 90 subjects added in 2018, the fiducials are inconsistent on the full size images. They were scanned at 300dpi, which can be used to establish the correct scale when measuring. These images are stored as .jpg and .pdf formats.

Fels Longitudinal

Fiducial Pattern: Standard pattern as shown in diagram on Page 1. Some images have 5 fiducials per side - in this case use the outer 4 corner fiducials
Full Size Image Scale: 300 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	0.1	-152.6	A-B 152.6
B	0.0	0.0	B-C 177.0
C	177.0	0.0	C-D 159.8
D	176.7	-159.8	D-A 176.7

Denver Growth

Fiducial Pattern: Standard pattern as shown in diagram on Page 1
Full Size Image Scale: 300 dpi
Special Note: Fiducials are not always visible on the full size images. The embedded scale measures true distances at 300 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	50.6	15.9	A-B 152.5
B	52.2	168.4	B-C 177.6
C	229.8	166.8	C-D 159.5
D	228.4	7.3	D-A 178.0

Michigan Growth

Fiducial Pattern: Standard pattern as shown in diagram on Page 1. Some images have 5 fiducials per side - in this case use the outer 4 corner fiducials.
Full Size Image Scale: 300 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	38.9	23.1	A-B 152.7
B	38.4	175.8	B-C 177.2
C	215.6	176.1	C-D 159.8
D	215.4	16.3	D-A 176.6

Oregon Growth

There are 9 earlier Subjects in the Oregon Growth Study that use the following fiducial values. They can be distinguished by the use of so-called Optical Fiducials, that consist of a small circle with a cross in the middle. The Subjects that use this set of fiducials are 015, 058, 133, 134, 183, 240, 242, 277, and 295.

Fiducial Pattern: Standard pattern as shown in diagram on Page 1
Full Size Image Scale: 300 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	-2.8	-132.8	A-B 132.8
B	0.0	0.0	B-C 266.0
C	266.0	0.0	C-D 139.9
D	262.9	-139.9	D-A 265.8

The remaining Oregon Growth Subjects use the following fiducials.

Fiducial Pattern: Standard pattern as shown in diagram on Page 1
Full Size Image Scale: 300 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	0.1	-152.6	A-B 152.6
B	0.0	0.0	B-C 177.0
C	177.0	0.0	C-D 159.8
D	176.7	-159.8	D-A 176.7

Burlington Growth

Fiducial Pattern: Standard pattern as shown in diagram on Page 1

Full Size Images Scale Prior to August 2013: 223 dpi (Early images were provided at this reduced scale)

Full Size Images Scale After August 2013: 300 dpi

Note: Prior versions of this document (before V1.2) had incorrect fiducial values for Burlington

Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	11.9	4.3	A-B 275.3
B	11.1	279.6	B-C 222.6
C	233.7	279.9	C-D 275.4
D	234.9	4.5	D-A 223.0

Bolton-Brush Growth

The Bolton-Brush fiducial pattern is complicated by the fact that the template is reversed on some of the images. For most purposes, scaled measurements can be determined accurately from the 300dpi image scale. If the fiducials are required for scaling, you will need to make a test measurement on each image to determine the fiducial orientation

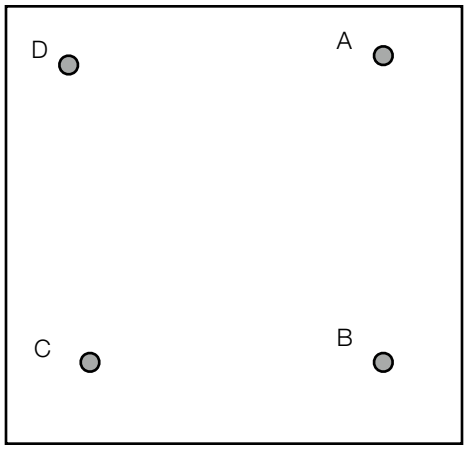


Figure 2 - Bolton-Brush Fiducials in Reversed Orientation

In general, if the distance from the Top Right to Bottom Right fiducials is approximately 159-160 mm, the the fiducials are in the standard orientation as as shown in Figure 1 on Page 1. If the distance from the Top Right to Bottom Right fiducials is approximately 152-153 mm, then the fiducials are in the reversed orientation as shown in the diagram above.

Fiducial Pattern: Standard pattern as shown in Figure 1 on Page 1, also reversed orientation as shown below
Full Size Image Scale: 300 dpi
Fiducial Coordinates in Millimeters:

Fiducial	X Coordinate (mm)	Y Coordinate (mm)	Distance (mm)
A	0.3	-152.5	A-B 152.3
B	0.0	0.0	B-C 177.1
C	177.1	0.0	C-D 159.6
D	176.9	-159.6	D-A 176.7

Magnification Factors

The use of the above fiducial information ensures that the digital images are correctly scaled to the films from which they were scanned. However, depending on the distance from the mid-sagittal plane to the film holder during the actual image exposure, the magnification factor of the images, and distances measured on them, can vary.

The industry standard for the x-ray emitter to the mid-sagittal plane was 60 inches, but the mid-sagittal plane to film distance varies from Collection to Collection, and sometimes within a Collection. Note that measured distances on the film are increased by the magnification factor, but angles and ratios of distances are not.

The current information that we have for average percentage magnification factors is as follows:

Michigan Growth: 12.9%

Oregon Growth: 7.8%

UOP Mathews: 8.0%

Forsyth: 6.0%

Iowa Growth:
6% for films before March 16, 1956
9% for films after March 16, 1956 and before September 19, 1957
13% for films after September 19, 1956 and before 1970
12.25% for films in 1970 and later

Denver Growth: 4%

Bolton Brush Growth: 8%, and in some cases the distance is written on the image as “ML”

Burlington Growth : See below

Fels Longitudinal: See below

Thanks to Richard Sherwood for the detailed information on magnification factors.

Sherwood, R.J. H.S. Oh, M. Valiathan, K.P. McNulty, D.L. Duren, R.P. Knigge, A.M. Hardin, C.L. Holzhauser, K.M. Middleton. 2021. Bayesian Approach to Longitudinal Craniofacial Growth: The Craniofacial Growth Consortium Study. *Anat. Rec.* **304**: 991-1019. PMID:33015973. PMCID: PMC8577187 https://doi.org/10.1002/ar.24520.

Burlington Growth

Requirements and limitation of Roentgenographic cephalometry

A) Magnification

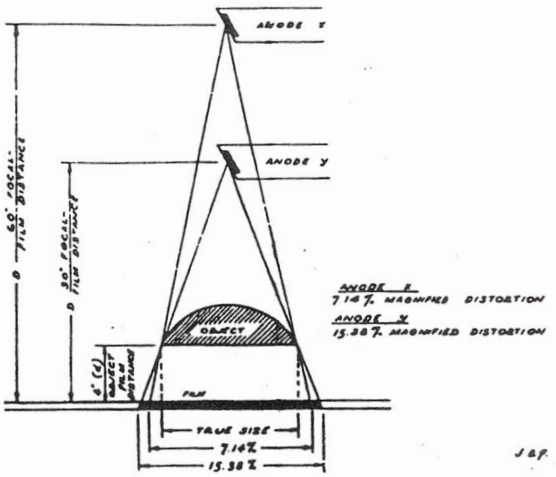
D = focal film distance

d = object film distance

Percentage of magnification =

$$\frac{D}{D-d} - 1 \times 100$$

The greater the focal-film distance, the smaller the magnification (limited by office size); the smaller the object-film distance, the smaller the magnification (limited by cranial size).



—Magnification distortion with short and long focal film distances.

Krogman and Sassouni

Burlington Records -

e.g. anode to subject distance = 60 in. or 152.4 cm.
subject to film distance = 6 in. or 15.0 cm.
therefore, anode to film distance = 66 in. or 167.4 cm.

$$\frac{D}{D-d} - 1 \times 100 = \frac{66}{66-6} - 1 \times 100 = \frac{66}{60} - 1 \times 100 = \frac{6}{60} \times 100 = 10\%$$

or

$$\frac{D}{D-d} - 1 \times 100 = \frac{167.4}{167.4-15.0} - 1 \times 100 = \frac{167.4}{152.4} - 1 \times 100 = \frac{15.0}{152.4} \times 100 = 9.84\%$$

Fels Longitudinal : Note that the Fels magnification factors are presented as 100% minus the percentage magnification.

Fels Longitudinal Study (Enlargement factor based on age of child and visit date.		
Age (yrs.)	**1930-1940**	**1941-1947**
0.1	93.2%	96.0%
0.2-0.4	92.3%	95.1%
0.5-0.7	91.9%	94.7%
0.8	91.7%	94.5%
0.9-1.5	91.6%	94.4%
1.6-3.0	91.4%	94.2%
3.1-5.0	91.1%	93.9%
5.1-7.0	90.9%	93.7%
7.1-9.0	90.7%	93.5%
9.1-11.0	90.5%	93.3%
11.1-13.0	90.3%	93.1%
13.1-15.0	90.1%	92.9%
15.1-17.0	89.9%	92.7%
17.1-19	89.7%	92.5%
19.1	89.6%	92.3%
Dates from January 1-March 31, 1941, have been recorded as 1940. Dates from January 1-August 15, 1948, have been recorded as 1947. Dates from January 1-May 31, 1953, have been recorded as 1952.		