9-1-2013

Comparison between Ceph Analysis on Lateral Cephs, CBCT Scans, and MRI Scans

Jeffrey W. Lam
Loma Linda University

LOMA LINDA UNIVERSITY
School of Dentistry
in conjunction with the
Faculty of Graduate Studies

A Comparison between Ceph Analysis on Lateral Cephs, CBCT Scans, and MRI Scans

by

Jeffrey W. Lam

A thesis submitted in partial satisfaction of
the requirements for the degree
Master of Science in Orthodontics and Dentofacial Orthopedics

---

September 2013

Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

_____, Chairperson

V. Leroy Leggitt, Professor of Orthodontics and Dentofacial Orthopedics

_____

James Farrage, Associate Professor of Orthodontics and Dentofacial Orthopedics

_____

Roland Neufeld, Associate Professor of Orthodontics and Dentofacial Orthopedics

_____

Gregory Olson, Assistant Professor of Orthodontics and Dentofacial Orthopedics

ACKNOWLEDGEMENTS

I would like to acknowledge the members of my committee for offering their direction and experience in the design and execution of this research. Dr. Leggitt was especially helpful in offering advice contributing to the construction and details of the data collection process.

I would especially like to thank Dr. Leggitt and Dr. Olson, who generously contributed their time to tracing the cephalograms and scans. Your effort is much appreciated. I would also like to thank Dr. Udo Oyoyo for his expertise in the area of statistical analysis.

Finally, I would like to thank my wife Lyndsay and my two children, Ethan and Ella. Your encouragement and support were invaluable.

CONTENTS

TABLES

Tables Page

FIGURES

Figures Page

ABBREVIATIONS

CBCT	Cone Beam Computed Tomography
MRI	Magnetic Resonance Imaging
MR	Magnetic Resonance
TMJ	Temporomandibular Joint
DNA	Deoxyribonucleic Acid
LC	Lateral Cephalogram

See Tables 5 and 6 for abbreviations of cephalometric landmarks

ABSTRACT OF THE THESIS

A Comparison between Ceph Analysis on Lateral Cephs,
CBCT Scans, and MRI Scans

by

Jeffrey W Lam

Master of Science, Graduate Program in Orthodontics and Dentofacial Orthopedics
Loma Linda University, September 2013
Dr. V. Leroy Leggitt, Chairperson

Introduction: Most current methods of obtaining images for orthodontic diagnosis and treatment planning involve the use of ionizing radiation. Given that patients often need records taken several times during treatment, an alternative should be found that does not involve ionizing radiation. Magnetic resonance imaging (MRI) exists as a possible alternative.

Purpose: The purpose of this study is to compare cephalometric measurements obtained from lateral cephs, cone beam computed tomography (CBCT) scans, and MR scans.

Methods: Lateral cephs, CBCTs, and MRIs were taken on 22 patients. 3 separate readers traced the images and the data was analyzed using Bland-Altman plots.

Results: The Bland-Altman plots indicated that the correlation between the imaging methods varied depending on the measurement. The agreement varied from very good to statistically significant bias. However, the bias was judged to have been within normal limits for cephalometric tracing error.

Conclusion: Under the conditions of this study, there were statistically significant differences in some of the cephalometric measurements. However, the differences were

not clinically significant. This suggests that cephalometric data obtained from MRIs can be used for the purposes of orthodontic diagnosis and treatment planning.

CHAPTER ONE

INTRODUCTION

Statement of the Problem

Lateral cephalometric analysis is an integral part of orthodontic diagnosis and treatment planning. Currently, the most common methods of obtaining images for cephalometric analysis involve the use of ionizing radiation, such as the traditional lateral cephalogram and cone beam computed tomography scans. Ionizing radiation has been shown to have potentially harmful effects, even in low doses.[1] The need arises for a method of obtaining images that does not involve the use of ionizing radiation.

One such method would be the use of magnetic resonance imaging scans, which do not employ any ionizing radiation. However, statistically and clinically significant differences may exist when performing cephalometric analysis on MR scans as opposed to lateral cephs or CBCT scans.

This study was designed to evaluate if any differences exist in the cephalometric values obtained when tracing either lateral cephs, CBCT scans, or MR scans.

Hypothesis

The null hypothesis was that there will be no difference in the cephalometric values obtained when tracing lateral cephs and CBCT scans, lateral cephs and MR scans, or CBCT and MR scans. The alternative hypothesis was that there will be a significant

difference between either lateral cephs and CBCT scans, lateral cephs and MR scans, or CBCT and MR scans.

CHAPTER TWO

REVIEW OF THE LITERATURE

History of Lateral Cephalometric Analysis

A large part of the process of orthodontic diagnosis and treatment planning has been based on the lateral cephalometric radiograph. Through the process of identification of cephalometric landmarks and planes, an understanding of a patient's skeletal relationships is gathered, especially anterior-posteriorly. Growth predictions can be made and the changes that have occurred due to treatment can be evaluated.

Traditionally, the lateral cephalogram is obtained by the standard method of taking a profile radiograph of a patient from a set distance away using ionizing radiation. However, in more recent times it has now also become possible to obtain lateral cephs by using displays of multi-planar CBCT volumes.[2] Recent studies have shown that there is no statistically significant nor clinically relevant difference when tracing images from conventional lateral cephs or images obtained from CBCT volumes.[3,4] In fact, the identification of skeletal landmarks may be even more precise when obtained from CBCT derived images.[5]

The Effects of Ionizing Radiation

However, the issue remains that these methods of obtaining diagnostic images involve the use of ionizing radiation. The effects of ionizing radiation on tissue have been

well documented. Studies have linked ionizing radiation exposure to DNA damage,[6] chronic cell dysfunction,[7] teratogenic effects,[8] and cancer[1] among other adverse effects.

These effects can occur at all levels of radiation, from levels as low as those occurring with background radiation and diagnostic radiology to the higher levels associated with radiotherapy and nuclear medicine.[1] There are also patients in whom the use of any ionizing radiation is contraindicated, such as patients who have gone through radiotherapy in the head and neck region and are at risk for salivary gland dysfunction and hence severe xerostomia.

Magnetic Resonance Imaging

The need arises for a method of obtaining images for diagnosis that does not involve the use of ionizing radiation. One such alternative would be the use of magnetic resonance imaging (MRI) as magnetic resonance (MR) scans do not involve the use of x-rays or other types of ionizing radiation.

MR scans are obtained by creating a magnetic field in the targeted portion of the body. The field causes the nuclei of hydrogen atoms, or protons, to align in a certain manner. When the field is removed, the nuclei return to their original orientation, emitting energy in forms detectable by the scanner. Different types of tissue react differently and release energy at different levels determined by the atoms' realignment times. These pulses can be recognized and differentiated by the MR machine.

An image is then created where the tissues of greater proton density are shown as whiter areas on an MR scan, and less proton dense tissues as darker areas. This allows differentiation of the various tissues. However, it must be noted that although trabecular

bone is visible due to the presence of bone marrow, cortical bone is not visible on MR scans.[9] Cortical bone tissue does not respond to magnetic fields and radio pulses in the same way as soft tissue and thus does not transmit the necessary energy pulses that the MR machine requires for imaging. It appears as a dark space on MR scans, no different on MR images from empty space.

Currently, MRIs are used mostly in the medical profession in the evaluation of soft tissue but the use of MR scans in evaluation of the head and neck in dental and orofacial issues is increasing. So far the most common dental uses have been in the evaluation of the temporomandibular joint (TMJ).[10] the patient's airway,[11] and the orofacial musculature.[12,13] However, innovative uses of MR scans to evaluate hard tissues are starting to appear. Some examples include evaluation of the relationship of impacted third molars to the mandibular canals in young patients[14] and the use of a recently developed MR imaging technique called SWeep Imaging with Fourier Transform (SWIFT) to evaluate dental tissues for pathosis and healing in the field of endodontics.[15]

Problems with Using MR Scans for Cephalometric Analysis

There exist potential issues with using MRI derived images for orthodontic diagnosis. MR scans are already currently in use in the cephalometric analysis of soft tissue of the head and neck.[16] However, many of the landmarks important in the numerous types of orthodontic diagnostic analyses are based on the location of cortical hard tissue skeletal structures, not only soft tissue. Thus the location of bony hard tissue landmarks and planes poses a challenge due to the phenomena of cortical bone not being

visible on MR images.[9] Despite that potential issue, MRI images have been shown to be as capable as CBCT images in evaluating the physical dimensions of bony material.[9]

MR scans are affected by the presence of certain metals present in the oral cavity or head and neck area.[17] At levels of 3T and above, they can also contribute to microleakage in dental amalgam restorations.[18] Since a large percentage of patients may already have metal dental restorations, metal implants, or already be wearing metal orthodontic appliances, the diagnostic usefulness of these images when the patient in question has any of those metals already present in the oral cavity may be compromised.

Besides the technical obstacles presented, there are also practical issues. One must also consider the current high cost of taking MR scans. MR scans also require more time to take and to process than conventional lateral cephs and CBCT images,[19] so their implementation in a clinical environment may not be straightforward. Some patients have also reported feeling claustrophobic inside the MR scanner,[20] and the noise and movement of the machine has frightened young patients.

Despite these drawbacks, there exists a need for alternatives to imaging techniques involving ionizing radiation should they be necessary or become more feasible in the future.

CHAPTER THREE

MATERIALS AND METHODS

Patient Selection

Two relevant previous studies regarding MRI, CBCT, and lateral cephalograms have been carried out by orthodontic residents in Loma Linda University.[21,22] The studies required each patient to have a digital lateral cephalogram, a CBCT scan, and an MRI taken. From these previous 2 studies, 22 patients were chosen for this study according to the following exclusion criteria:

1. No metallic dental restorations
2. No medical or dental implants
3. Not claustrophobic
4. Female subjects are not pregnant

The study received IRB approval from the Loma Linda University (LLU) Institutional Review Board (IRB) before any images were obtained.

Image Capture

The patients were placed in maximum intercuspation and sagittal images for comparison were taken using three different methods:

1. A digital lateral cephalogram (Orthophos XG Plus, Sirona, Bensheim, Germany) was taken of each patient with the patient standing in an upright position. The lateral ceph images was acquired with a standardized distance

of 60 inches from x-ray source to mid-sagittal plane. The Orthophos XG Plus uses a horizontal x-ray beam for scanning and then software corrects the data to obtain undistorted images.

2. A CBCT scan (NewTom 3G, AFP Imaging, Elmsford, New York, USA) was taken on each patient with a 12-inch field of view (FOV) and a total exposure time of 5.4 seconds. The images were obtained with the patients lying prone with their faces up. Axial slices 0.5 mm thick were created and exported in Digital Imaging and Communications in Medicine (DICOM) format.
3. The MR scans (TIM/Trio, Siemens Medical Solutions, Erlangen, Germany) were performed using a 3.0T MR imaging system in a 12 channel head array coil. A T1-weighted 3D imaging sequence [Magnetization Prepared Rapid Acquisition by Gradient Echo (MP-RAGE), TR/TE = 1950/2.26 ms] was used to produce contiguous sagittal images of the entire head with an isotropic resolution of 1.0x1.0x1.0 mm. The slices were also exported in DICOM format.

Cephalometric Tracing

Three orthodontists digitized the obtained images. Prior to tracing the images, the readers were required to undergo a calibration session to determine how the locations of each of the landmarks should be chosen. The calibration entailed having the readers going through landmark digitization for one complete set of patient images (lateral cephalogram, CBCT, and MRI) together and determining how placements for each

landmark would be chosen. The readers then each traced a second set of images and compared the obtained cephalometric values and tracings.

Digitization of the images was done in Dolphin Imaging software. Cephalometric landmarks (Tables 1 and 2) were chosen to locate relevant planes (Table 3) and thus allow calculation of 26 total Ricketts and Steiner analysis values (Tables 4 and 5) for each image of each patient. The digitized lateral cephs were traced in 2 dimensions, and the CBCT and MRI 3D volumes were traced in Dolphin Imaging software in the '3D' setting. Readers used image optimization tools of zooming in and/or contrast modulation as necessary for maximum accuracy.

Each reader's obtained values were weighted equally for statistical analysis. The images were traced in random order with no organization by patient or type of image. Readers only traced a maximum of 10 images in any given session to avoid errors due to fatigue.

Pilot Study

A pilot study was undertaken to discover any potential complications in landmark location and hence determination of planes and calculation of values. There were 3 main problems identified.

The first issue was that on a digitized lateral ceph, bilateral landmarks are averaged and a corresponding landmark location determined by eye. However, due to software limitations when tracing the CBCTs and MRIs in 3 dimensions only one side could be traced at a time. To account for this, the 3 dimensional DICOM volumes were

Table 1: Digitized and Constructed Landmarks for Digital Lateral Cephalogram

	Digitized Landmarks	Description
1	Porion (Pr)	Averaged most lateral and superior point of the bony external auditory meatus
2	Orbitale (Or)	Averaged most inferior point on the infraorbital rim
3	Pterygoid point (Pt)	Averaged intersection of inferior edge of foramen rotundum and pterygomaxillary fissure
4	Sella (S)	Midpoint of Sella Turcica
5	Nasion (N)	Intersection of internasal and nasofrontal sutures
6	Basion (Ba)	Most inferior point on the anterior margin of foramen magnum
7	DC Point (DC)	Averaged midpoint of mandibular condyle along the NaBa plane
8	Tip of Nose (NT)	Most prominent point at tip of nose
9	Lower Lip (LL)	Most prominent point of the lower lip
10	Soft Tissue Pogonion (sPo)	Most prominent point of soft tissue chin
11	B Point (B)	Deepest point between pogonion and mandibular dental alveolus
12	Pogonion (Po)	Most anterior point of mandibular symphysis
13	Menton (Me)	Most inferior point of mandibular symphysis
14	Gonion (Go)	Averaged most convex point at the posterior-inferior curve of ramus
15	Mid Ramus (R1)	Averaged most concave point on anterior ramus (to construct Xi)
16	R2 (R2)	Averaged most convex point on posterior border of ramus (to construct Xi)
17	Sigmoid Notch (R3)	Averaged most inferior point of the sigmoid notch (to construct Xi)
18	R4 (R4)	Averaged most superior point along inferior border of ramus (to construct Xi)
19	A point (A)	Deepest point between ANS and dental alveolus
20	Anterior Nasal Spine (ANS)	Tip of the anterior nasal spine
21	Upper 6 Occlusal (U6O)	Averaged mesial-buccal cusp tip of maxillary 1st molar
22	Lower 6 Occlusal (L6O)	Averaged mesial-buccal cusp tip of mandibular 1st molar
23	Upper 6 Distal (U6D)	Averaged distal height of contour of maxillary 1st molar
24	Upper 6 Mesial (U6M)	Averaged mesial height of contour of maxillary 1st molar
25	Lower 6 Distal (L6D)	Averaged distal height of contour of mandibular 1st molar
26	Lower 6 Mesial (L6M)	Averaged mesial height of contour of mandibular 1st molar
27	Lower 1 Crown (L1C)	Averaged tip of crown of lower central incisor
28	Lower 1 Root (L1R)	Averaged tip of root of lower central incisor
29	Upper 1 Crown (U1C)	Averaged tip of crown of upper central incisor
30	Upper 1 Root (U1R)	Averaged tip of root of upper central incisor
31	Gnathion (Gn)	Most anterior-inferior point of the mandibular symphysis
32	Protuberance Menti (PM)	Point of inflection between B and Po

	Constructed Landmarks	Descripton
33	Xi Point (Xi)	Geometric center of box formed by R1, R2, R3, and R4
34	Constructed Gnathion (cGn)	Intersection of the facial and mandibular planes
35	Center Frankfort (CF)	Intersection of Frankfort and Pterygoid Vertical Planes

Table 2: Digitized and Constructed Landmarks for CBCT and MRI

	Digitized Landmarks	Description
1	Porion (Pr)	Most lateral and superior points of the roofs of the bony external auditory meatus
2	Orbitale (Or)	Most inferior points on the infraorbital rim
3	Pterygoid point (Pt)	Intersections of inferior edge of foramen rotundum and pterygomaxillary fissure
4	Sella (S)	Midpoint of Sella Turcica
5	Nasion (N)	Intersection of internasal and nasofrontal sutures
6	Basion (Ba)	Most inferior point on the anterior margin of foramen magnum
7	DC Point (DC)	Midpoints of neck of condyle at its narrowest point when visible at slice level of Pr
8	Tip of Nose (NT)	Most prominent point at tip of nose
9	Lower Lip (LL)	Most prominent point of the lower lip
10	Soft Tissue Pogonion (sPo)	Most prominent point of soft tissue chin
11	B Point (B)	Deepest point between pogonion and dental alveolus
12	Pogonion (Po)	Most anterior point of mandibular symphysis
13	Menton (Me)	Most inferior point of mandibular symphysis
14	Gonion (Go)	Most convex points at the posterior-inferior curve of ramus
15	Mid Ramus (R1)	Most concave points on anterior ramus (to construct Xi)
16	R2 (R2)	Most convex points on posterior border of ramus (to construct Xi)
17	Sigmoid Notch (R3)	Most inferior points of the sigmoid notch (to construct Xi)
18	R4 (R4)	Most superior points along inferior border of ramus (to construct Xi)
19	A point (A)	Deepest point between ANS and dental alveolus
20	Anterior Nasal Spine (ANS)	Tip of the anterior nasal spine
21	Upper 6 Occlusal (U6O)	Mesial-buccal cusp tip of maxillary 1st molar
22	Lower 6 Occlusal (L6O)	Mesial-buccal cusp tip of mandibular 1st molar
23	Upper 6 Distal (U6D)	Distal height of contour of maxillary 1st molar
24	Upper 6 Mesial (U6M)	Mesial height of contour of maxillary 1st molar
25	Lower 6 Distal (L6D)	Distal height of contour of mandibular 1st molar
26	Lower 6 Mesial (L6M)	Mesial height of contour of mandibular 1st molar
27	Lower 1 Crown (L1C)	Tip of crown of lower central incisor
28	Lower 1 Root (L1R)	Tip of root of lower central incisor
29	Upper 1 Crown (U1C)	Tip of crown of upper central incisor
30	Upper 1 Root (U1R)	Tip of root of upper central incisor
31	Gnathion (Gn)	Most anterior-inferior point of the mandibular symphysis
32	Protuberance Menti (PM)	Point of inflection between B and Po

	Constructed Landmarks	Descripton
33	Xi Point (Xi)	Geometric center of box formed by R1, R2, R3, and R4
34	Constructed Gnathion (cGn)	Intersection of the facial and mandibular planes
35	Center Frankfort (CF)	Intersection of Frankfort and Pterygoid Vertical Planes

Table 3: Cephalometric Planes

	Plane	Description
	Ricketts Analysis	
1	Frankfort Horizontal (FH)	Plane from Pr to Or
2	Nasion to Basion (NaBa)	Plane from Na to Ba
3	Nasion to A point (NA)	Plane from N to A point
4	Nasion to B point (NB)	Plane from N to B point
5	Facial Axis (FA)	Plane from Pt to cGn
6	Facial Plane (FP)	Plane from N to Po
7	Corpus Axis (CA)	Plane from PM to Xi
8	Pterygoid Vertical Plane (PtV)	The vertical plane through Pt perpendicular to FH plane
9	Mandibular Plane (MP)	Plane from Go to Me
10	Lower Incisor Axis (L1)	Plane from lower incisor incisal edge to lower incisor root tip
11	Upper Incisor Axis (U1)	Plane from upper incisor incisal edge to upper incisor root tip
12	A-Po plane (A-Po)	Plane from A to Po
13	Xi-ANS plane (Xi-ANS)	Plane from Xi to ANS
14	Esthetic Plane (E-plane)	Plane from NT to sPo
	Steiner Analysis	
1	Sella-Nasion (SN)	Plane from S to N
2	Nasion to A point (NA)	Plane from N to A point
3	Nasion to B point (NB)	Plane from N to B point
4	Mandibular Plane (Go-Gn)	Plane from Go to Gn
5	Occlusal Plane (Occ)	Plane drawn through overlapping cusps of 1st molars and 1st premolars

Table 4: Ricketts Analysis Measurements

	Ricketts Analysis	Description
	Angular Measurements	
1	Cranial Deflection (CD)	Angle formed by NaBa and FH planes
2	Maxillary Depth (MD)	Angle formed by NA and FH planes
3	Facial Depth (FD)	Angle formed by N-Po and FH planes
4	Facial Axis (FA)	Angle formed by NaBa and FA planes
5	Total Face Height (TFH)	Angle formed by NaBa and CA planes
6	Lower Face Height (LFH)	Angle formed by CA and X-ANS planes
7	Mandibular Arc (MA)	90° - Angle formed by DC-Xi-PM
8	Mandibular Plane Angle (MPA)	Angle formed by FH and MP planes
9	L1 to A-Po (L1-APo)	Angle formed by L1 and A-Po planes
10	U1 to A-Po (U1-APo)	Angle formed by U1 and A-Po planes
11	Interincisal Angle (1/1)	Angle formed by L1 and U1 axes
	Linear measurements	
1	Upper 6 to PtV (6-PtV)	Horizontal distance from distal of the maxillary 6 to PtV
2	Upper Incisor Protrusion (U1P)	Horizontal distance from tip of U1 to A-Po
3	Lower Incisor Protrusion (L1P)	Horizontal distance from tip of L1 to A-Po
4	Convexity (Conv)	Most prominent point at tip of nose
5	Lower Lip to E-plane (LL-EP)	Most prominent point of the lower lip

Table 5: Steiner Analysis Measurements

	Steiner Analysis	Description
	Angular Measurements	
1	SNA	Angle formed by SN and NA planes
2	SNB	Angle formed by SN and NB planes
3	ANB	Angle formed by NA and NB planes
4	Upper 1 Angle (U1/NA)	Angle formed by U1 and NA
5	Lower 1 Angle (L1/NB)	Angle formed by L1 and NB
6	Occlusal Plane Angle (OPA)	Angle formed by the functional occlusal plane and SN
7	Mandibular Plane Angle (GoGn-SN)	Angle formed by Go-Gn and SN planes
	Linear Measurements	
1	Upper 1 to NA (U1-NA)	Perpendicular distance from U1C to NA plane
2	Lower 1 to NB (L1-NB)	Perpendicular distance from L1C to NB plane
3	Pogonion to NB (Po-NB)	Perpendicular distance from Po to NB plane

traced twice, once for the right side and once for the left. The obtained values were then averaged to account for any differences.

The next problem that arose was locating the landmark porion when tracing the CBCT and MRI scans in 3D. A traditional lateral ceph offers a flattened 2 dimensional viewpoint into the auditory canals and the most superior point is selected. However, in a 3D DICOM volume, the highest point can only be located by scrolling through the sagittal slices. For the purposes of this study, when tracing a 3D volume porion was defined as the most superior points of the roofs of the bony external meatus when tracing either the right or left side.

Another issue concerned the landmark DC point. The traditional definition of DC point in Rickett's analysis is the midpoint of the mandibular condyle along the NaBa plane. In a traditional lateral ceph, this point is easily identifiable after drawing the NaBa plane. However, when tracing in 3D the NaBa plane is not viewable on the screen, making it difficult to locate DC point according to it's traditional definition. As such, for the purposes of this study DC point is defined as the midpoint of the condyle at it's narrowest point when viewing the sagittal slice where Po is marked.

The final difficulty encountered was in the orientation of the CBCT and MRI images. A significant number of the 3 dimensional DICOM volumes did not have a correct patient head orientation. For the CBCT images, the head images could be reoriented and saved in the software. However, for the MRI images, it was not possible to reorient the volumes and save the new orientation in the software so that all 3 tracers would have an identical head orientation. Given a choice of each tracer self-reorienting the images or having all 3 tracers trace the images with a rotated head position, the choice

was made to retain the original orientation in hopes of improving agreement among the readers.

Statistical Analysis

The results were analyzed using Bland-Altman plots to compare each of the 26 Ricketts and Steiner measurements. For each measurement, lateral ceph was compared to CBCT and MRI, and then CBCT was compared to MRI.

CHAPTER FOUR

RESULTS

Results

Table 6 shows a summary of the mean differences and standard deviations found when comparing lateral cephs to both CBCT and MRI, then CBCT to MRI using data from all three readers. Figures 1-26 then show the corresponding Bland-Altman plots for each selected cephalometric value. The plots show the mean difference, as well as the range from 2 standard deviations above mean difference to 2 standard deviations below mean difference.

As Table 6 and the Bland-Altman plots show, the agreement between the imaging modalities is varied. To evaluate the agreement between MRI and the two other imaging modalities, the average of the ceph-MRI and CBCT-MRI mean deviations was divided by the standard clinical deviation range as taken from Dolphin Imaging (2013) and expressed as a percentage. Table 8 shows these percentage deviations, ranked from least to greatest and grouped from 0%-10%, 10%-20%, 20%-30%, and over 30%.

Upon examination of the Bland-Altman plots and the raw data, it was noted that the tracing values obtained by one reader in particular contained several large outliers. As such, the plots were reconstructed using data from the other two readers. Table 7 summarizes the mean differences and standard deviations found when using data from the two closest readers. Figures 27-52 show the corresponding Bland-Altman plots for 2 readers. Table 9 details the percentage deviations as described above.

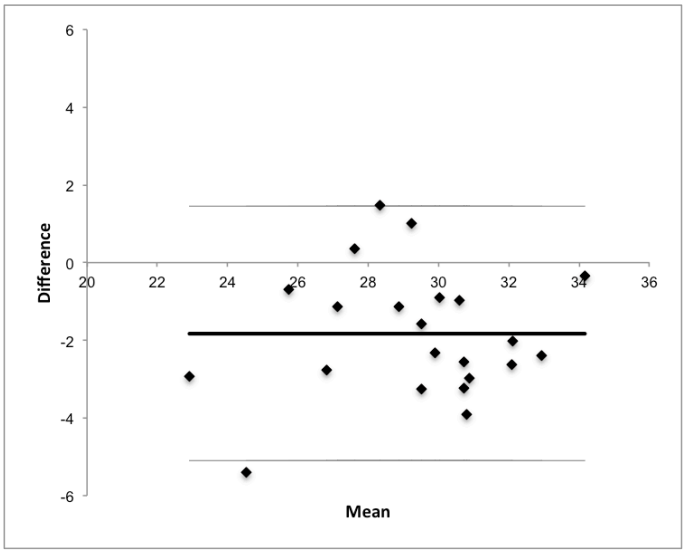
Table 6. Mean Differences and Standard Deviations for 3 Readers

Measurement	Ceph-CBCT		Ceph-MRI		CBCT-MRI	
	Mean Difference	Standard Deviation	Mean Difference	Standard Deviation	Mean Difference	Standard Deviation
(R)Cranial Deflection (º)	-1.83	1.64	-1.43	2.04	0.40	1.14
(R)Maxillary Depth (FH-NA) (º)	-1.27	1.32	-1.45	1.77	-0.18	1.19
(R)Facial Depth (FH-NPo) (º)	-0.90	1.09	-0.54	1.56	0.37	1.06
(R)Facial Axis (NaBa-PtGn)(º)	1.92	1.02	1.09	1.19	-0.82	0.95
(R)Total Face Height (NaBa-PmXi) (º)	-1.14	1.15	0.20	1.26	1.34	1.35
(R)Lower Face Height (ANS-Xi-Pm)(º)	-0.98	1.40	-0.98	1.76	0.00	1.32
(R)Mandibular Arc (º)	1.10	2.61	-0.63	2.58	-1.73	2.39
(R)FMA (MP-FH) (º)	0.87	1.27	2.36	2.84	1.49	2.32
(R)L1 to A-Po (º)	0.49	2.31	-0.87	3.22	-1.36	3.03
(R)U1 to A-Po (º)	2.91	2.42	-1.12	3.50	-4.03	2.30
(R)Interincisal Angle (U1-L1) (º)	-3.40	3.44	1.99	3.87	5.38	3.64
(R)U6 - PT Vertical (mm)	-1.02	1.42	-1.78	2.25	-0.76	1.91
(R)U1 Protrusion (U1-APo) (mm)	0.24	0.44	-0.71	0.78	-0.95	0.63
(R)L1 Protrusion (L1-APo) (mm)	0.27	0.43	-0.32	0.63	-0.59	0.51
(R)Convexity (A-NPo) (mm)	-0.38	0.54	-0.97	1.15	-0.59	0.99
(R)Lower Lip to E-Plane (mm)	0.51	1.15	-0.28	1.13	-0.79	1.20
(S)SNA (º)	-0.25	0.96	-2.14	1.51	-1.89	1.32
(S)SNB (º)	-0.03	0.83	-1.51	1.05	-1.48	0.94
(S)ANB (º)	-0.21	0.46	-0.63	0.93	-0.42	0.88
(S)U1 - NA (º)	3.70	2.48	0.99	3.23	-2.71	2.01
(S)L1 - NB (º)	-0.08	2.25	-2.13	3.15	-2.06	3.42
(S)Occ Plane to SN (º)	-0.21	1.42	2.09	2.62	2.30	2.07
(S)MP - SN (º)	-0.18	1.13	3.02	2.38	3.20	2.21
(S)U1 - NA (mm)	0.56	0.77	-0.02	1.26	-0.58	0.88
(S)L1 - NB (mm)	0.16	0.35	-0.55	0.69	-0.71	0.75
(S)Pog - NB (mm)	0.17	0.46	0.57	0.73	0.39	0.53

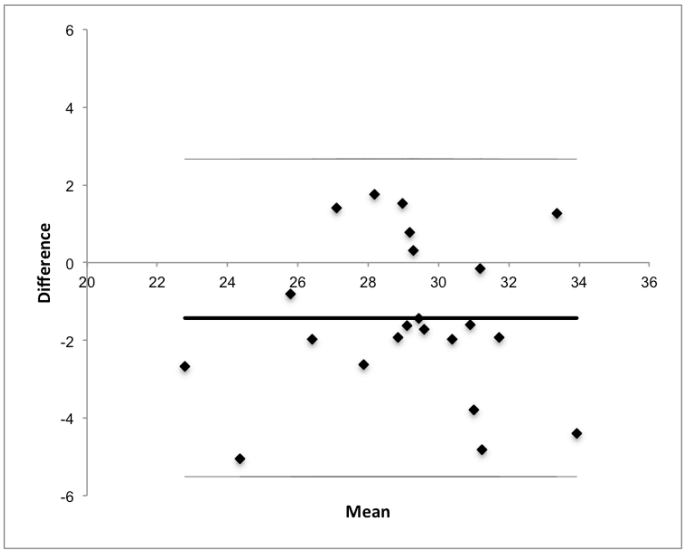
Table 7. Mean Differences and Standard Deviations for 2 Readers

Measurement	Ceph-CBCT		Ceph-MRI		CBCT-MRI	
	Mean Difference	Standard Deviation	Mean Difference	Standard Deviation	Mean Difference	Standard Deviation
(R)Cranial Deflection (º)	-1.60	1.78	-1.33	2.08	0.27	1.16
(R)Maxillary Depth (FH-NA) (º)	-1.06	1.40	-1.80	2.13	-0.74	1.30
(R)Facial Depth (FH-NPo) (º)	-0.81	1.31	-0.77	1.84	0.04	1.22
(R)Facial Axis (NaBa-PtGn)(º)	1.71	1.05	0.91	1.33	-0.80	0.88
(R)Total Face Height (NaBa-PmXi) (º)	-1.35	1.19	0.24	1.54	1.59	1.19
(R)Lower Face Height (ANS-Xi-Pm)(º)	-1.05	1.16	-0.47	1.75	0.58	1.18
(R)Mandibular Arc (º)	1.18	2.85	-0.67	2.92	-1.85	2.29
(R)FMA (MP-FH) (º)	1.01	1.45	2.92	2.40	1.91	1.75
(R)L1 to A-Po (º)	0.30	2.44	-0.83	3.38	-1.13	2.67
(R)U1 to A-Po (º)	2.41	2.42	-1.28	3.28	-3.69	2.62
(R)Interincisal Angle (U1-L1) (º)	-2.70	3.31	2.11	4.11	4.81	3.96
(R)U6 - PT Vertical (mm)	-0.90	1.55	-1.58	2.36	-0.67	1.76
(R)U1 Protrusion (U1-APo) (mm)	0.16	0.46	-0.56	0.87	-0.72	0.61
(R)L1 Protrusion (L1-APo) (mm)	0.24	0.44	-0.09	0.76	-0.33	0.66
(R)Convexity (A-NPo) (mm)	-0.26	0.49	-1.09	1.25	-0.83	1.02
(R)Lower Lip to E-Plane (mm)	0.65	0.68	-0.27	1.12	-0.93	0.93
(S)SNA (º)	-0.09	0.91	-2.24	1.59	-2.15	1.48
(S)SNB (º)	-0.04	0.82	-1.59	1.10	-1.55	0.95
(S)ANB (º)	-0.05	0.38	-0.65	1.03	-0.60	0.93
(S)U1 - NA (º)	3.00	2.17	0.89	2.67	-2.11	2.04
(S)L1 - NB (º)	-0.22	2.56	-2.38	3.49	-2.16	3.38
(S)Occ Plane to SN (º)	-0.49	1.48	0.97	2.64	1.46	1.99
(S)MP - SN (º)	0.00	1.18	3.36	1.93	3.36	1.23
(S)U1 - NA (mm)	0.40	0.77	0.19	1.25	-0.21	0.74
(S)L1 - NB (mm)	0.24	0.32	-0.33	0.87	-0.56	0.89
(S)Pog - NB (mm)	0.22	0.60	0.65	0.84	0.43	0.56

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

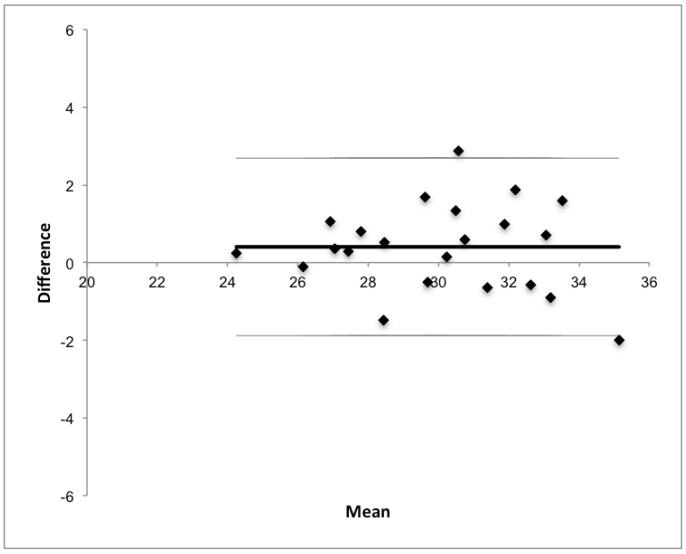
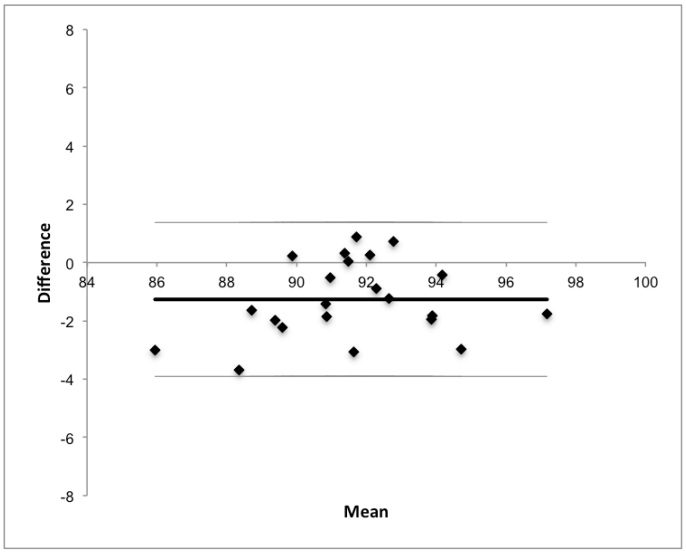
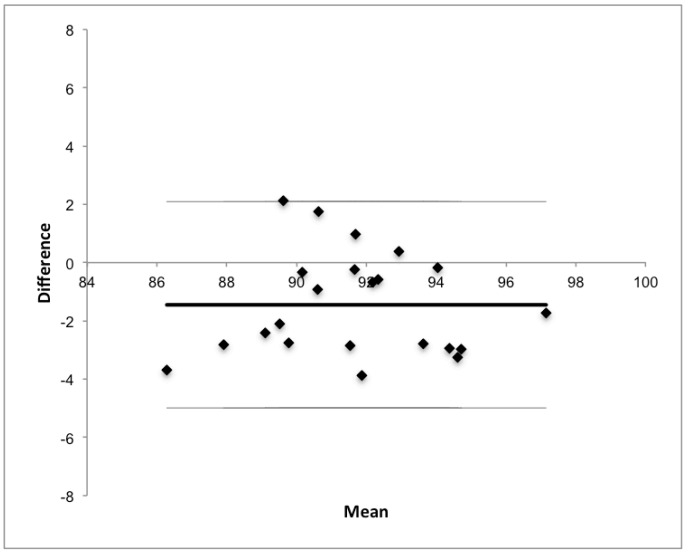


Figure 1. Cranial Deflection - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

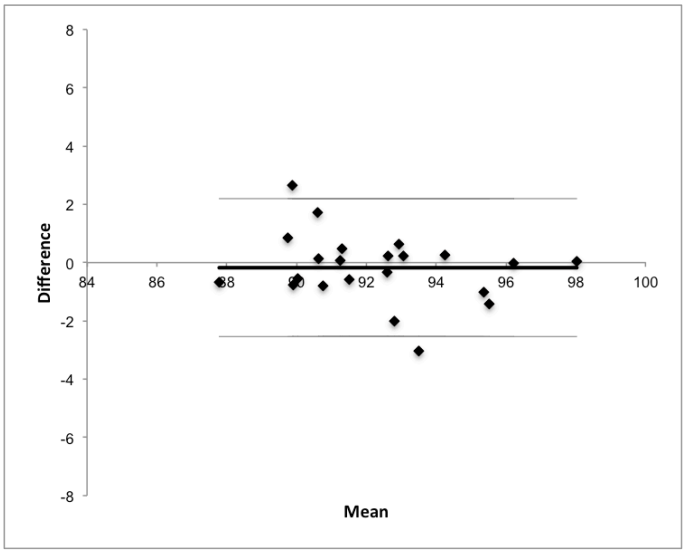
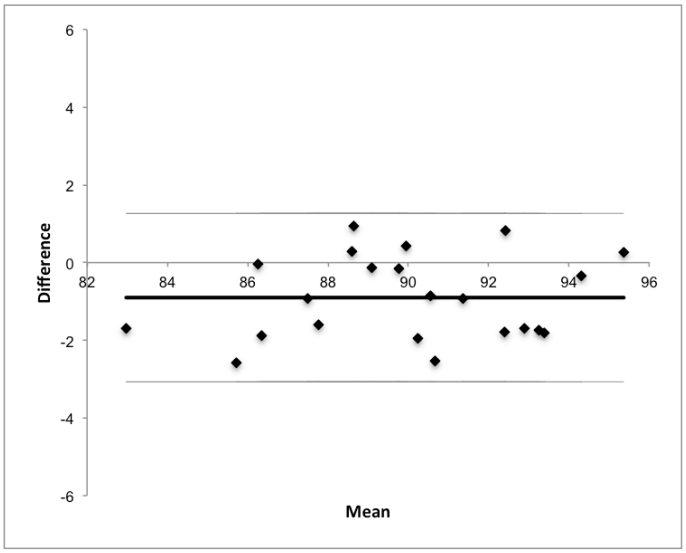
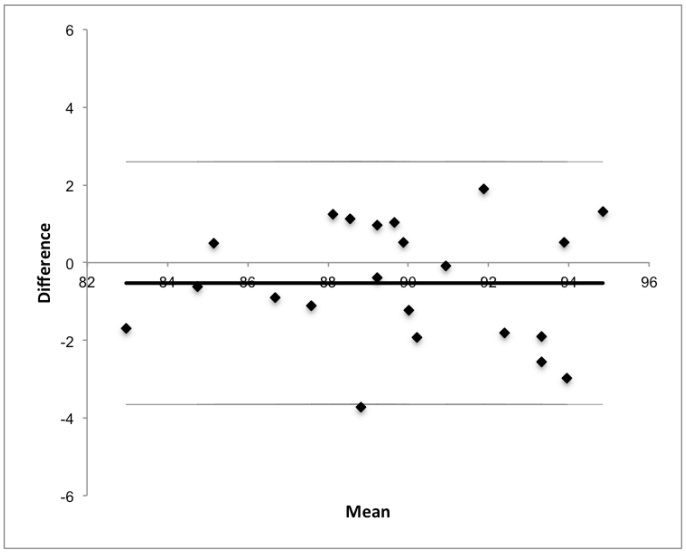


Figure 2. Maxillary Depth - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

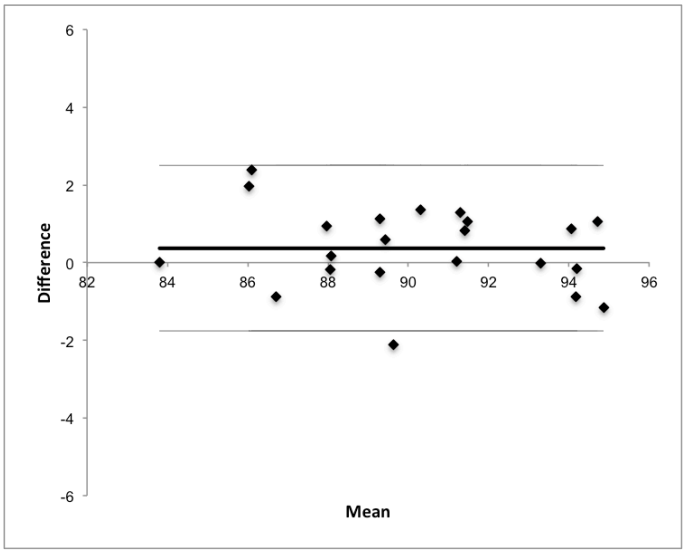
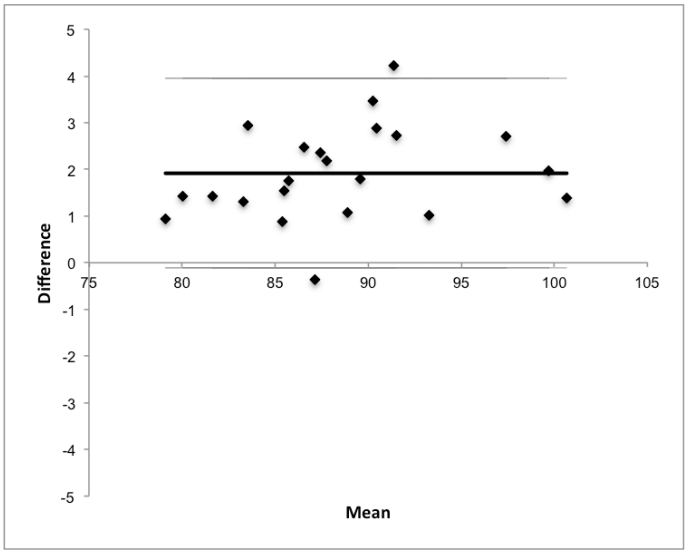
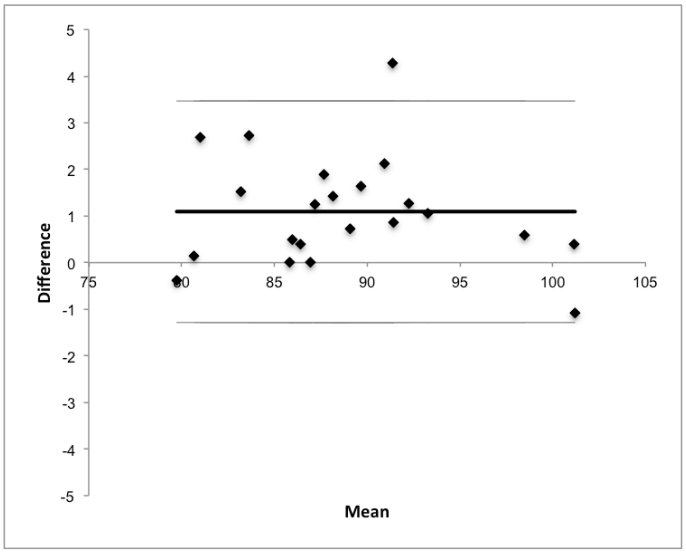


Figure 3. Facial Depth - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

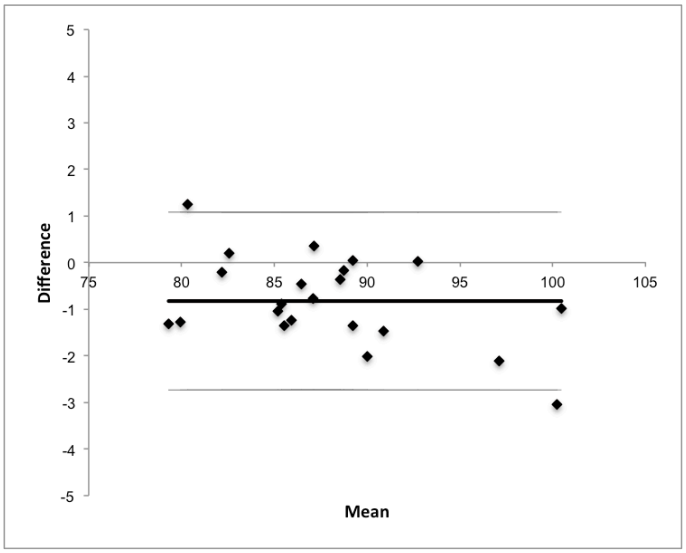
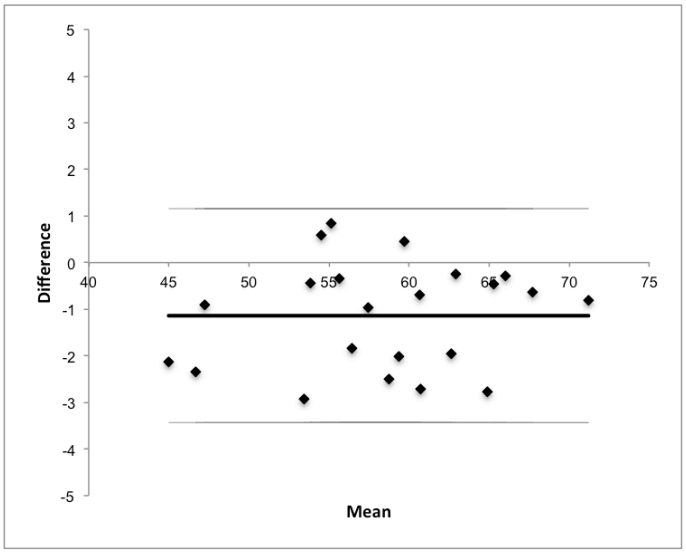
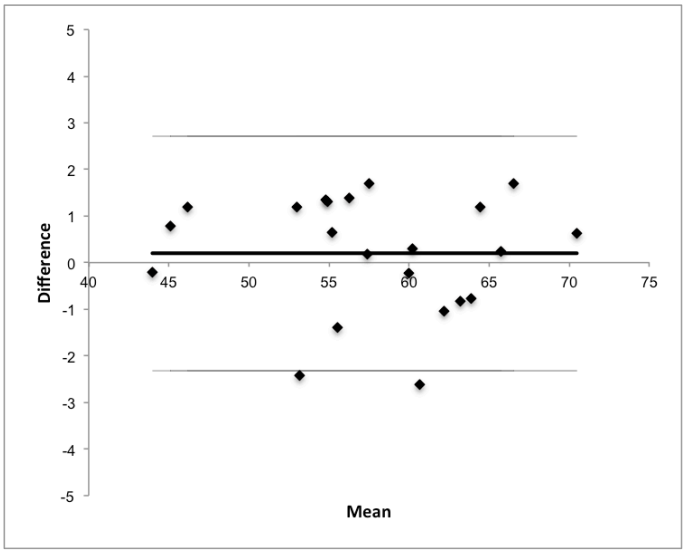


Figure 4. Facial Axis - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

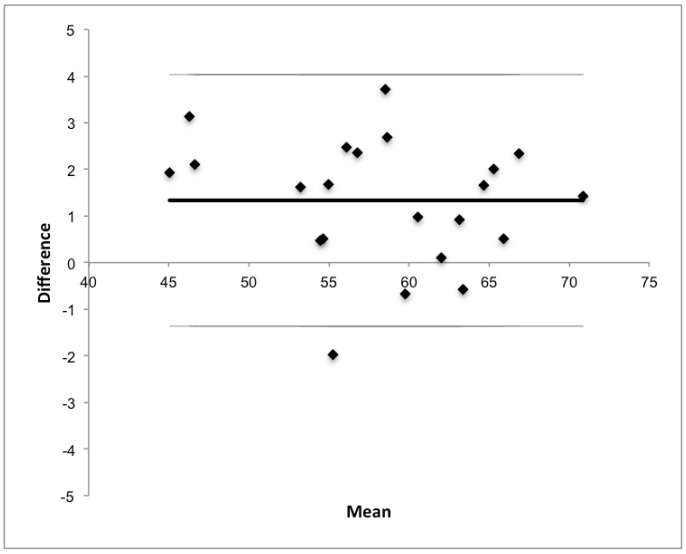
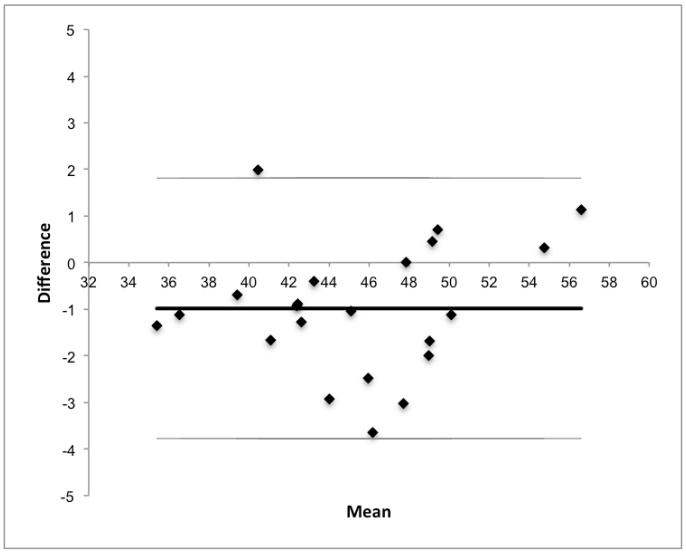
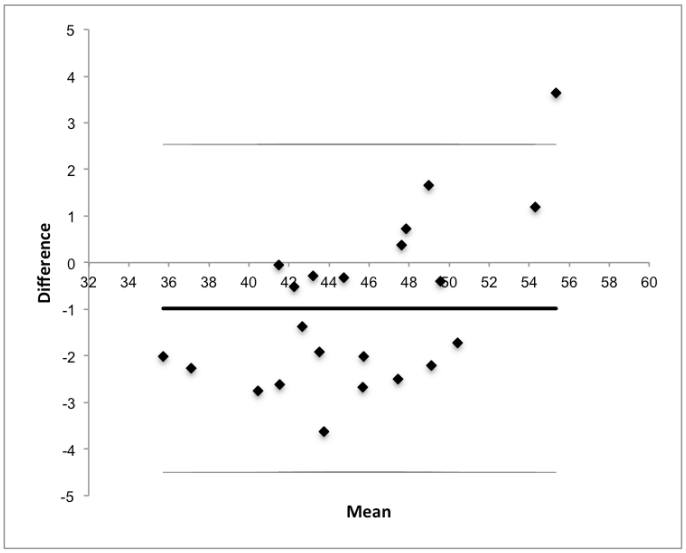


Figure 5. Total Face Height - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

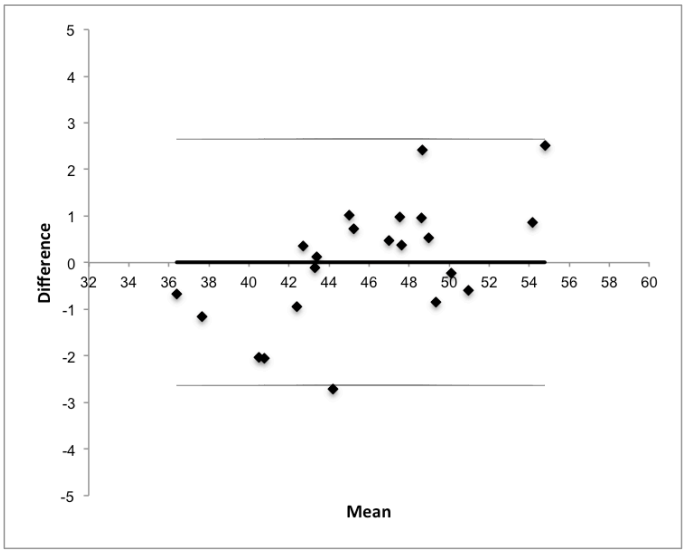
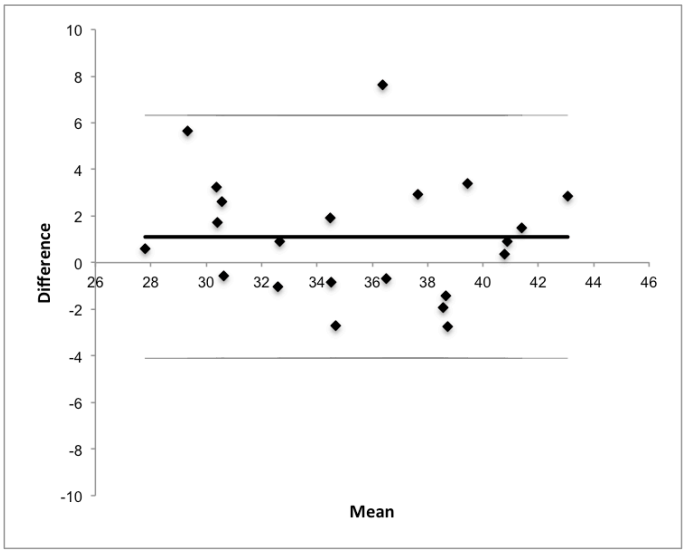
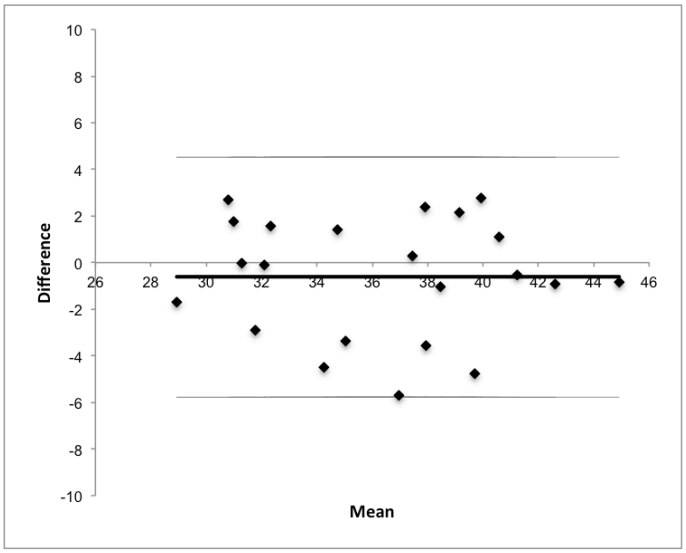


Figure 6. Lower Face Height - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

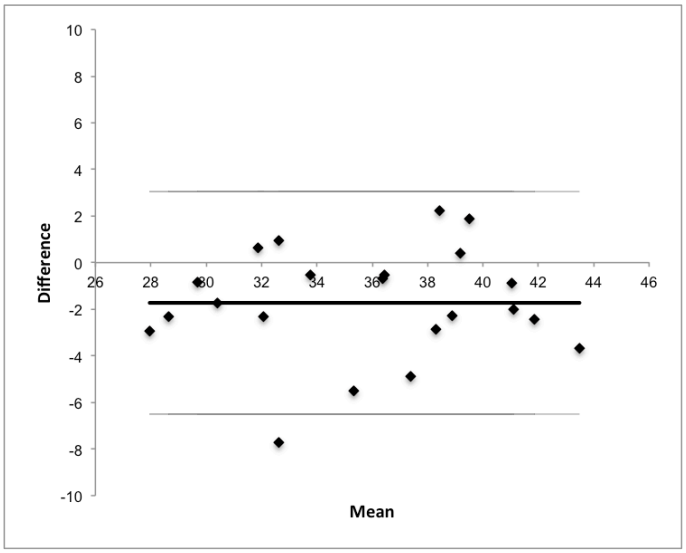
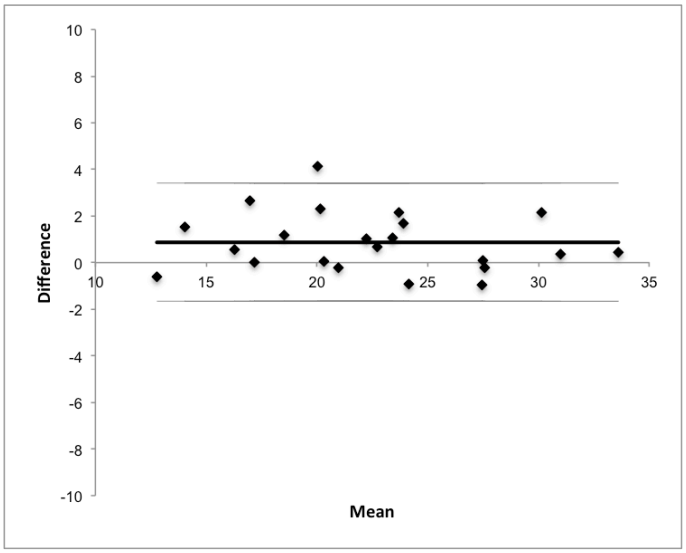
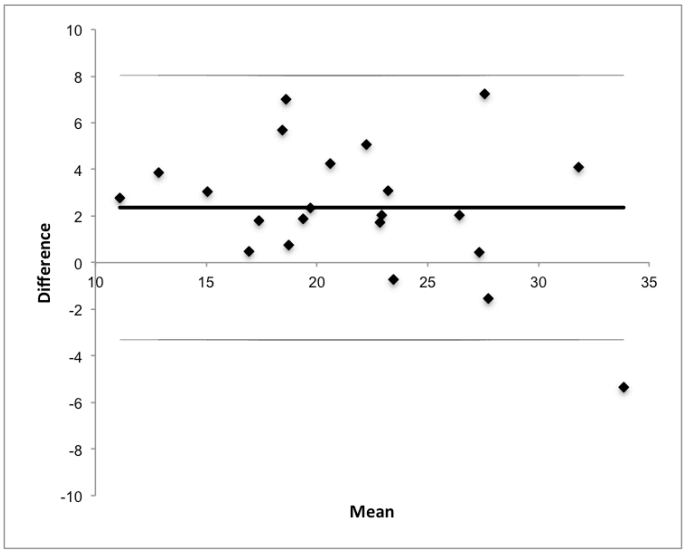


Figure 7. Mandibular Arc - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

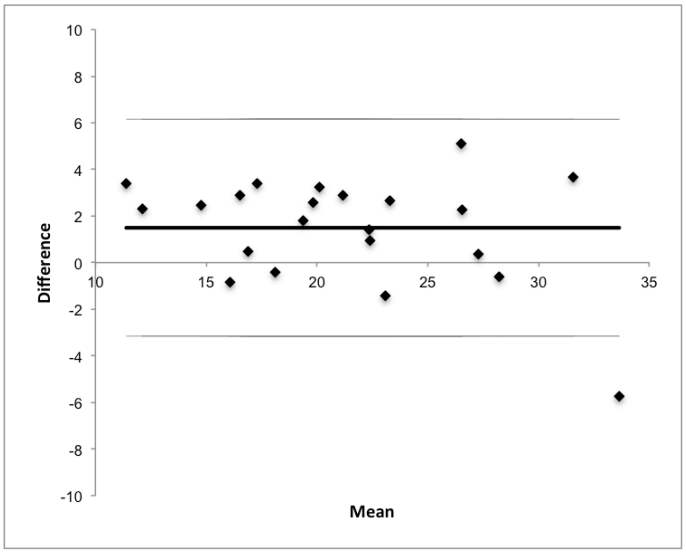
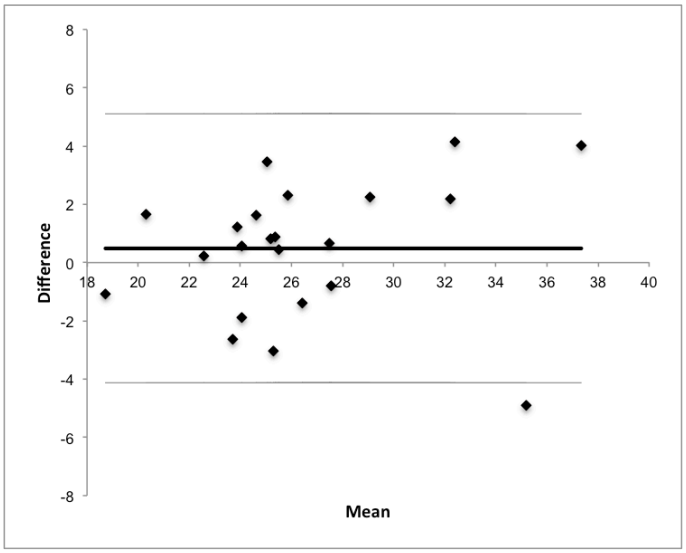
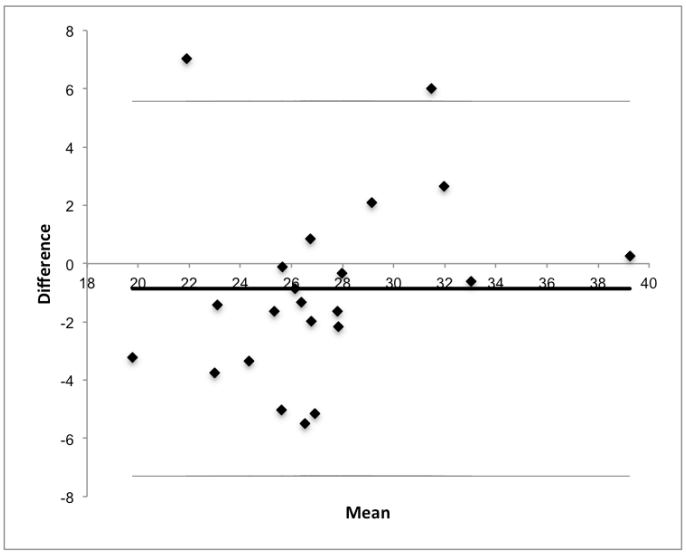


Figure 8. Mandibular Plane Angle - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

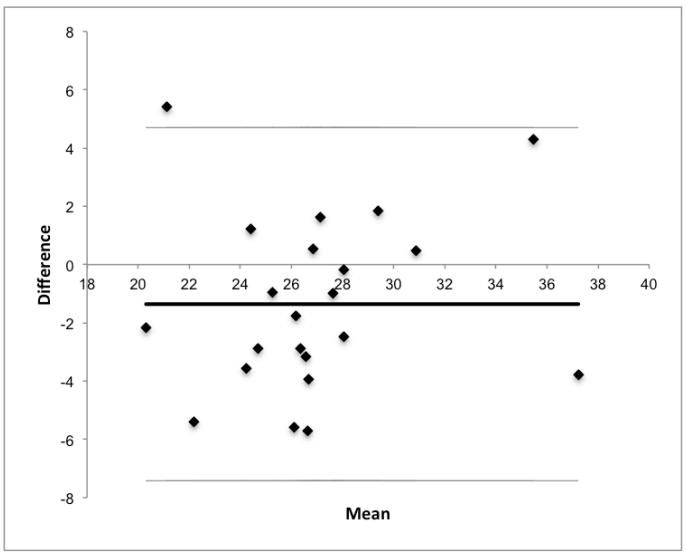
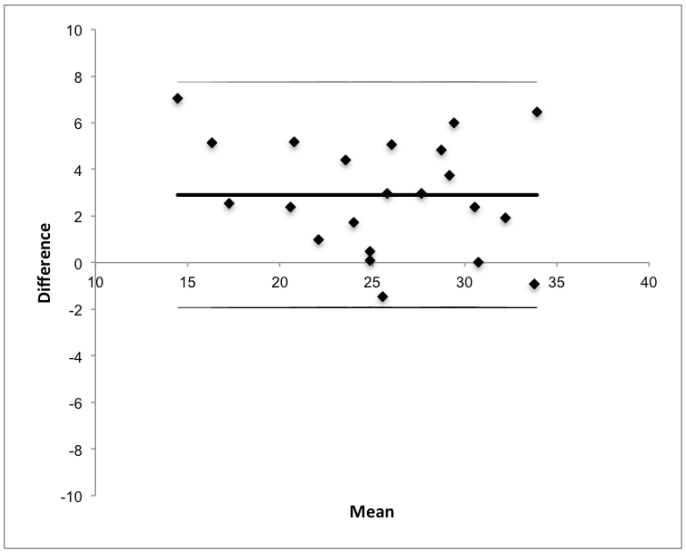
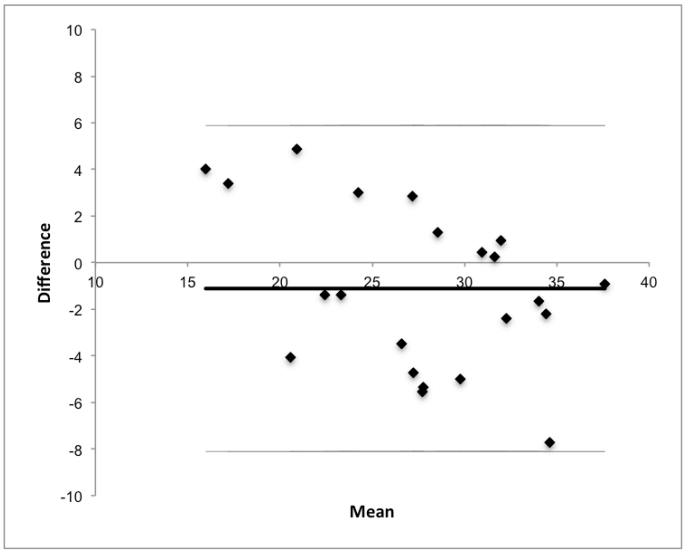


Figure 9. L1 to A-Po Angle - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

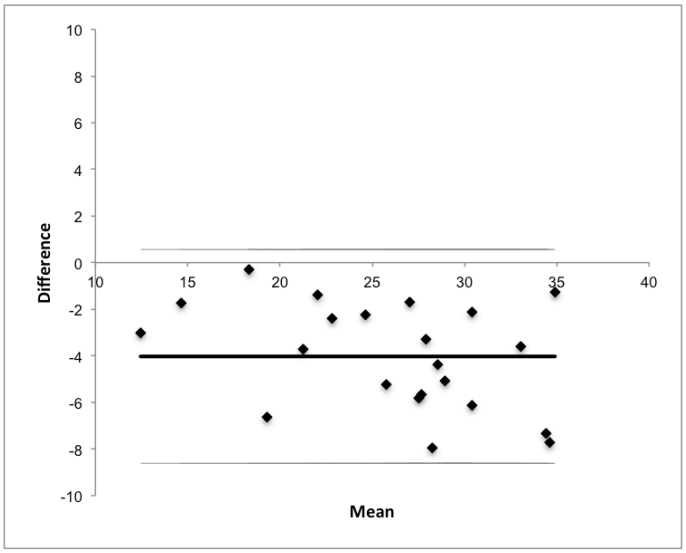
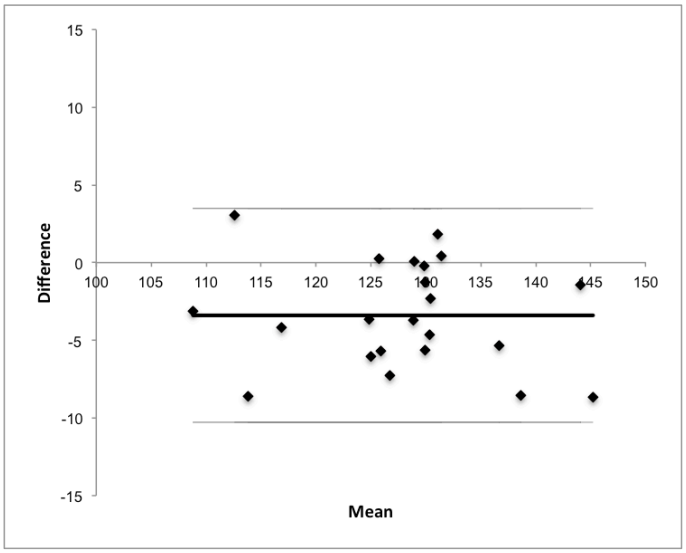
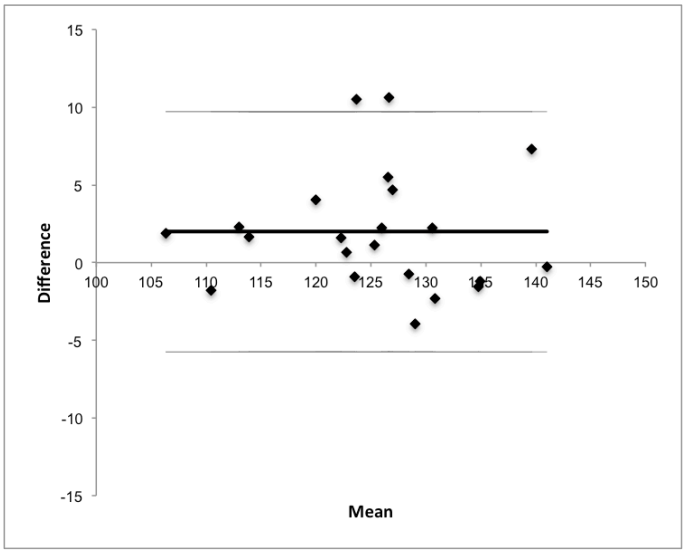


Figure 10. U1 to A-Po Angle - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

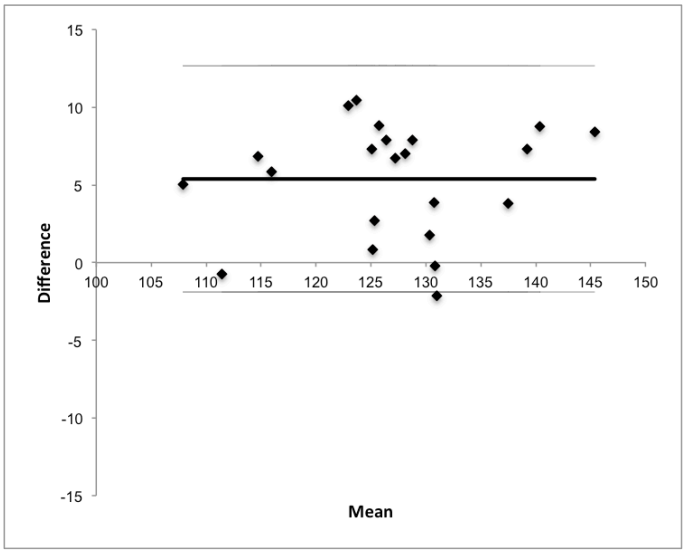
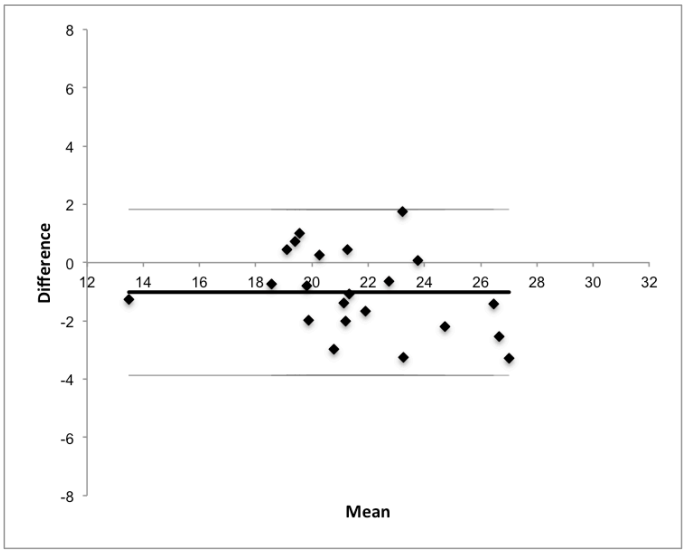
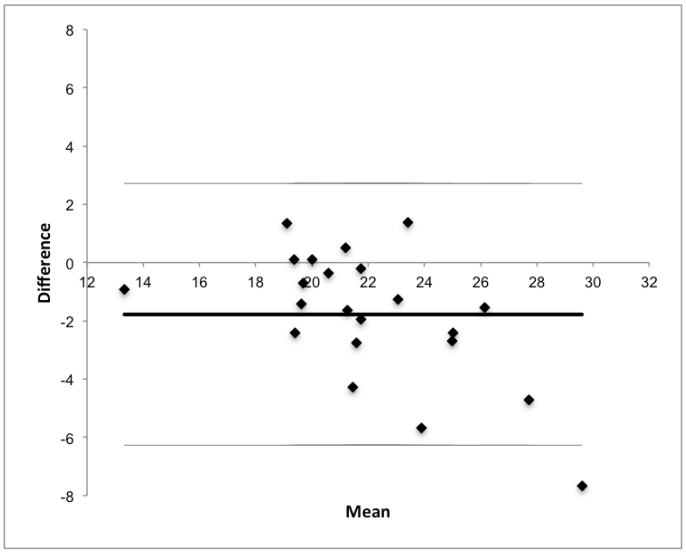


Figure 11. Interincisal Angle - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

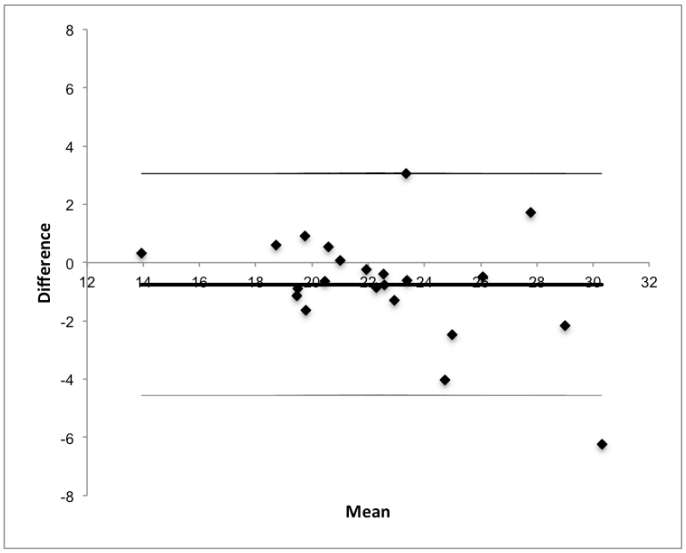
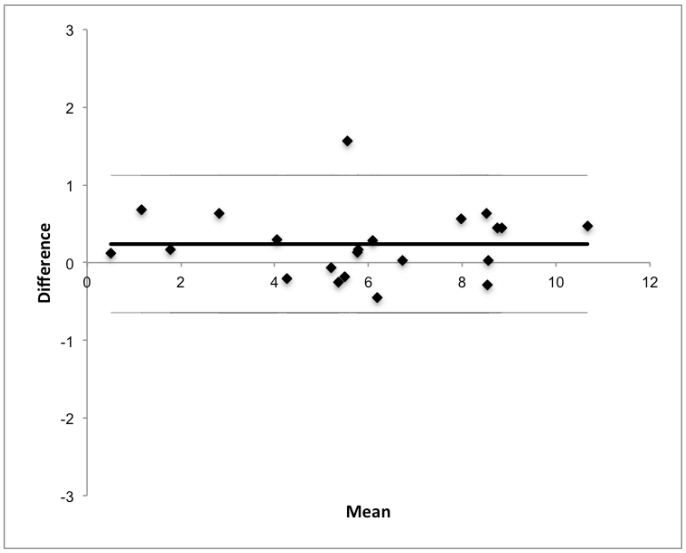
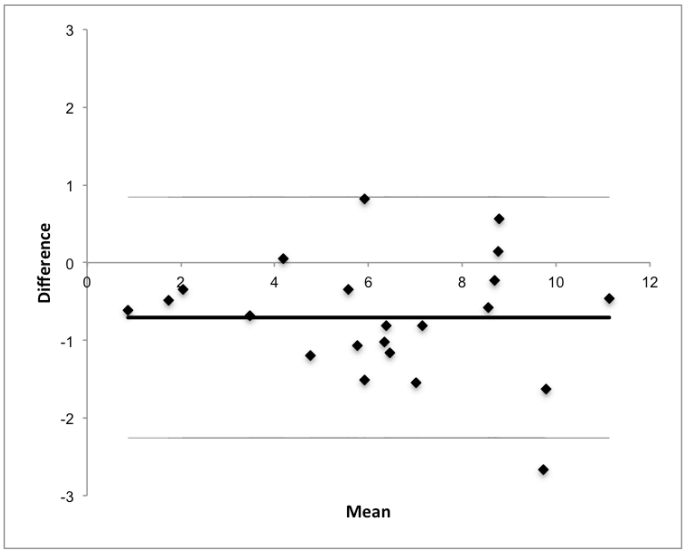


Figure 12. U6 to PtV - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

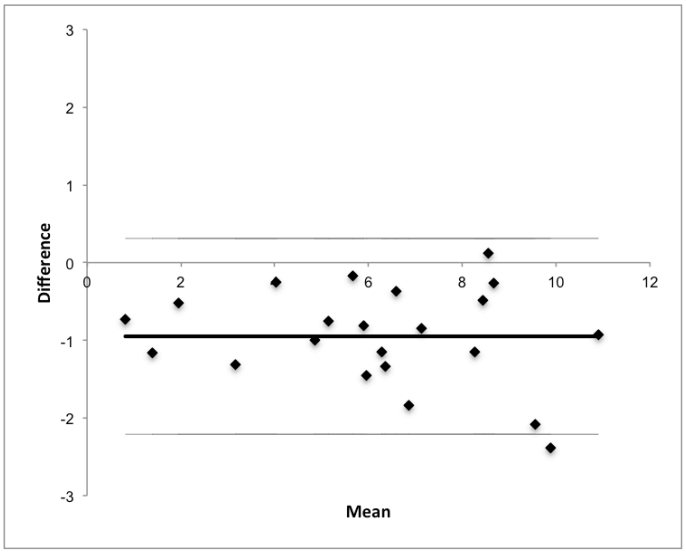
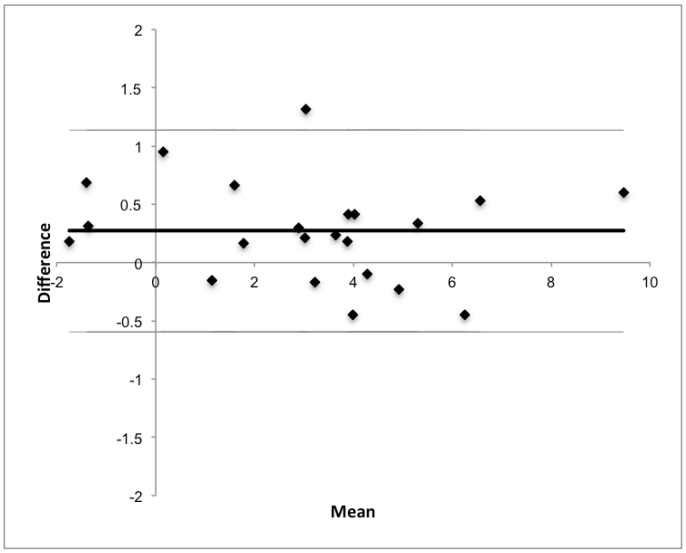
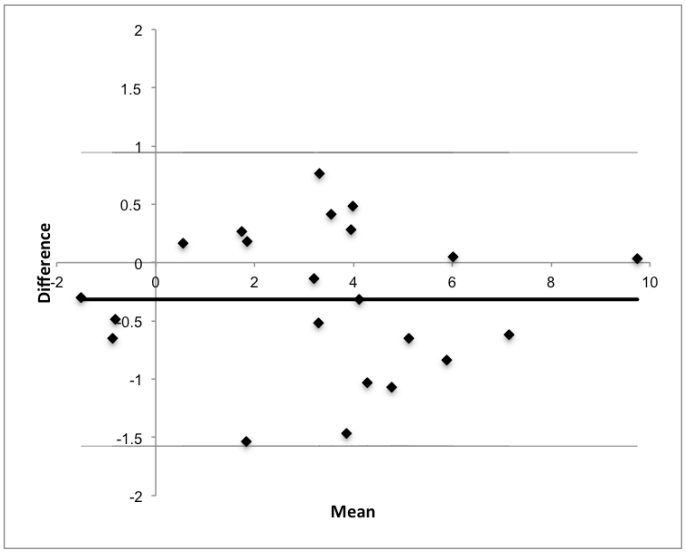


Figure 13. U1 Protrusion - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

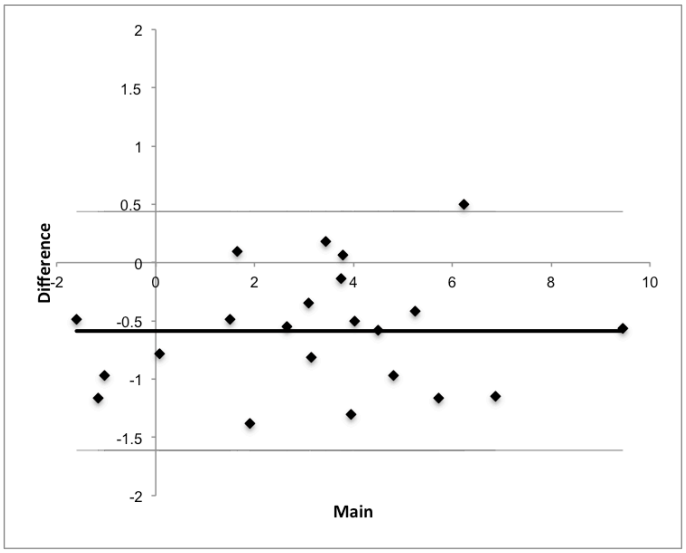
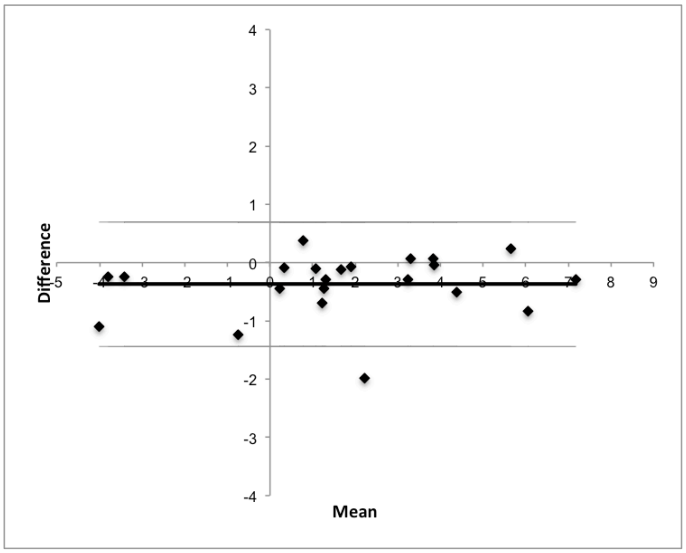
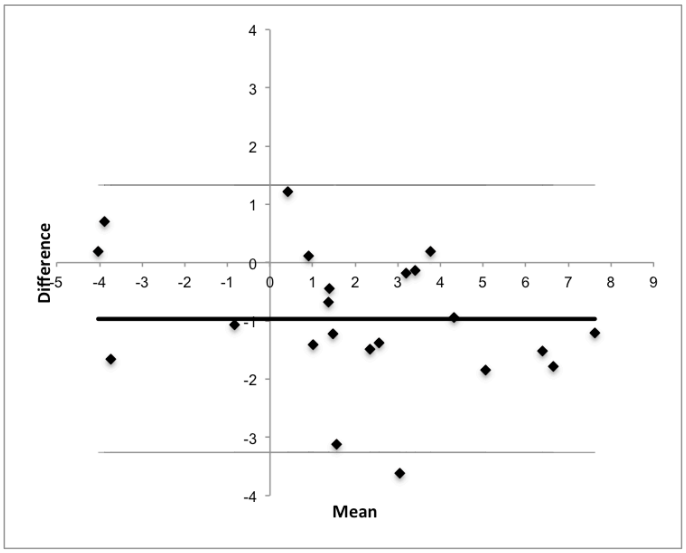


Figure 14. L1 Protrusion - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

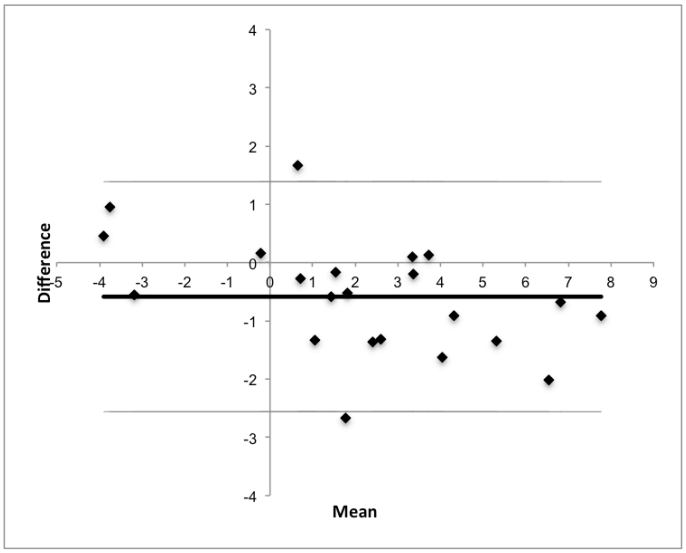
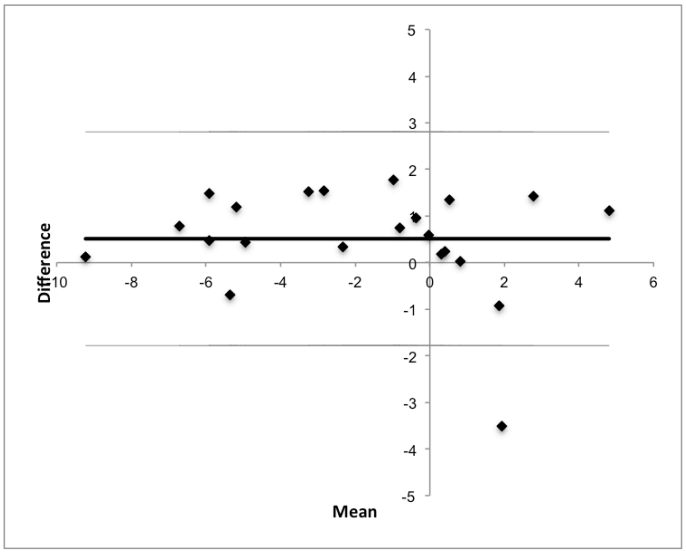
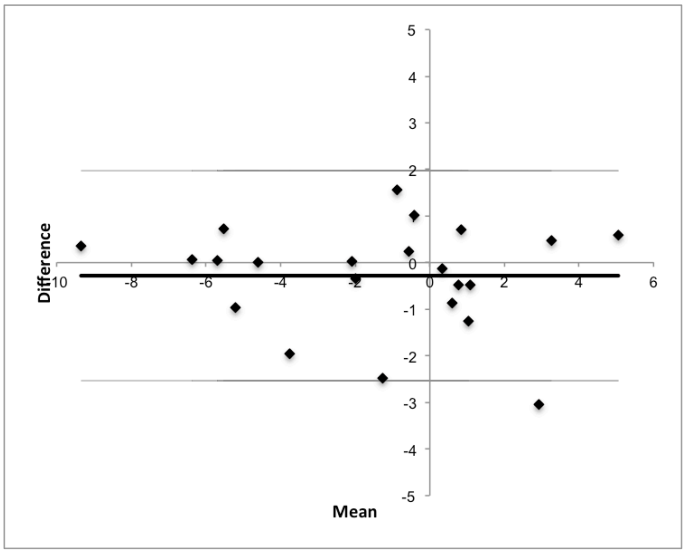


Figure 15. Convexity - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

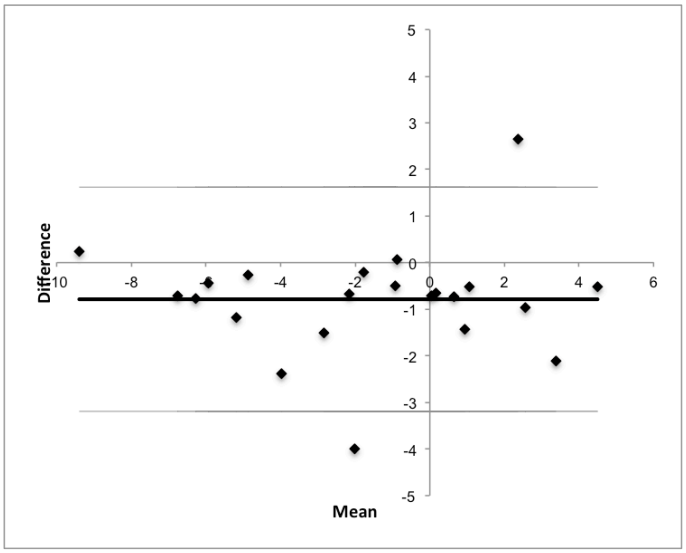
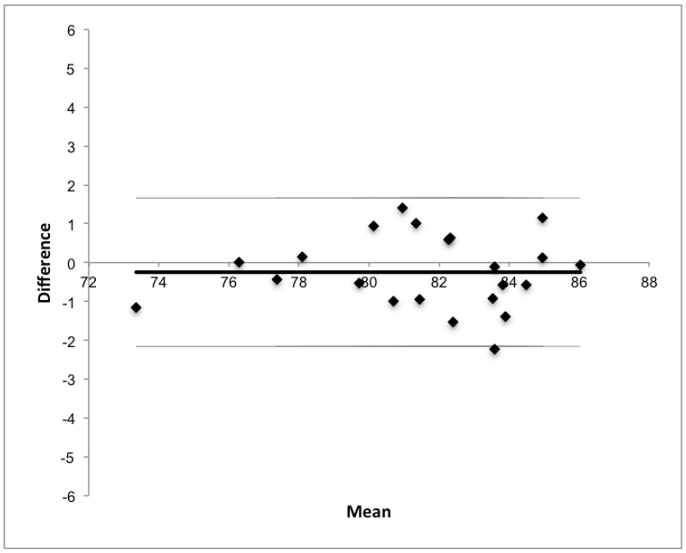
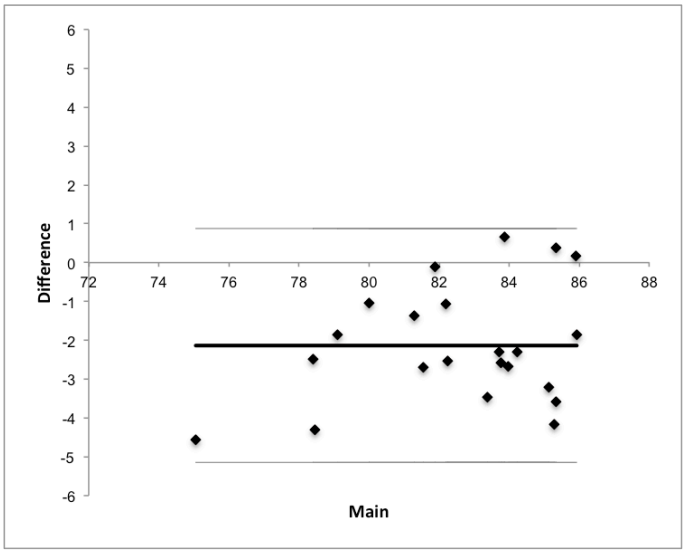


Figure 16. Lower Lip to E-Plane - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

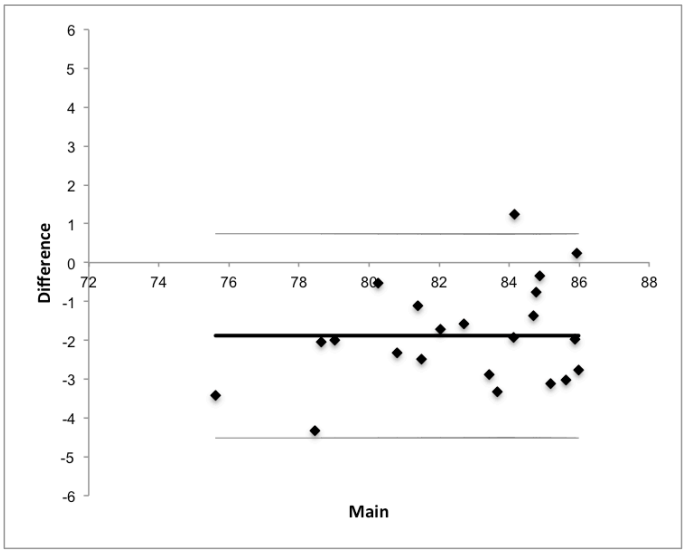
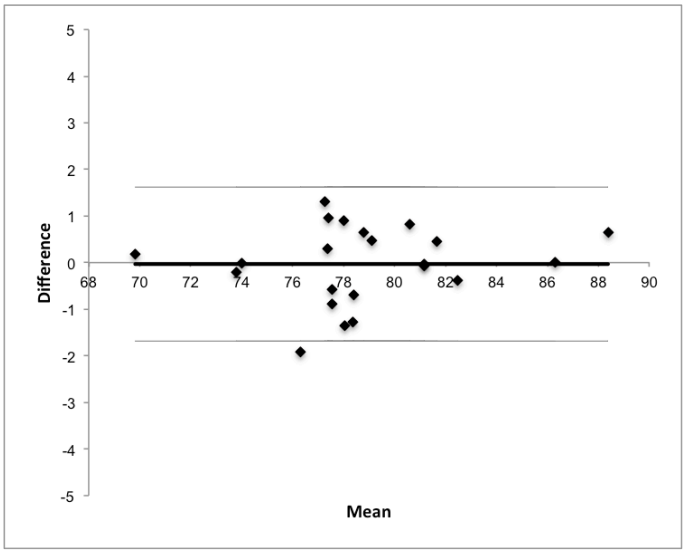
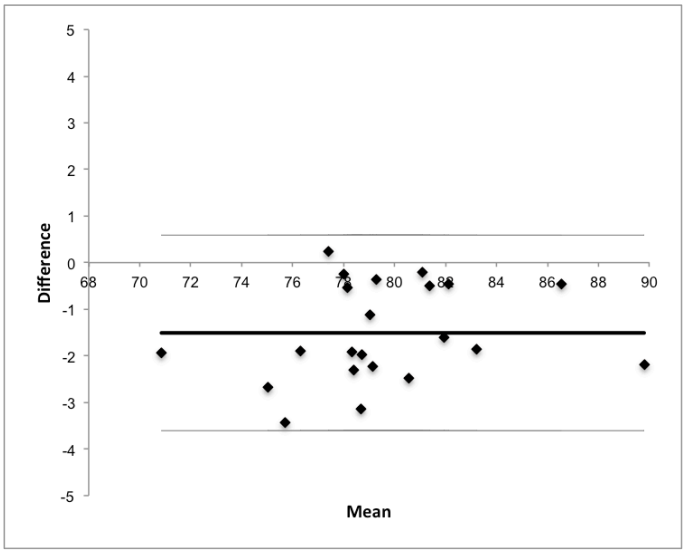


Figure 17. SNA - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

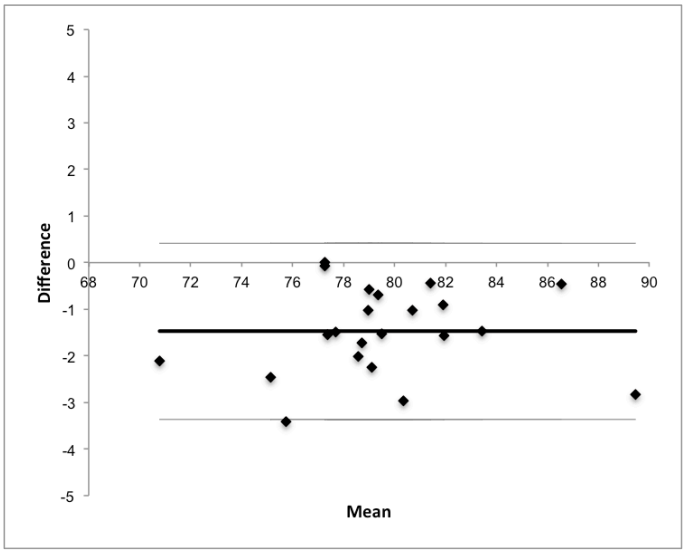
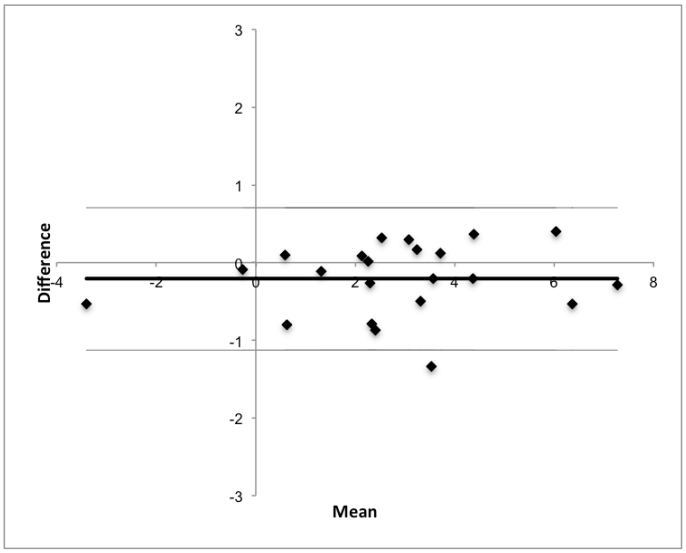
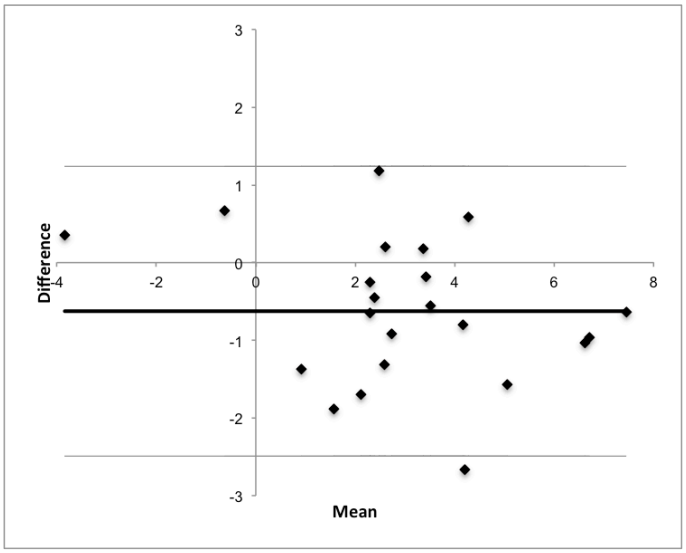


Figure 18. SNB - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

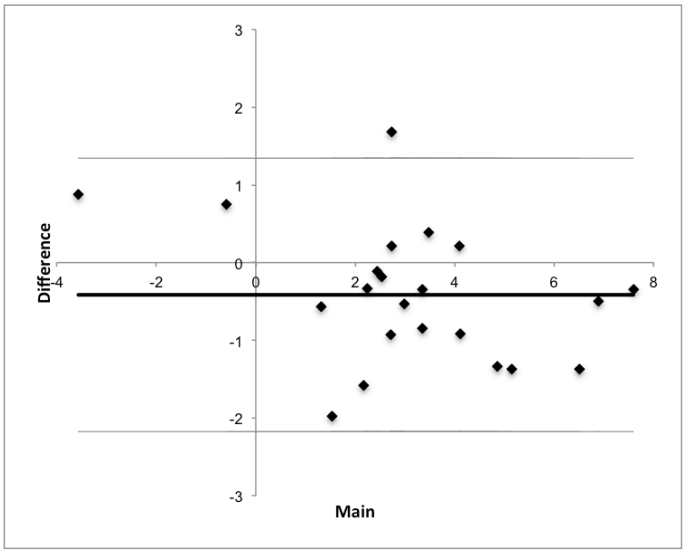
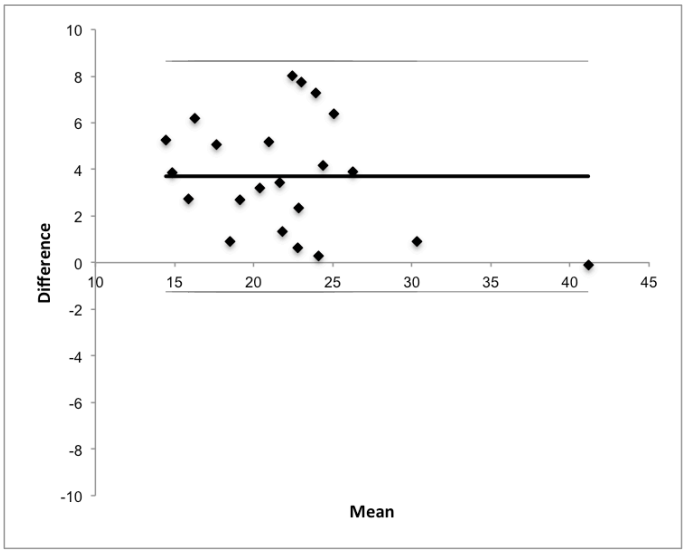
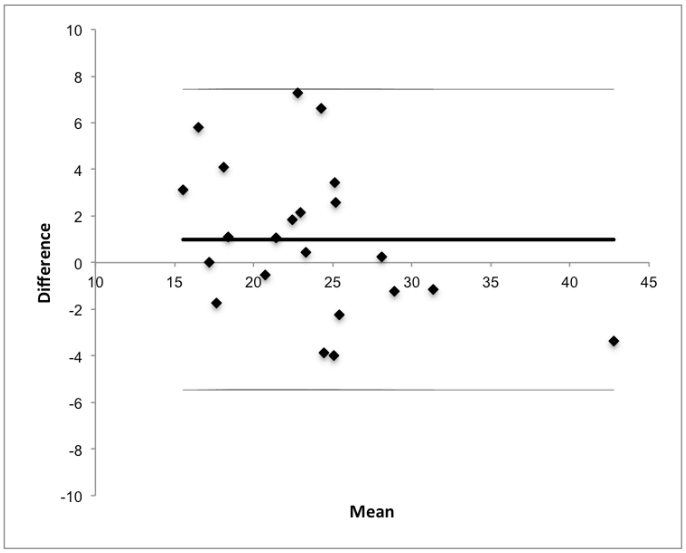


Figure 19. ANB - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

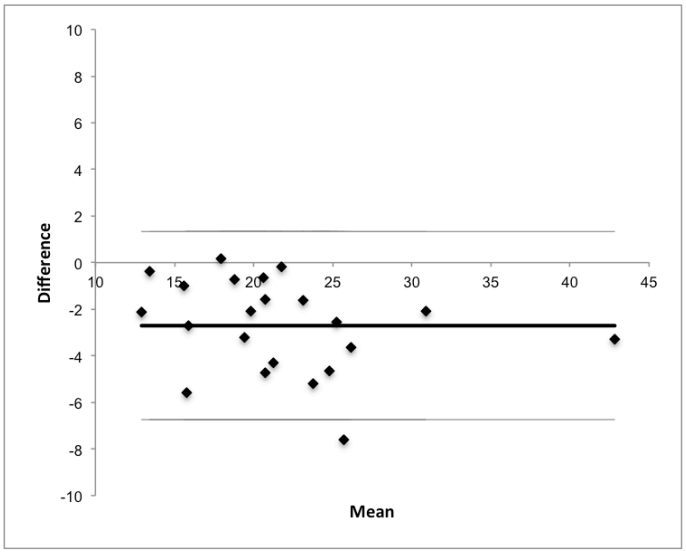
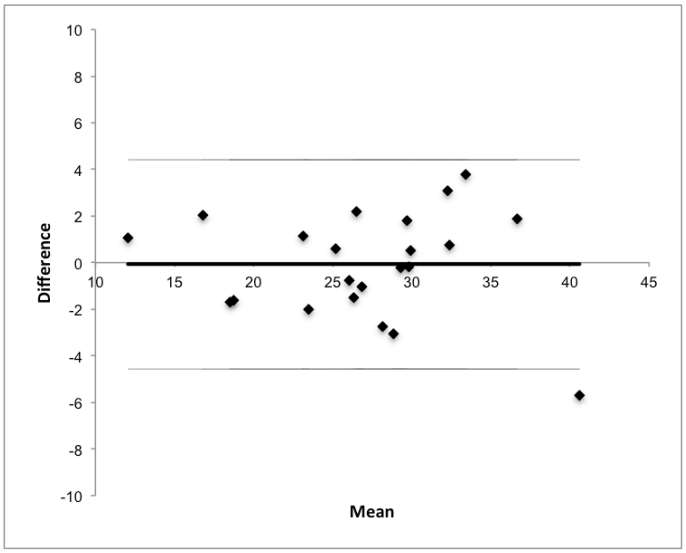
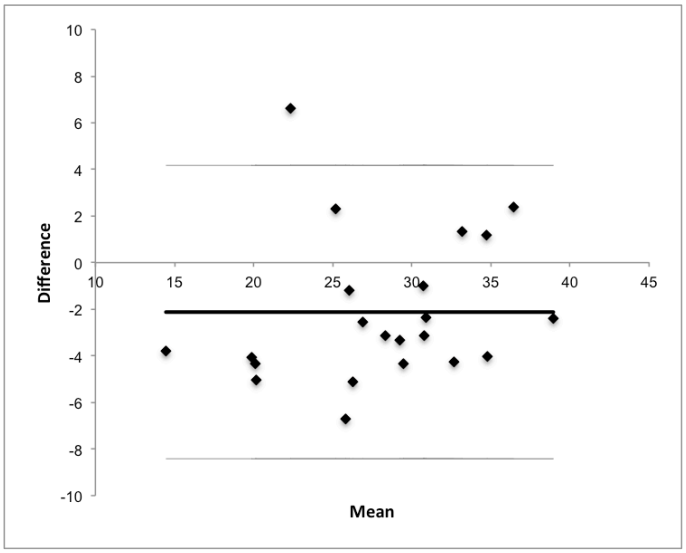


Figure 20. U1-NA Angle - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

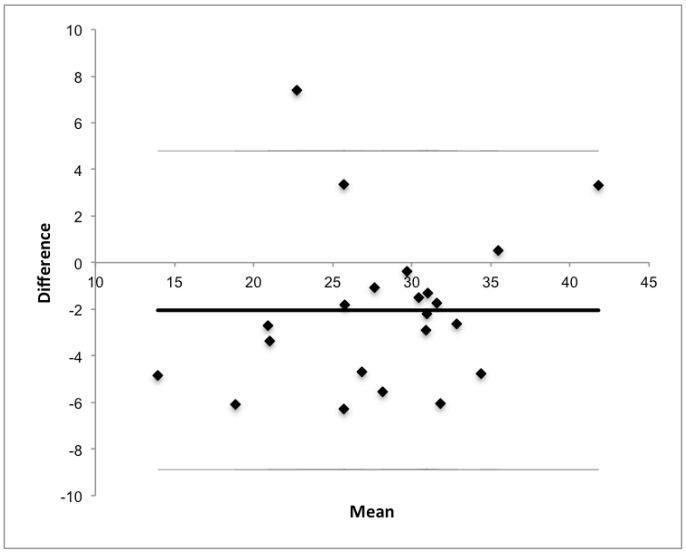
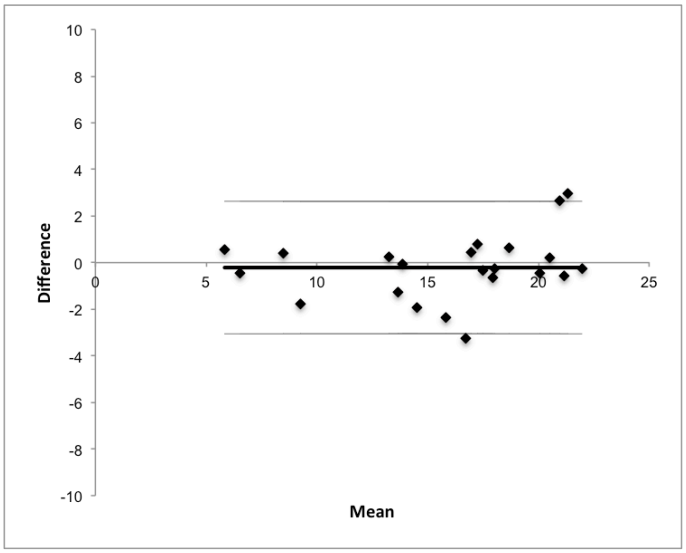
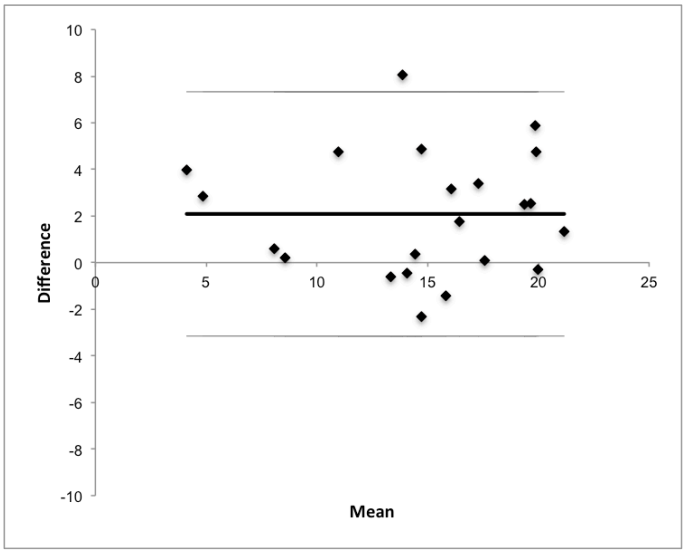


Figure 21. L1-NB Angle - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

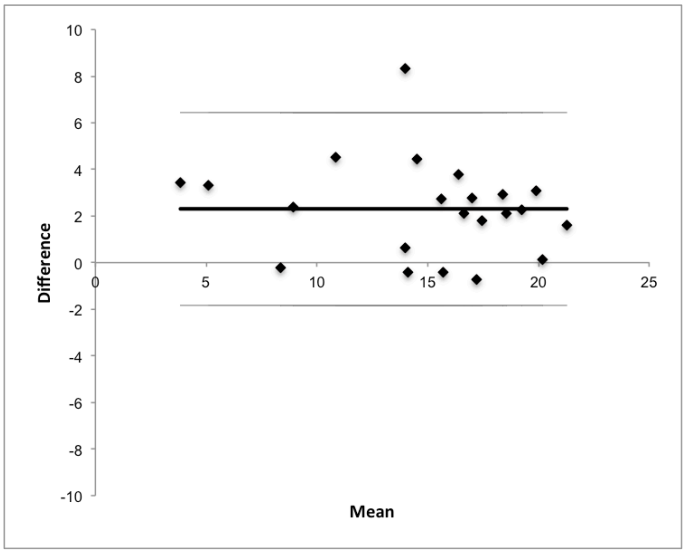
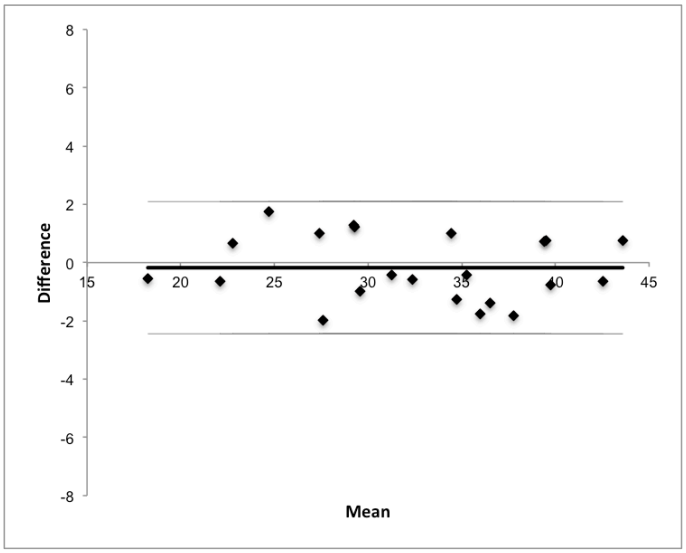
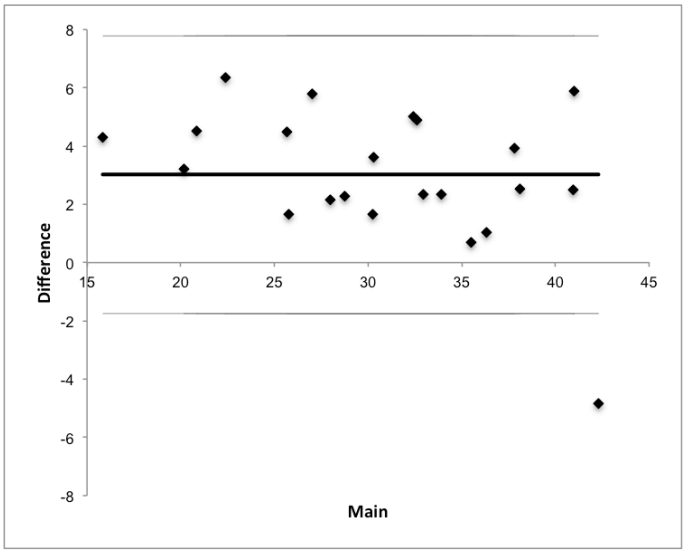


Figure 22. Occlusal Plane to SN - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

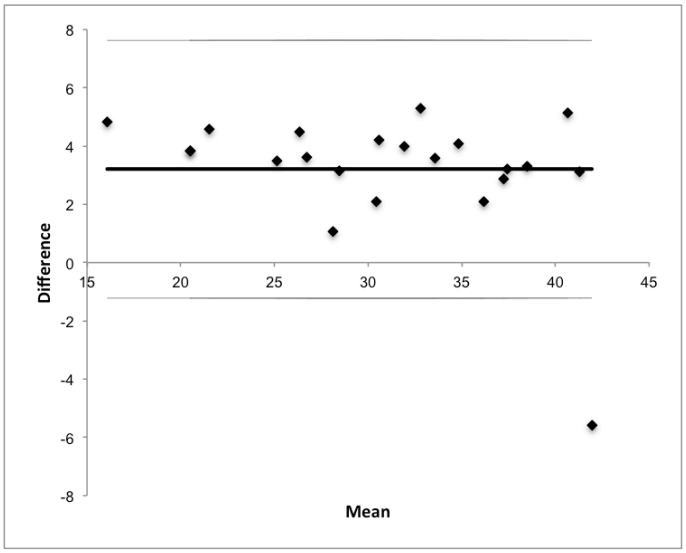
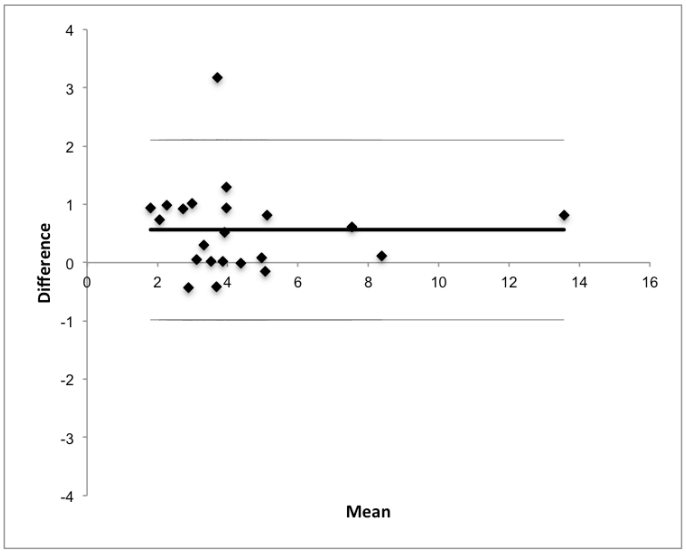
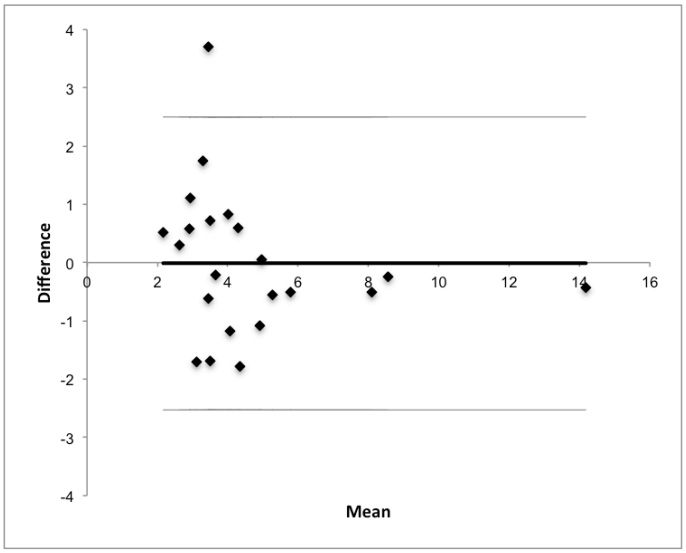


Figure 23. SN-MP - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

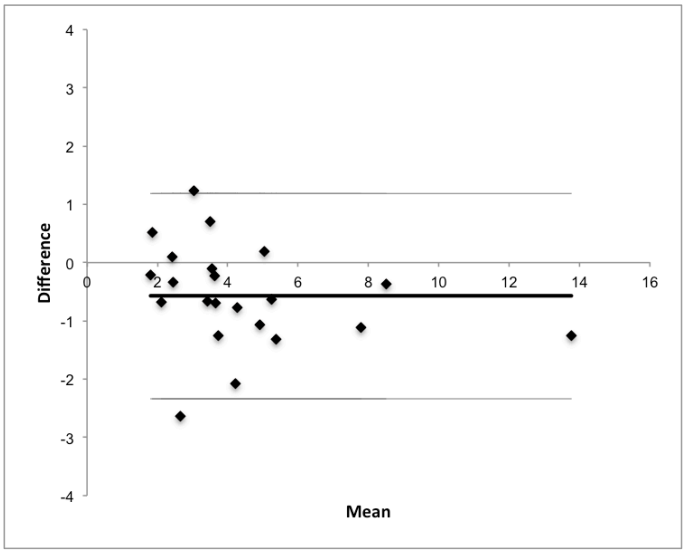
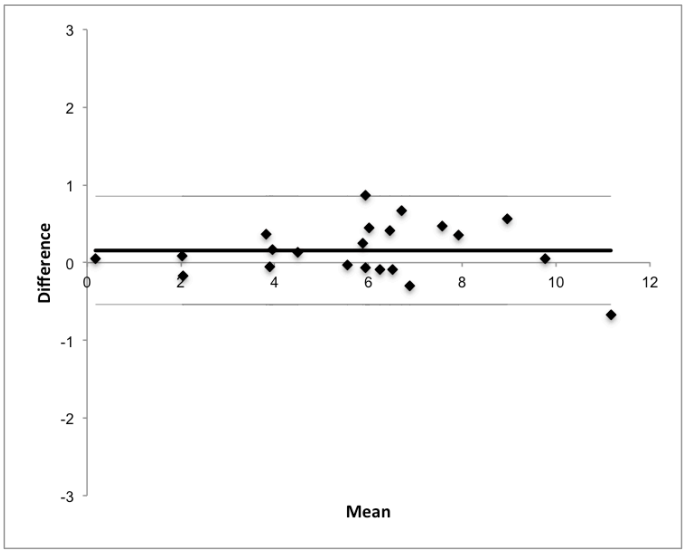
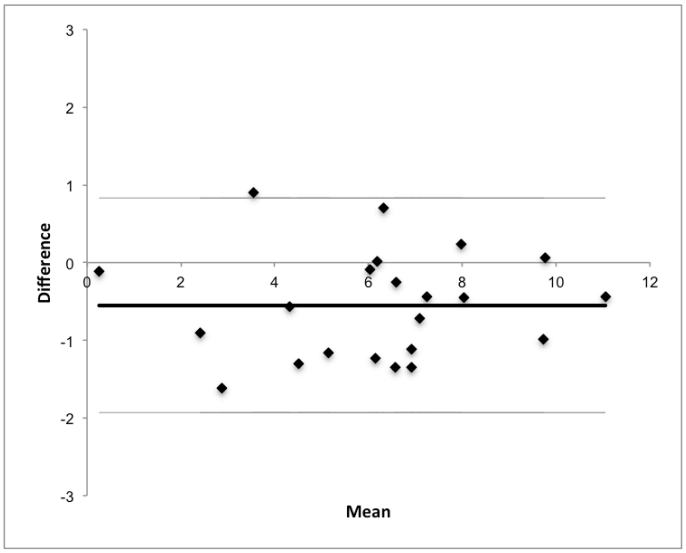


Figure 24. U1-NA Distance - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

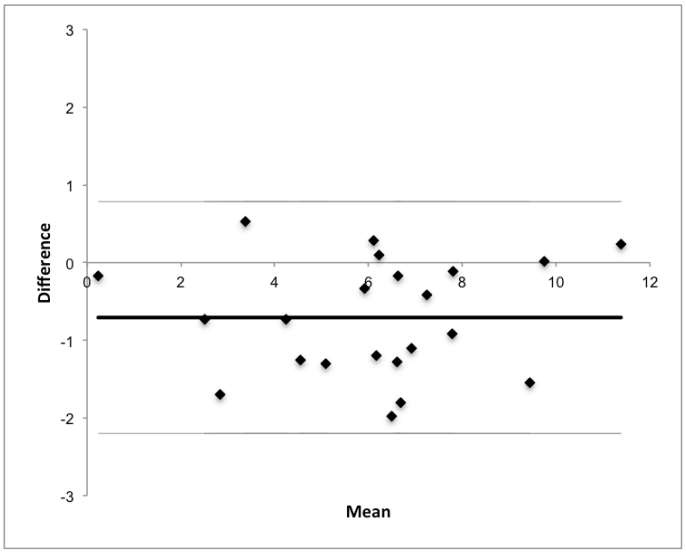
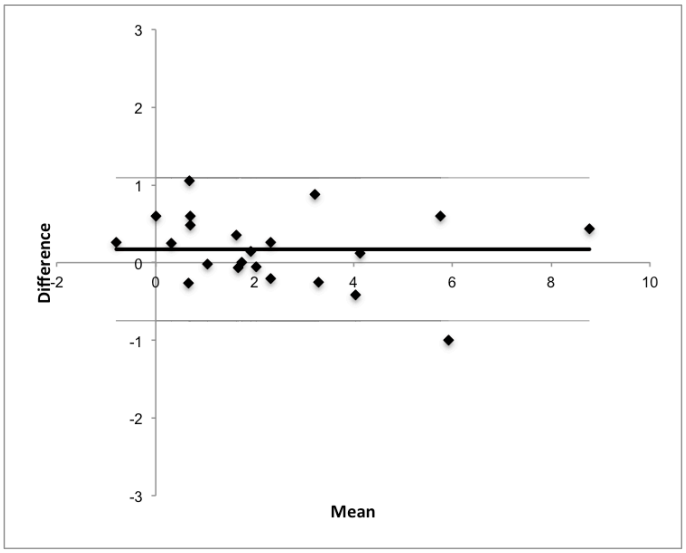
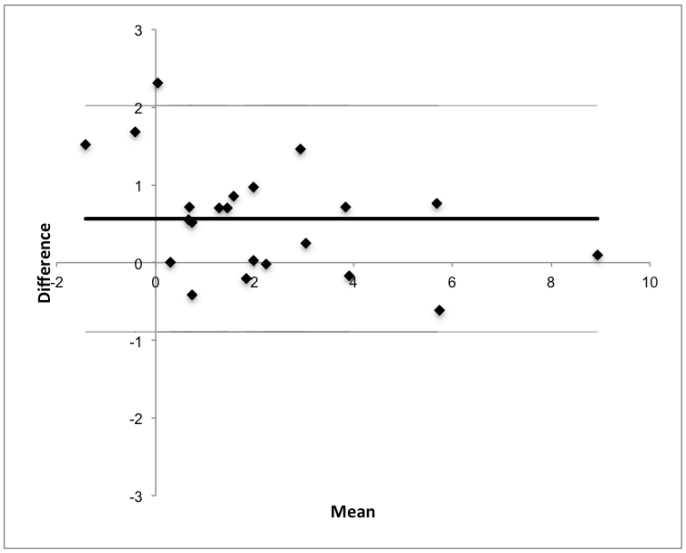


Figure 25. L1-NB Distance - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

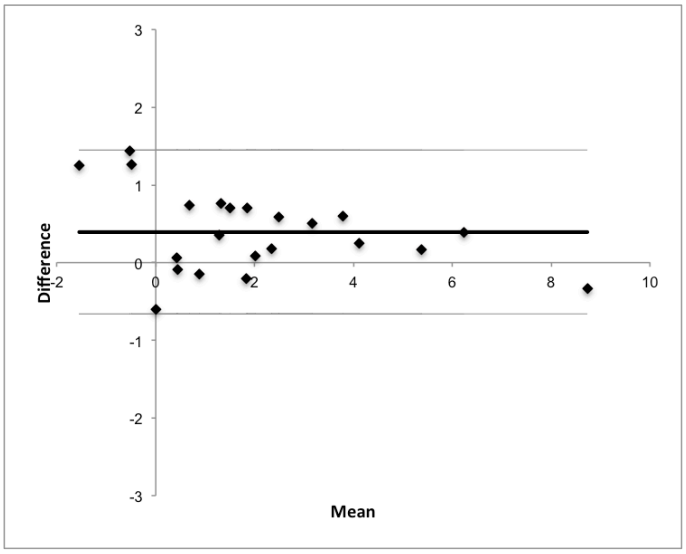
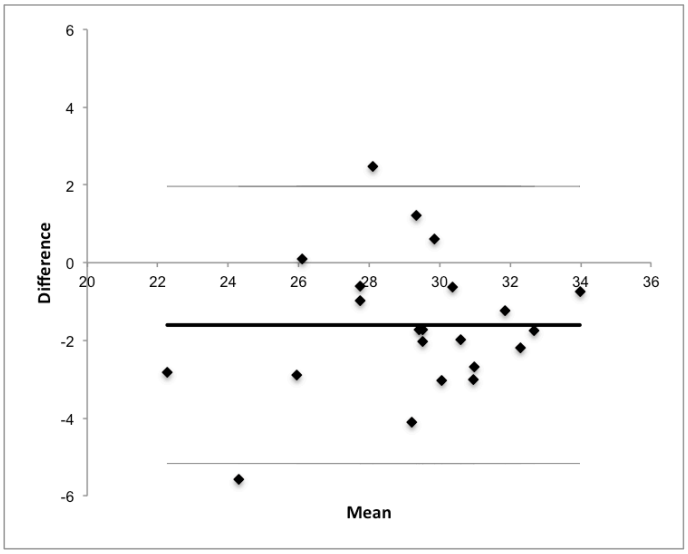
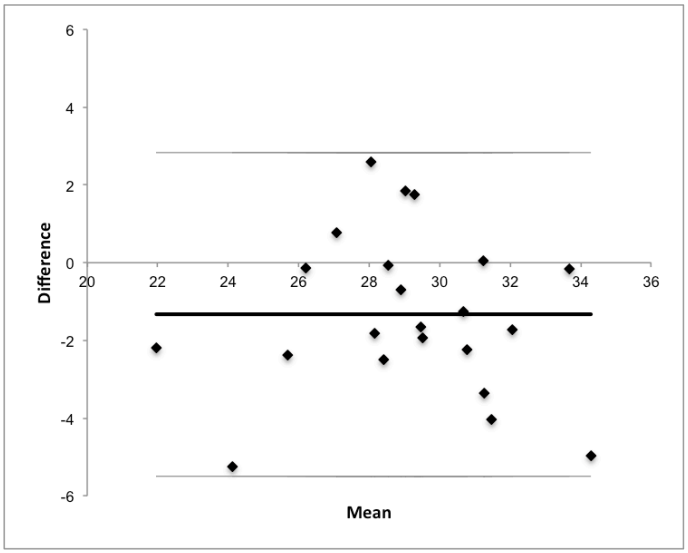


Figure 26. Pog-NB - 3 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

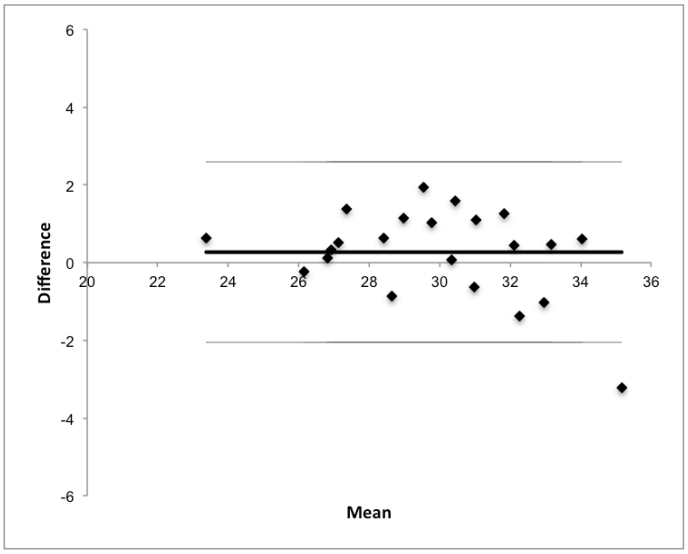
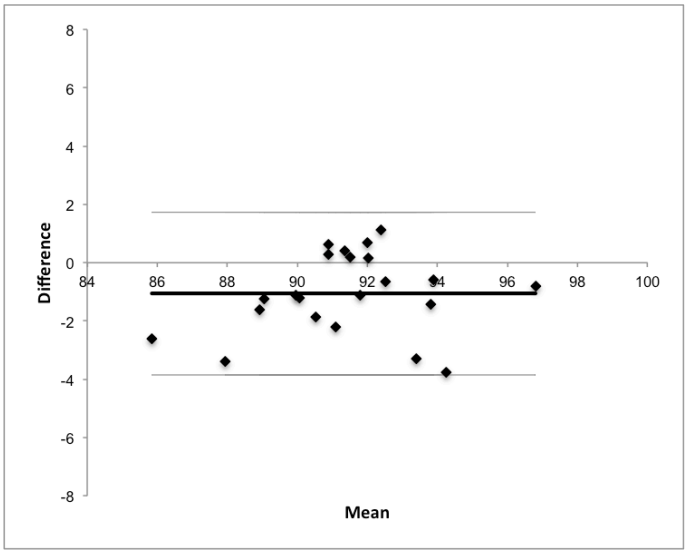
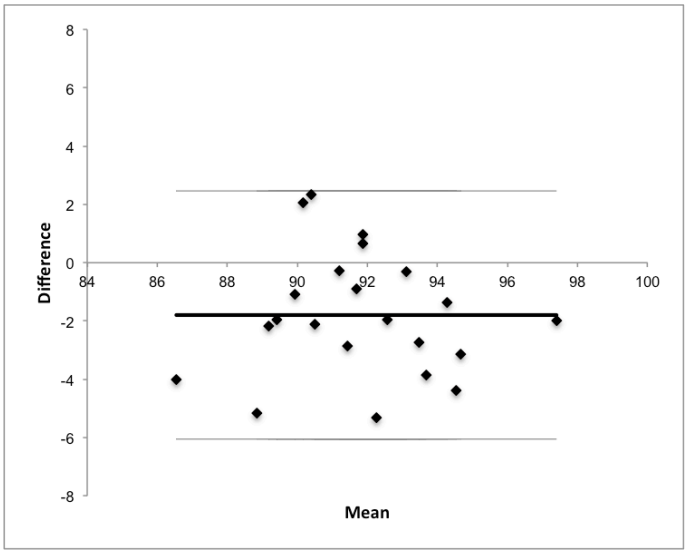


Figure 27. Cranial Deflection - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

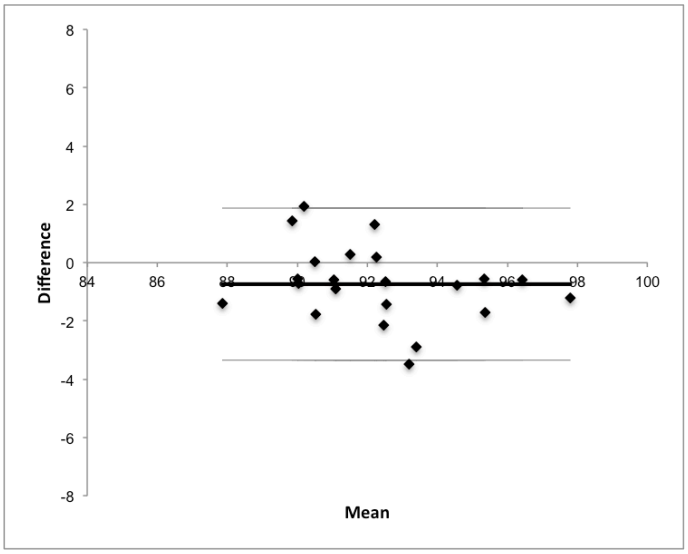
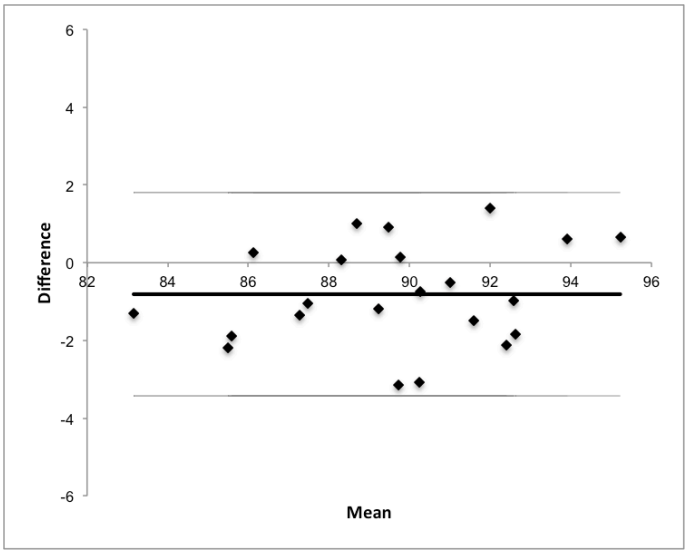
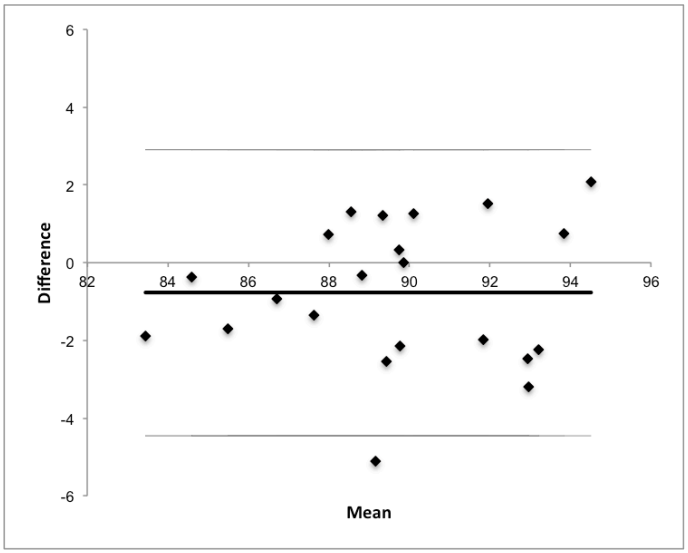


Figure 28. Maxillary Depth - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

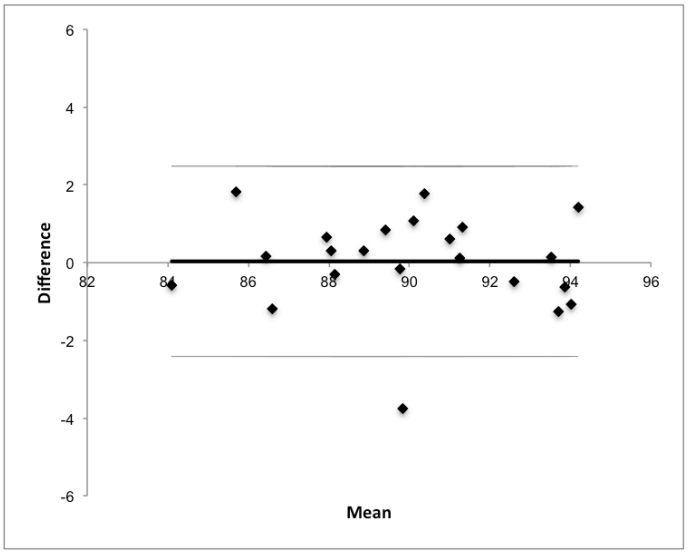
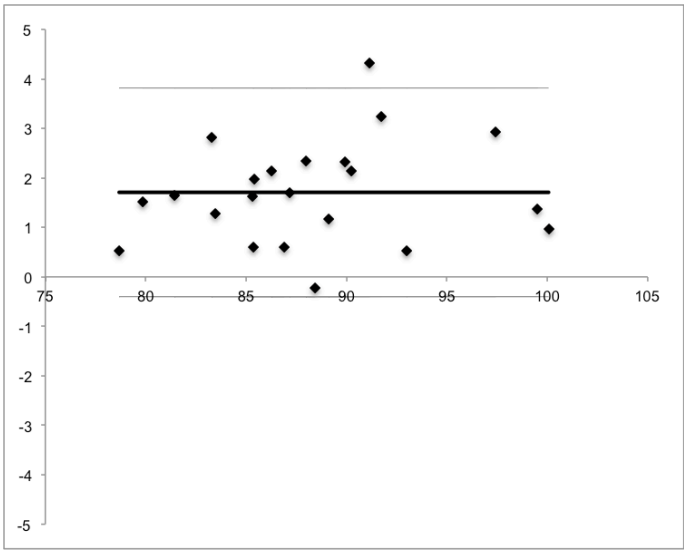
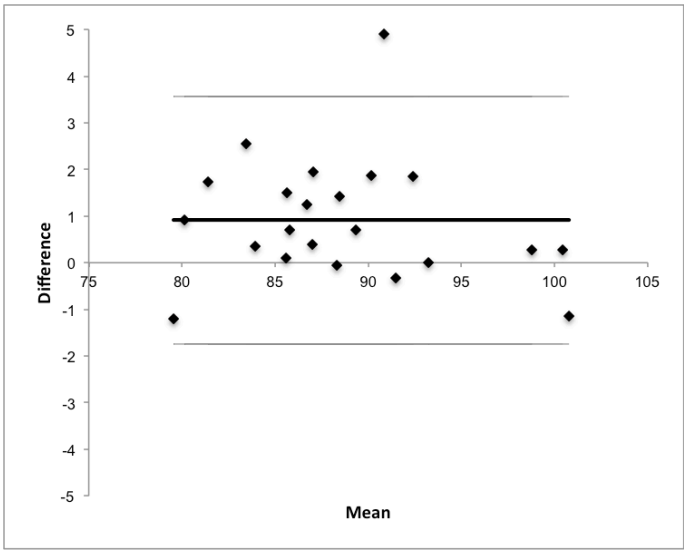


Figure 29. Facial Depth - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

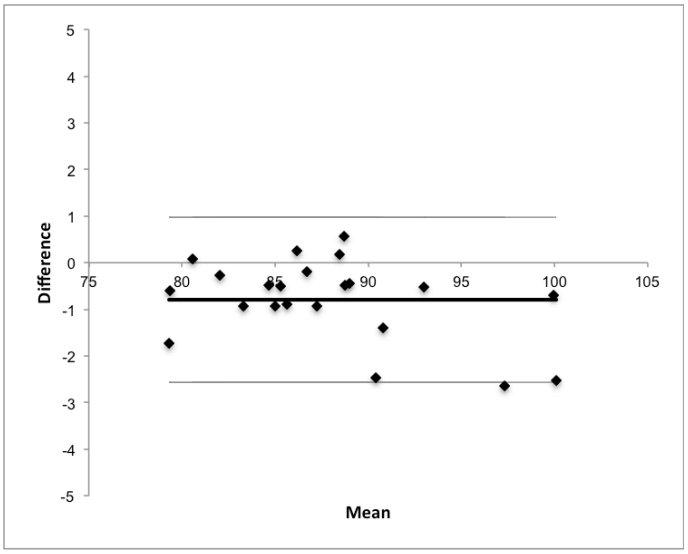
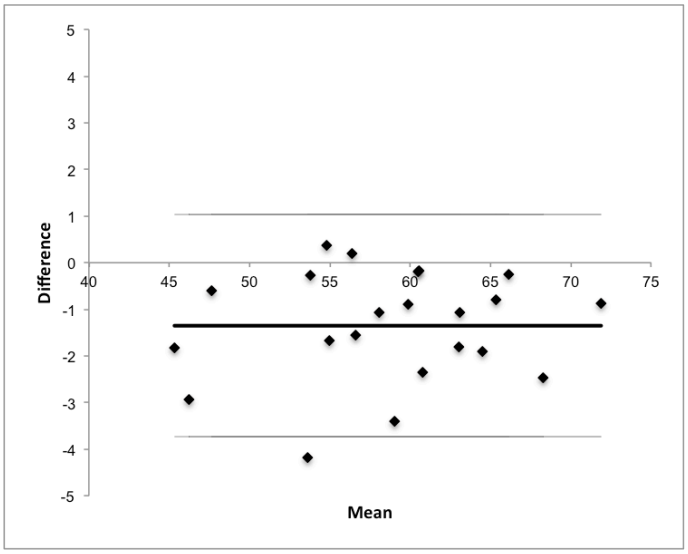
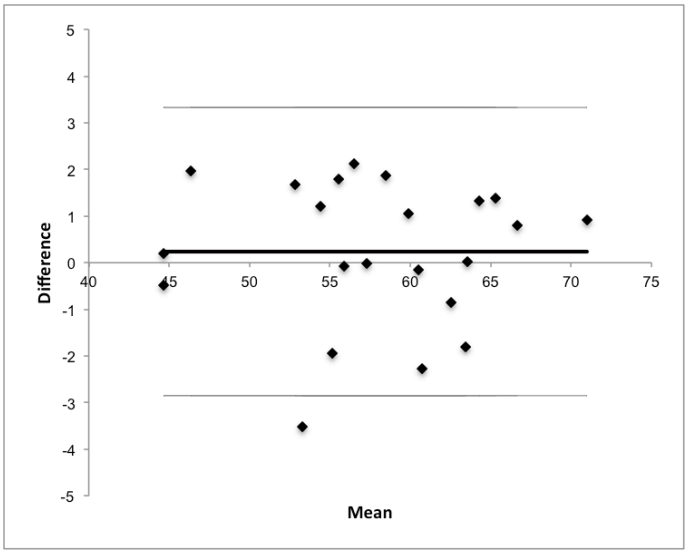


Figure 30. Facial Axis - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

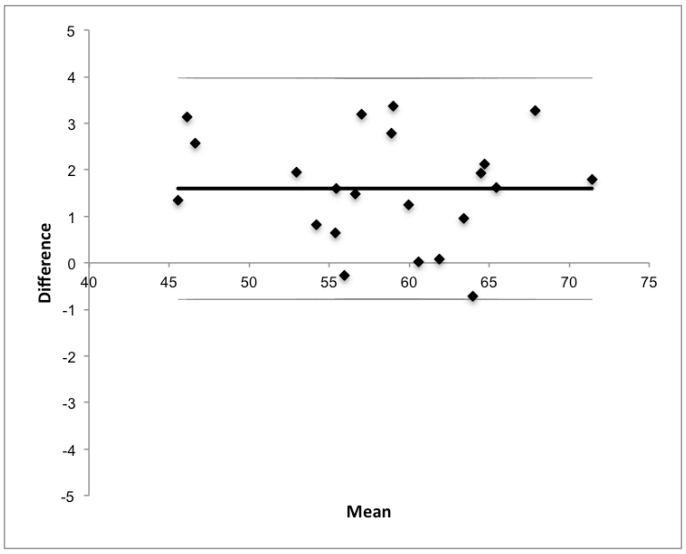
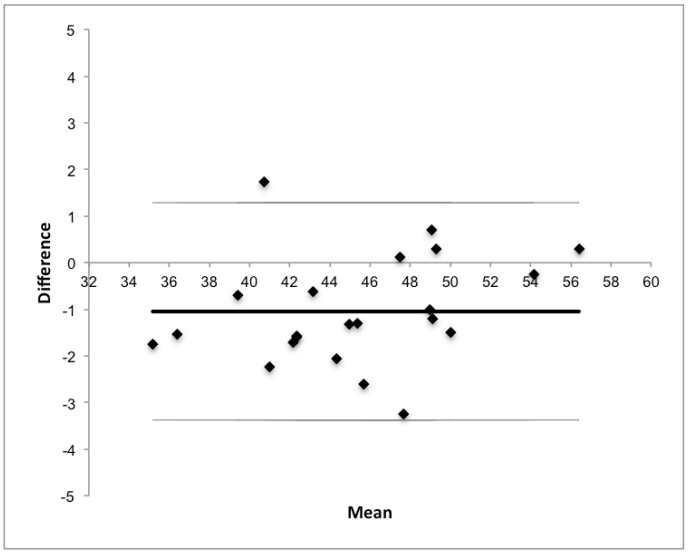
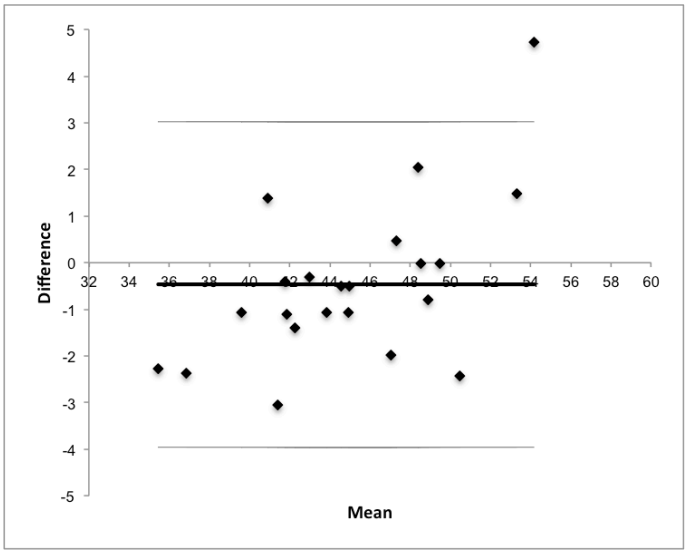


Figure 31. Total Face Height - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

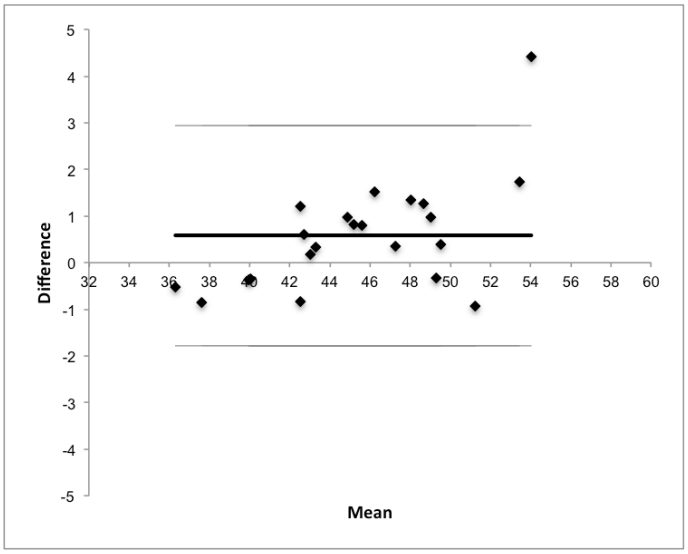
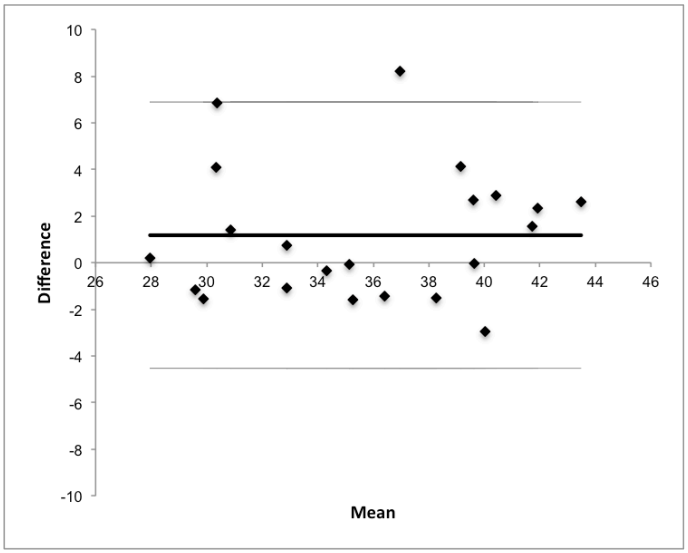
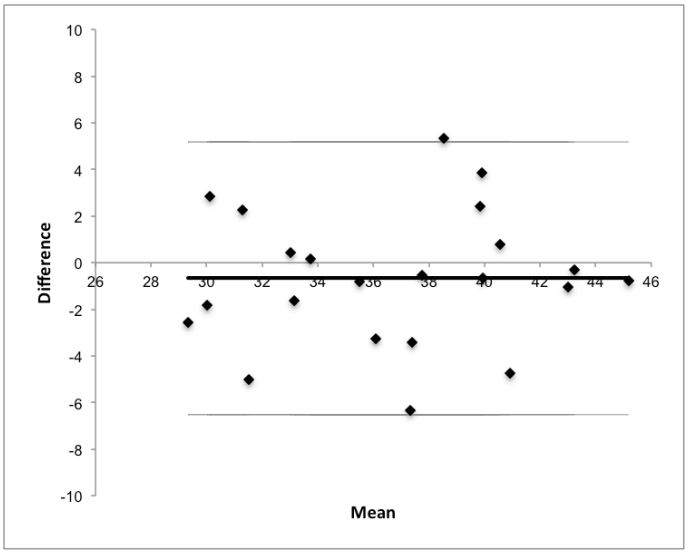


Figure 32. Lower Face Height - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

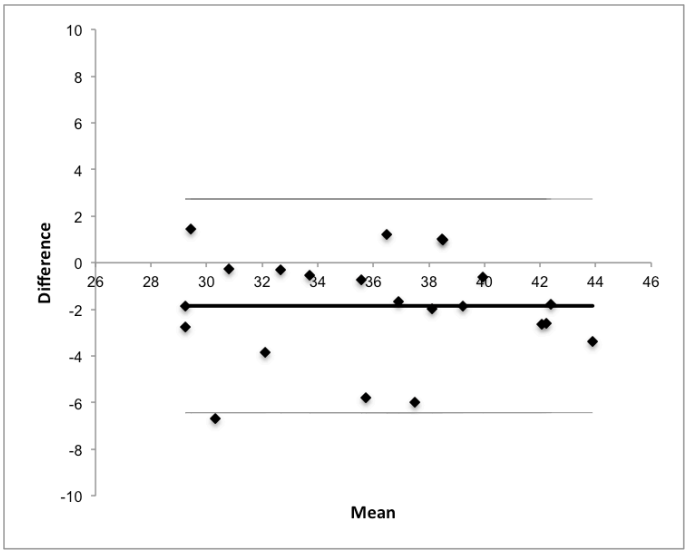
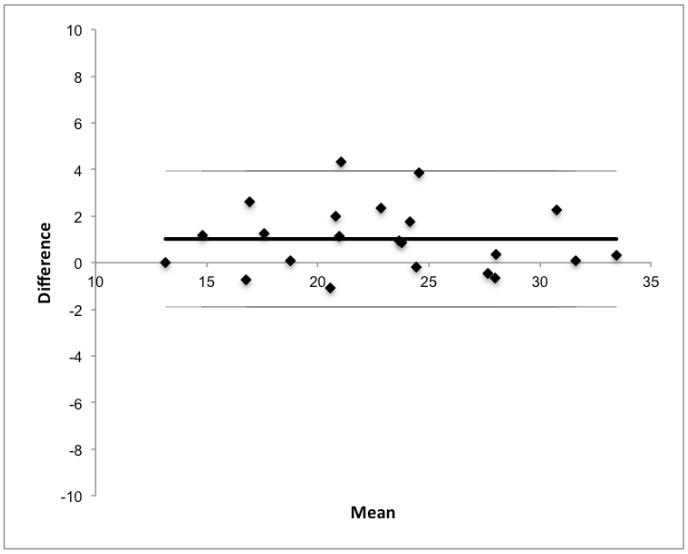
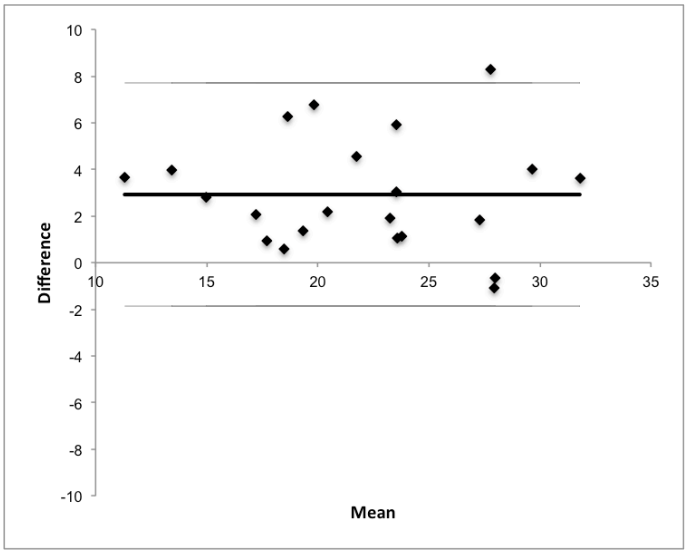


Figure 33. Mandibular Arc - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

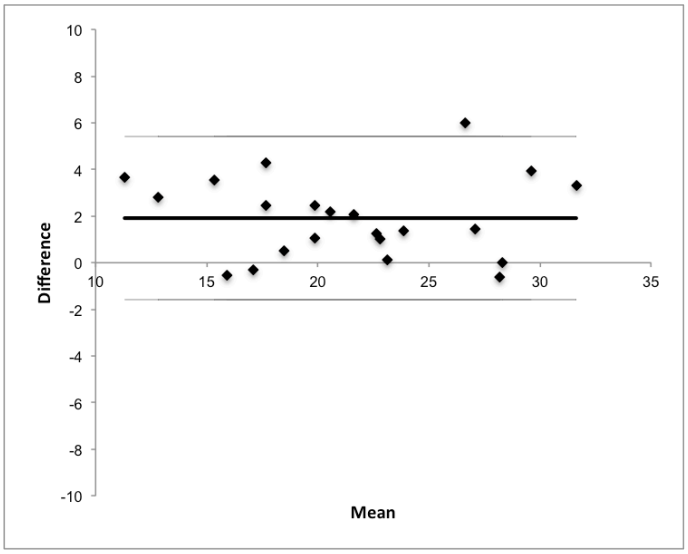
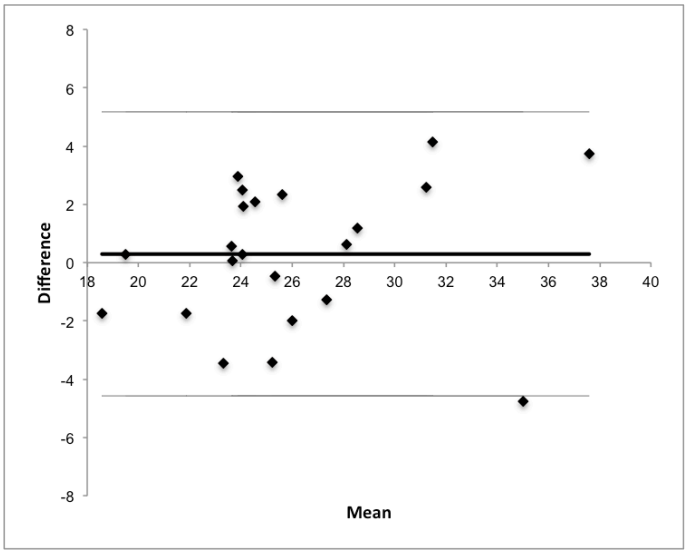
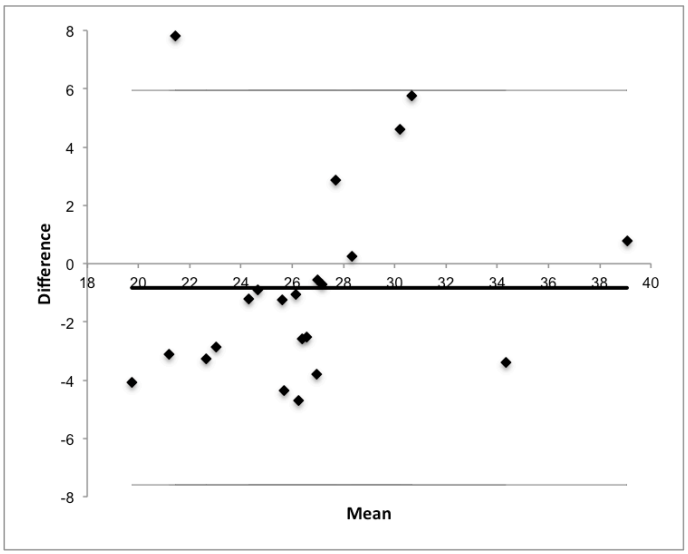


Figure 34. Mandibular Plane Angle - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

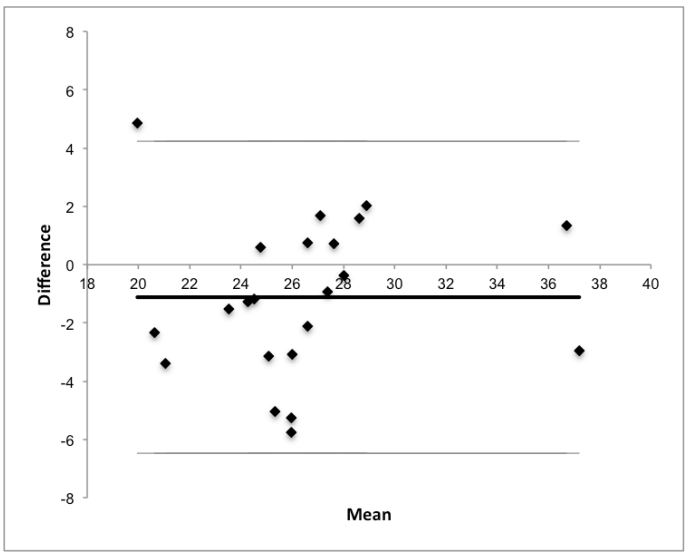
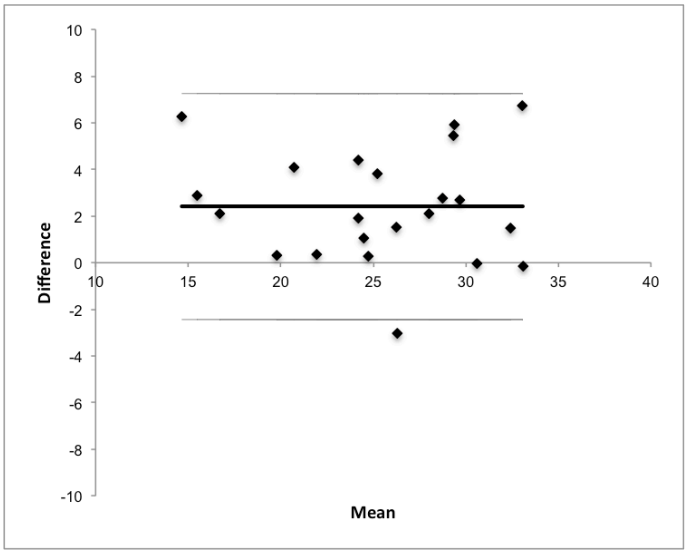
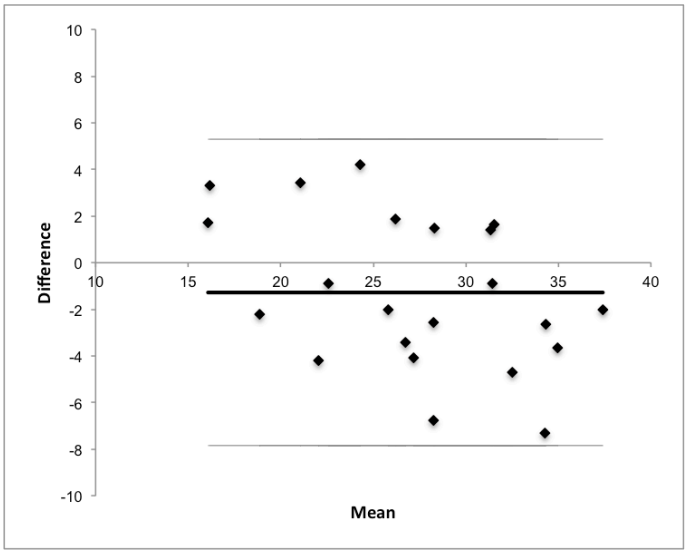


Figure 35. L1 to A-Po Angle - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

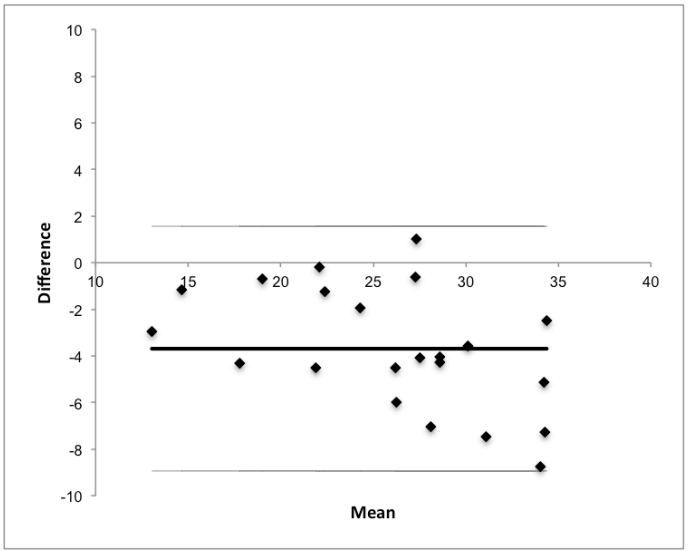
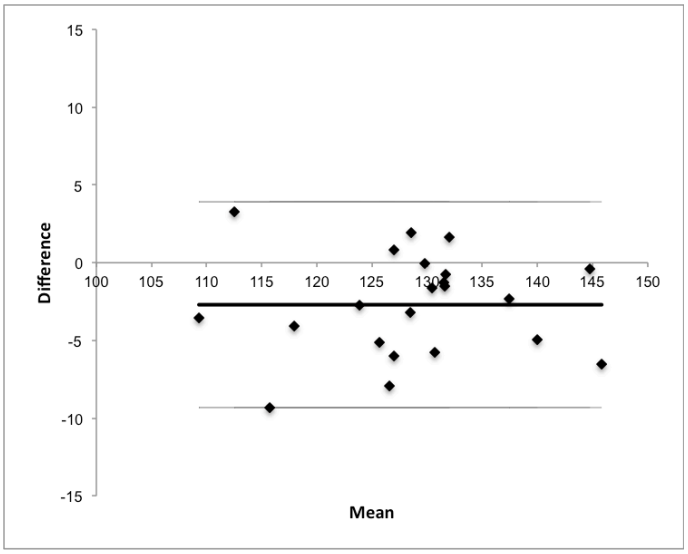
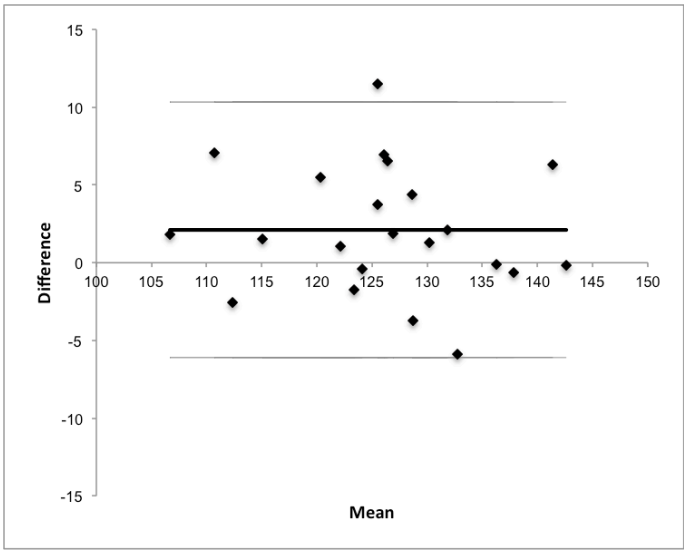


Figure 36. U1 to A-Po Angle - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

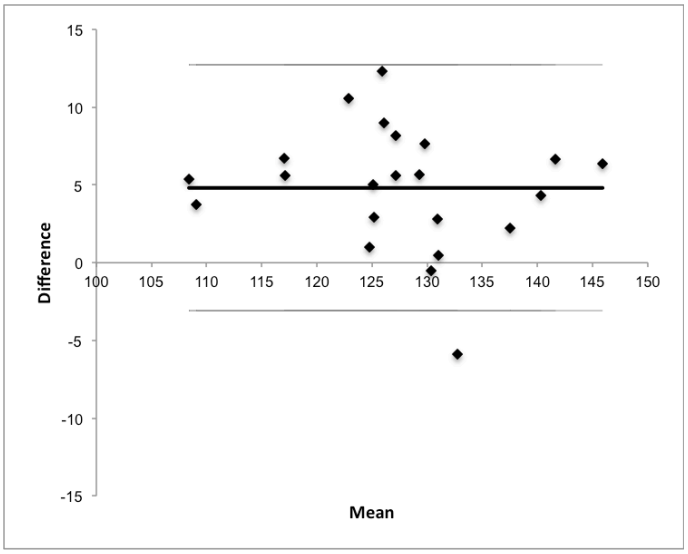
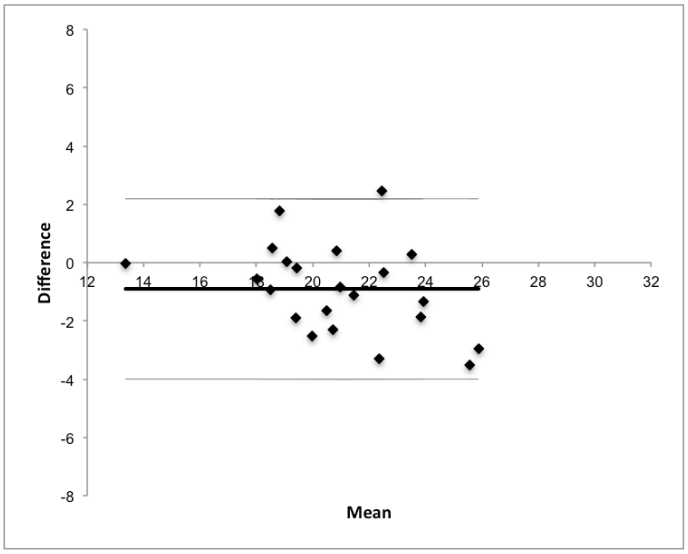
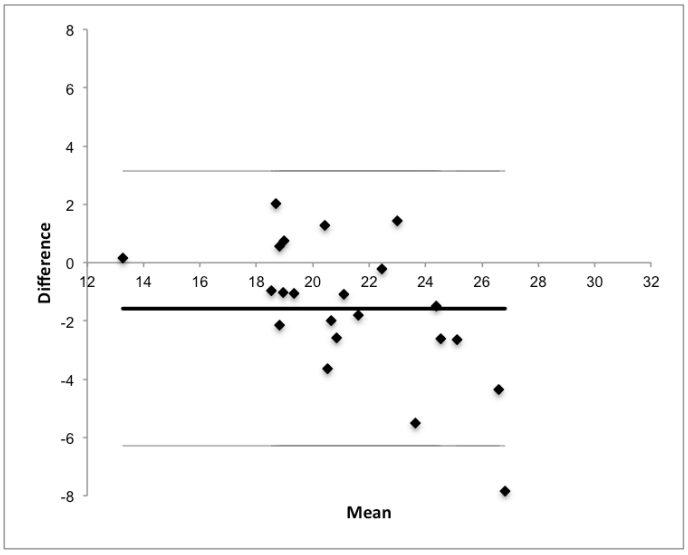


Figure 37. Interincisal Angle - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

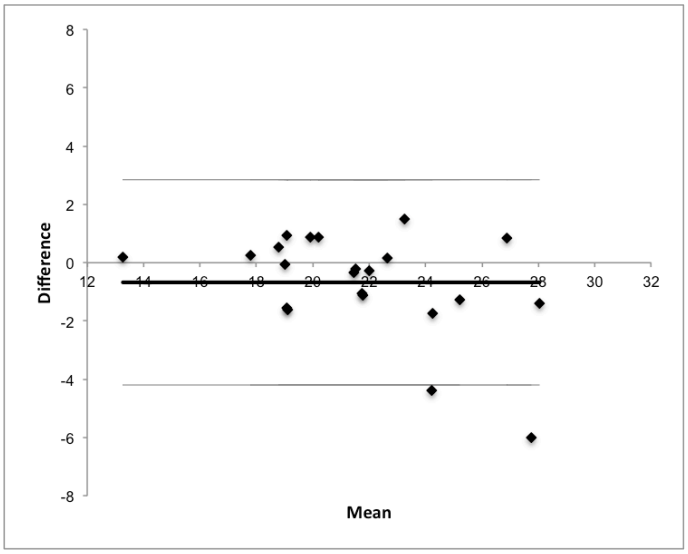
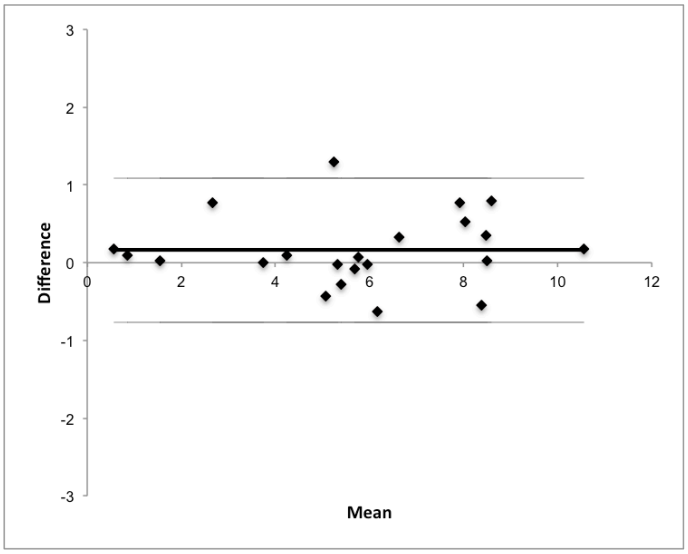
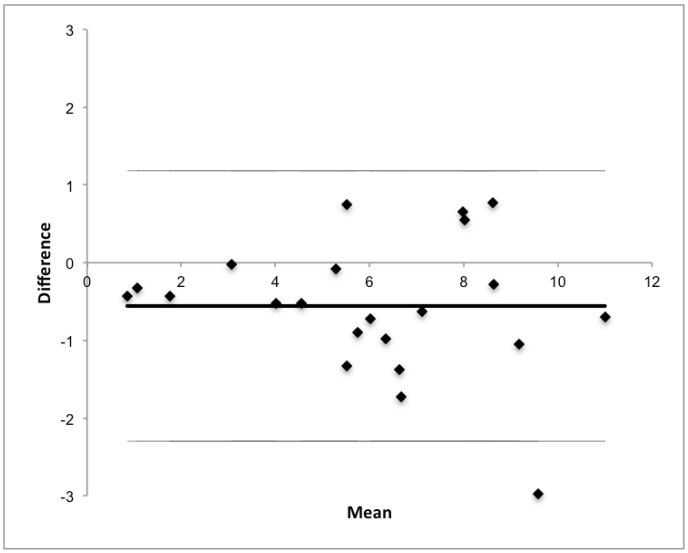


Figure 38. U6 to PtV - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

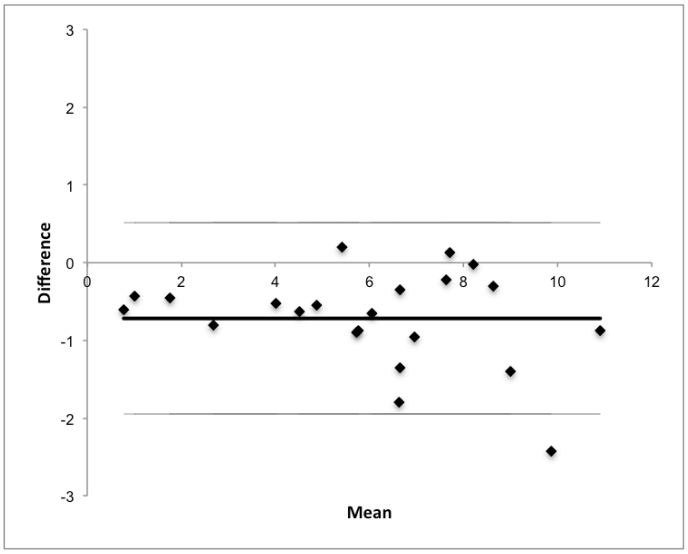
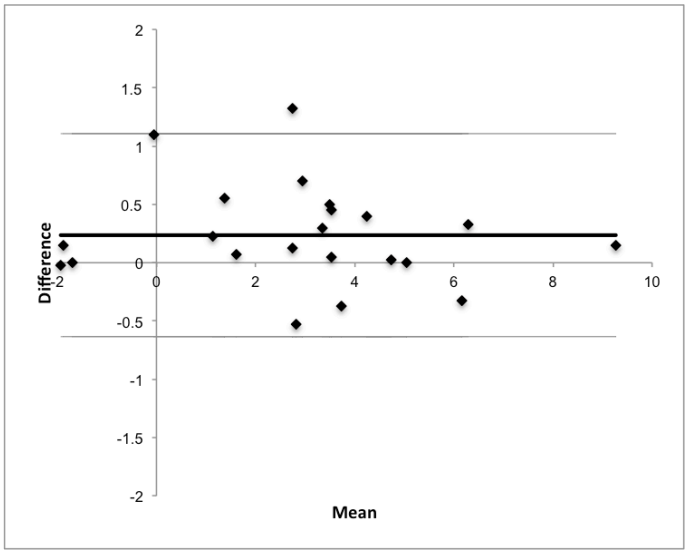
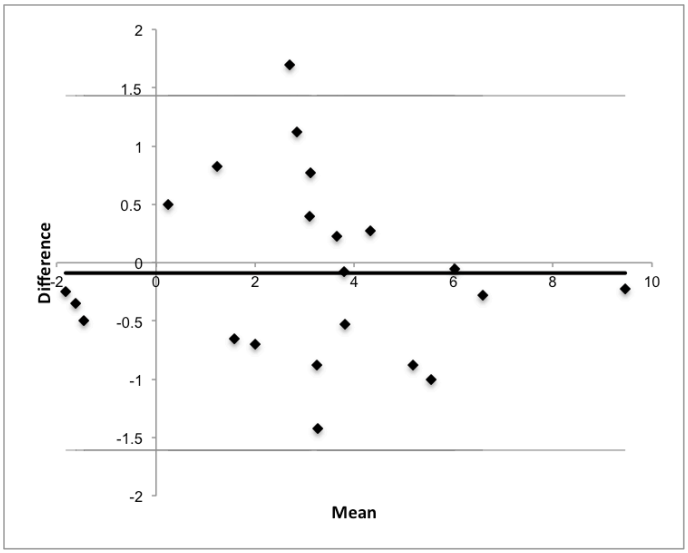


Figure 39. U1 Protrusion - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

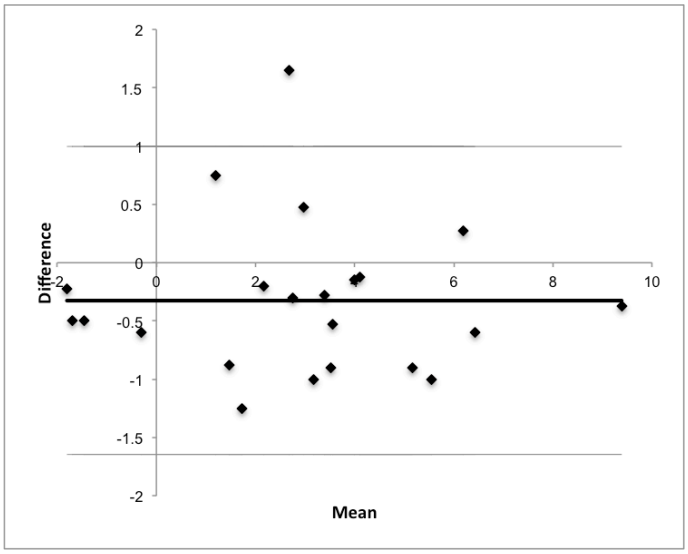
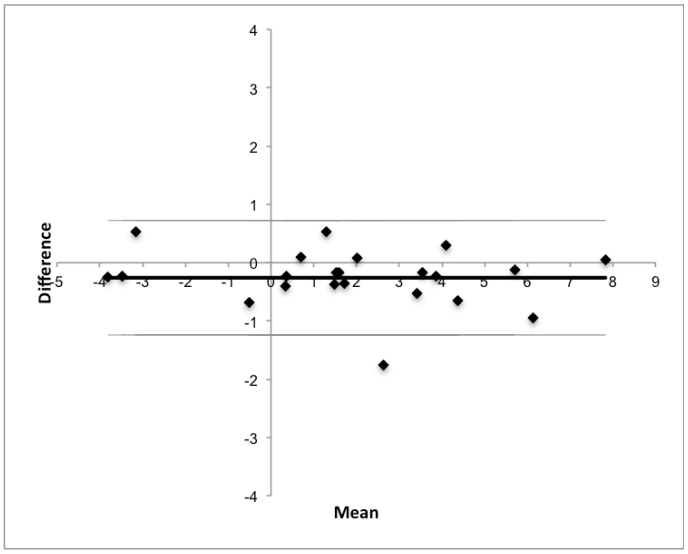
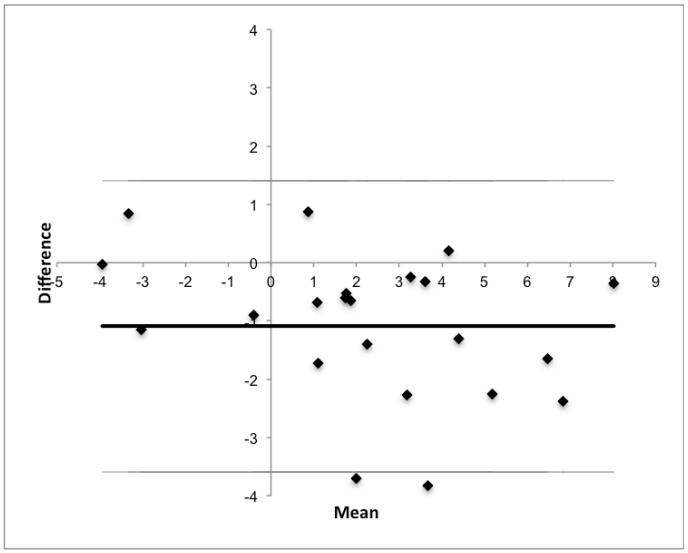


Figure 40. L1 Protrusion - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

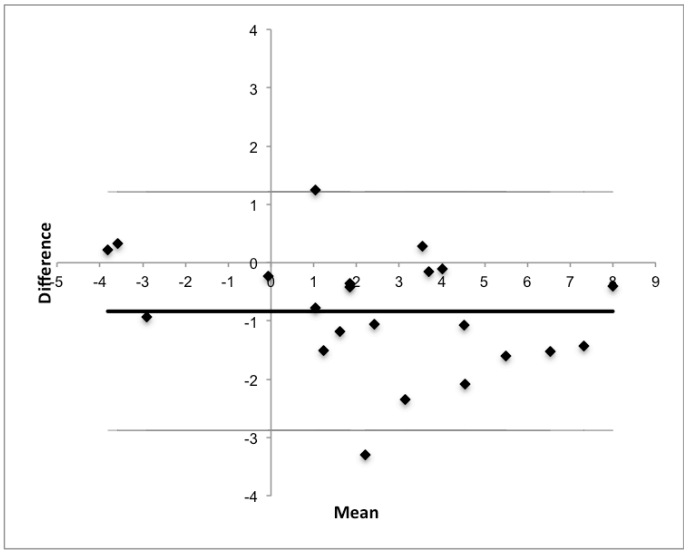
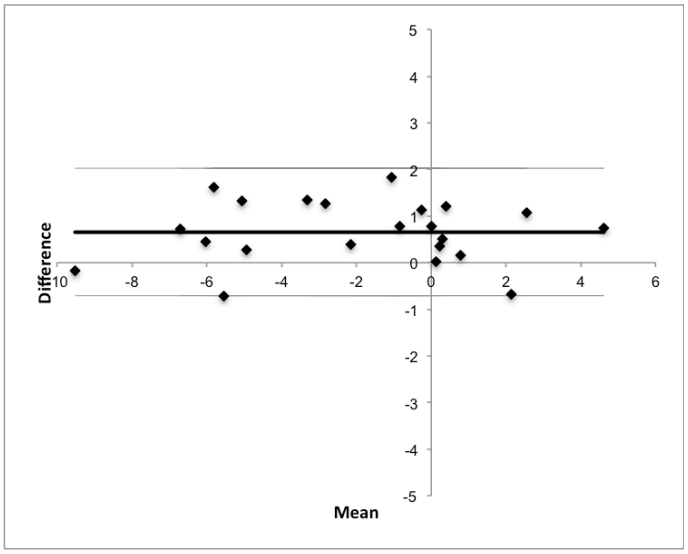
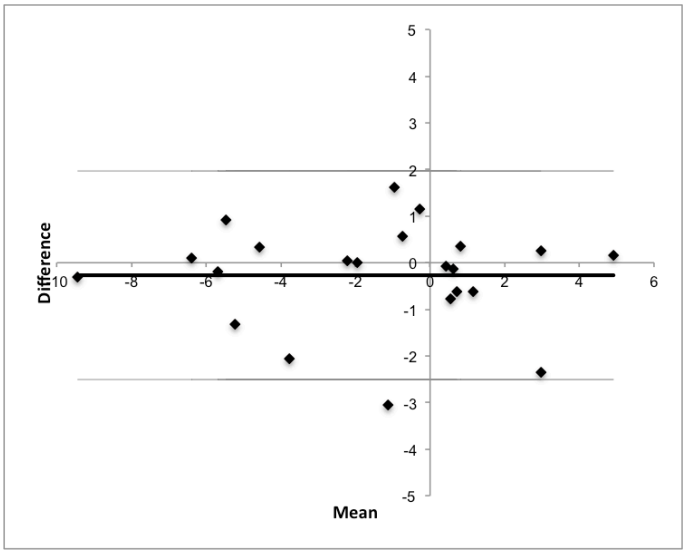


Figure 41. Convexity - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

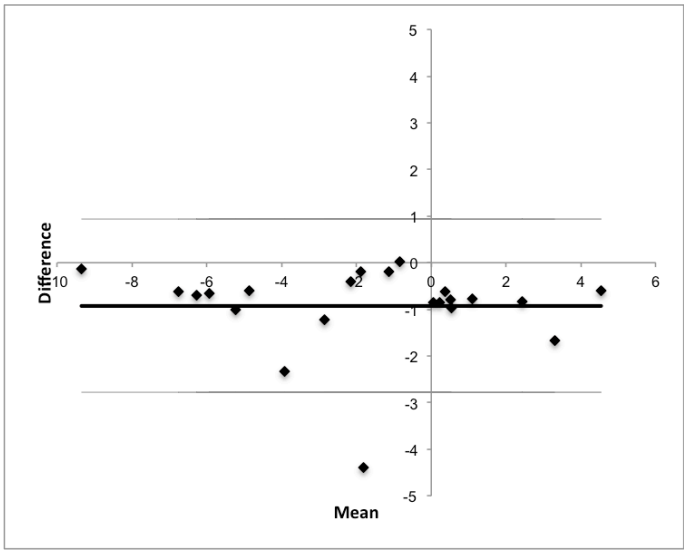
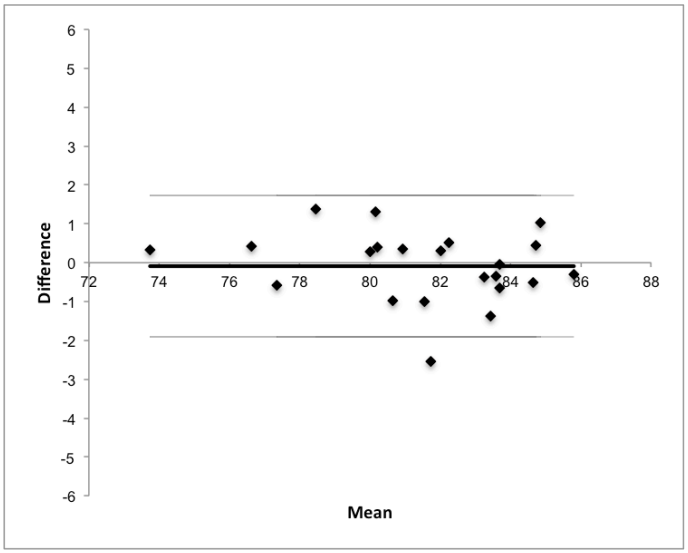
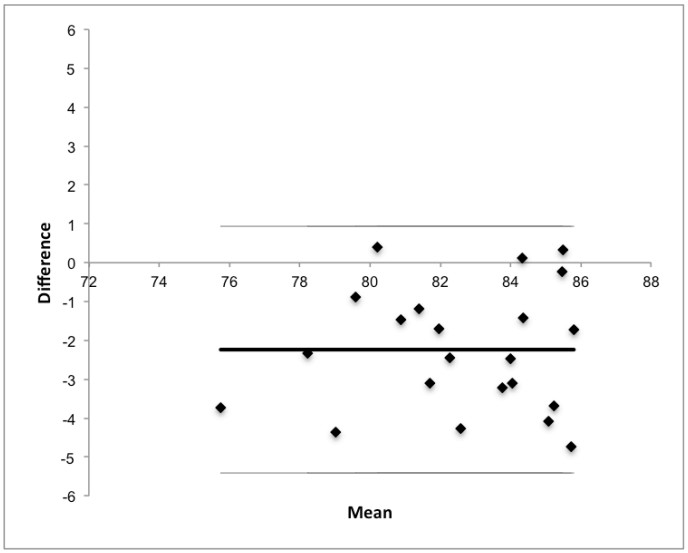


Figure 42. Lower Lip to E-Plane - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

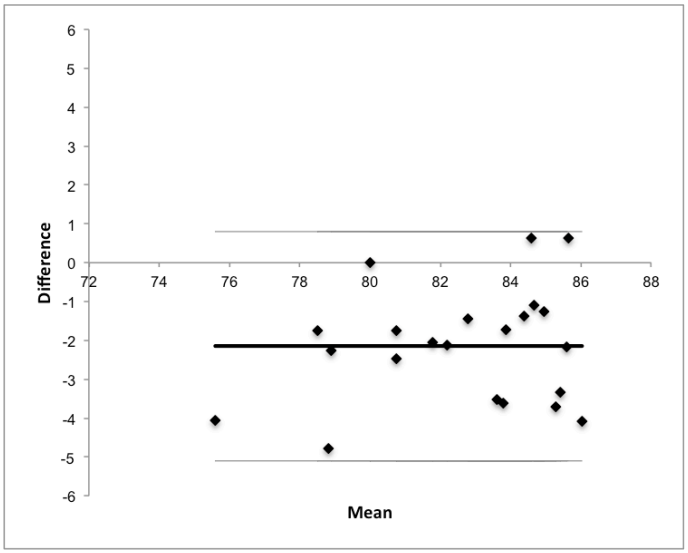
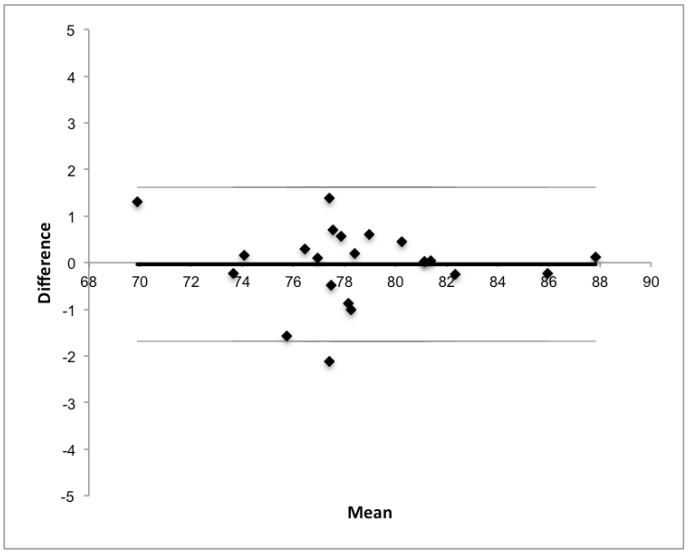
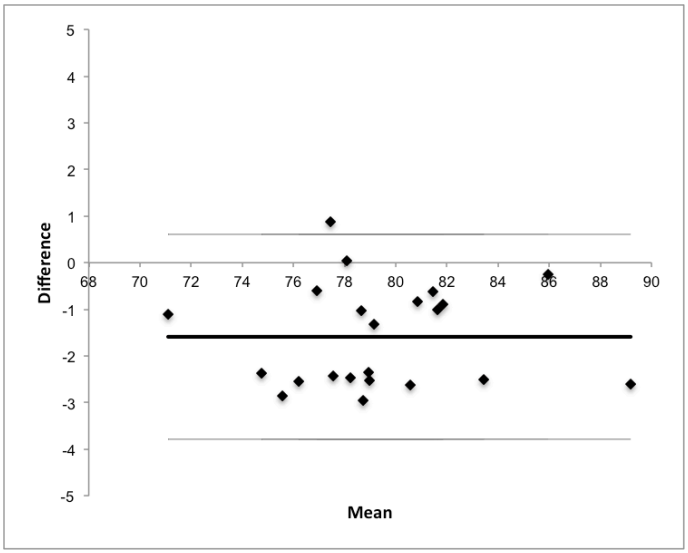


Figure 43. SNA - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

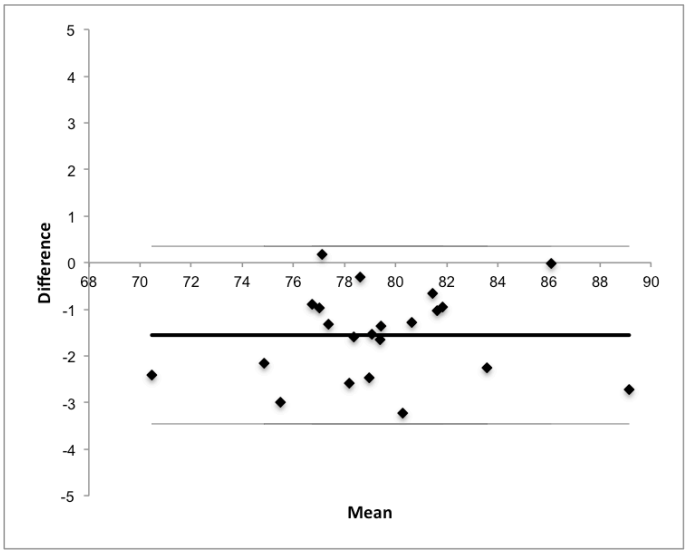
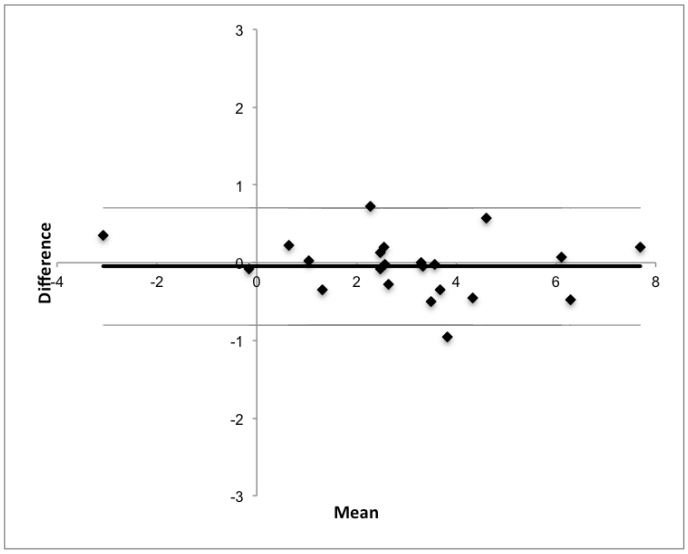
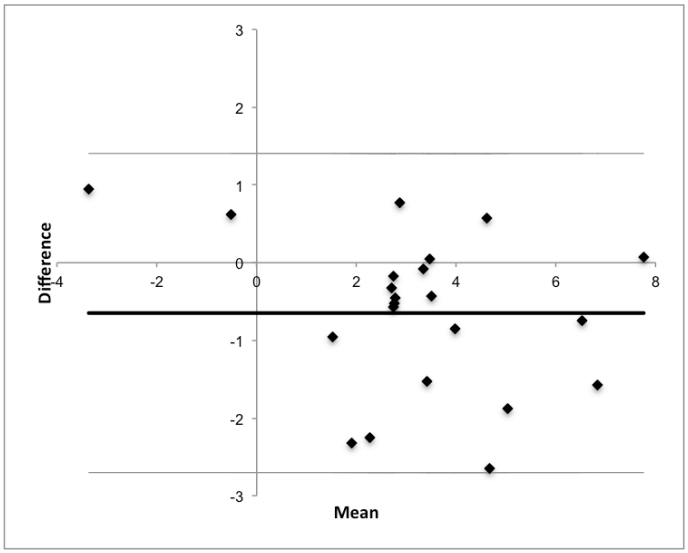


Figure 44. SNB - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

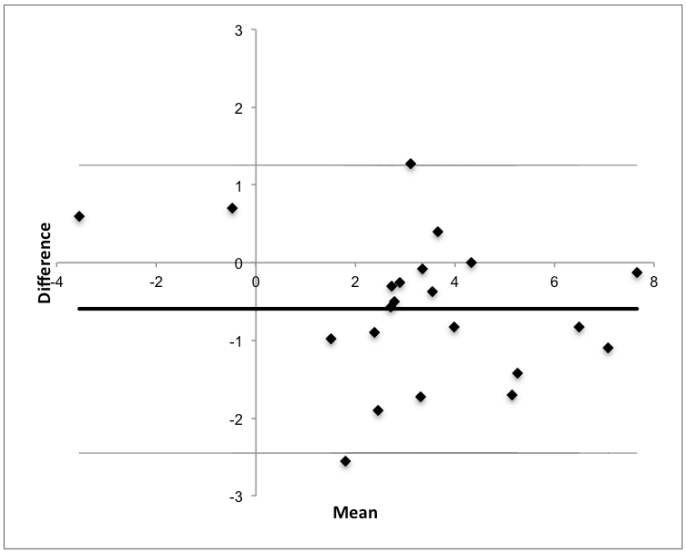
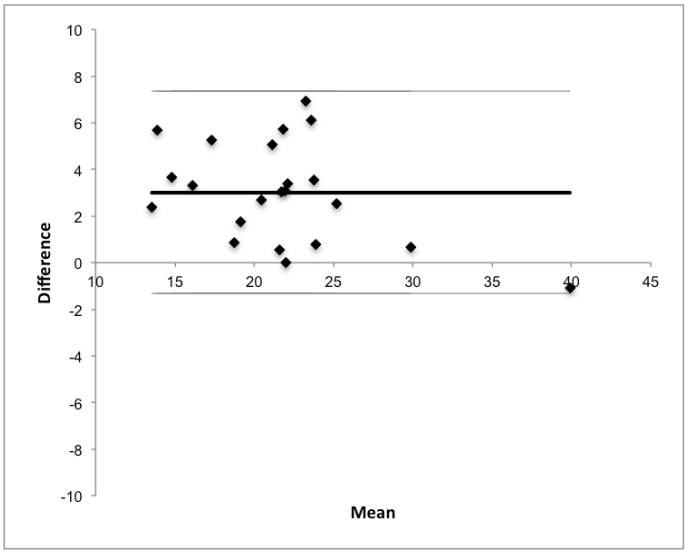
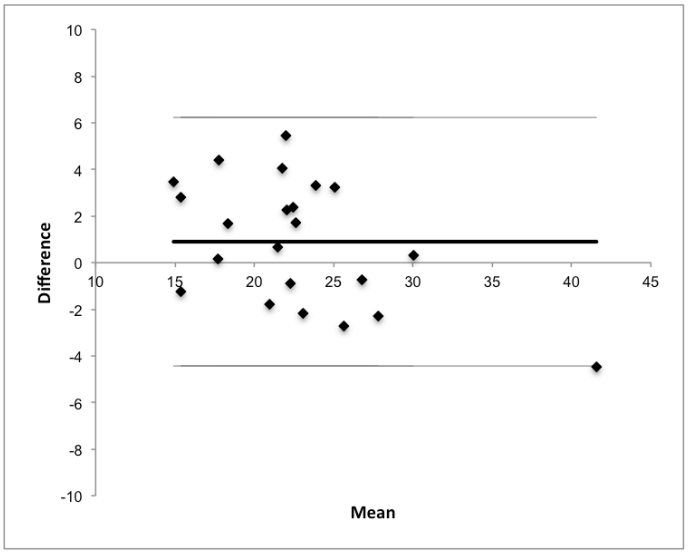


Figure 45. ANB - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

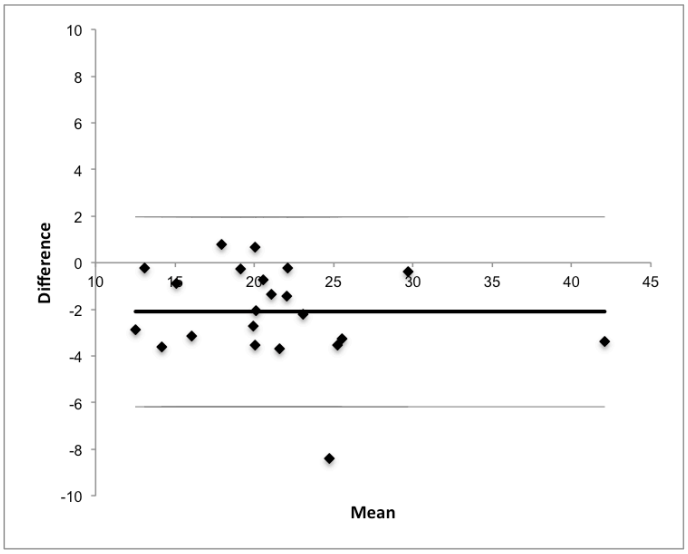
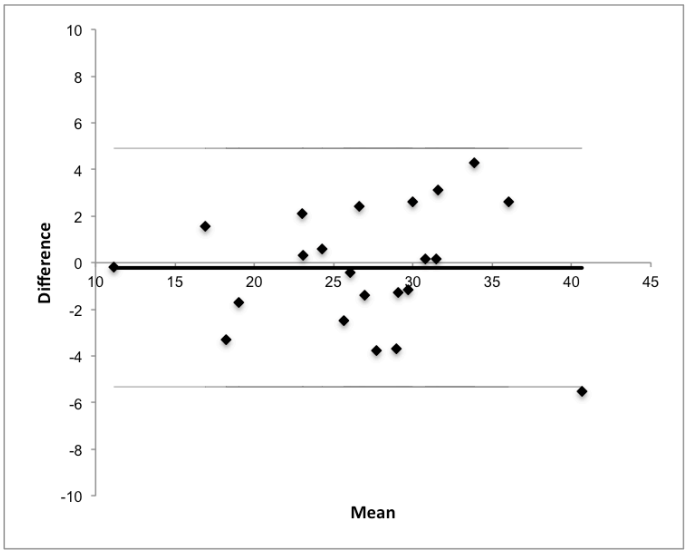
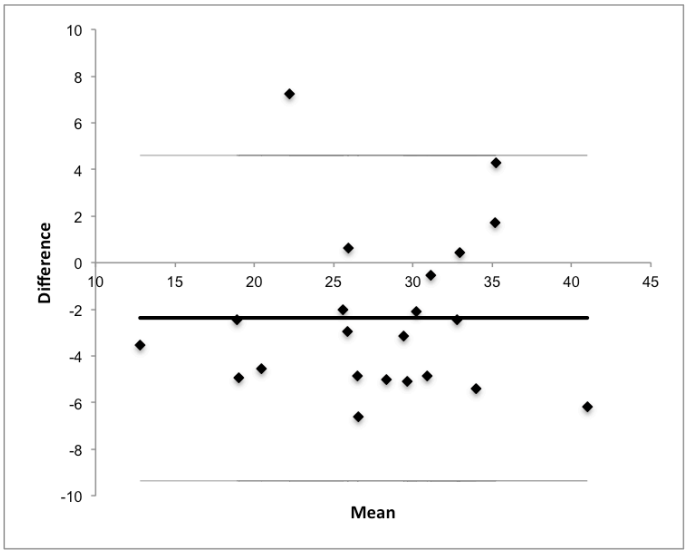


Figure 46. U1-NA Angle - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

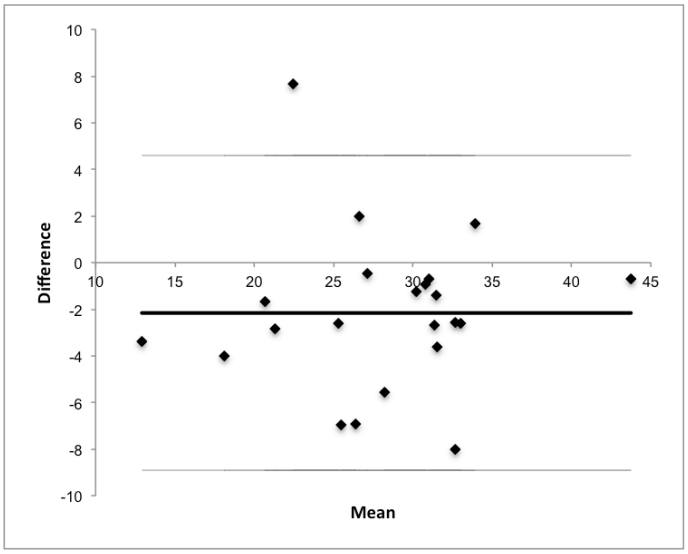
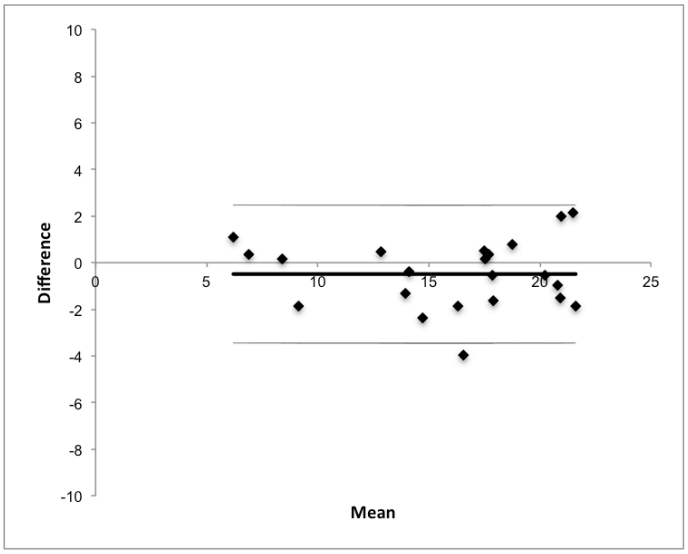
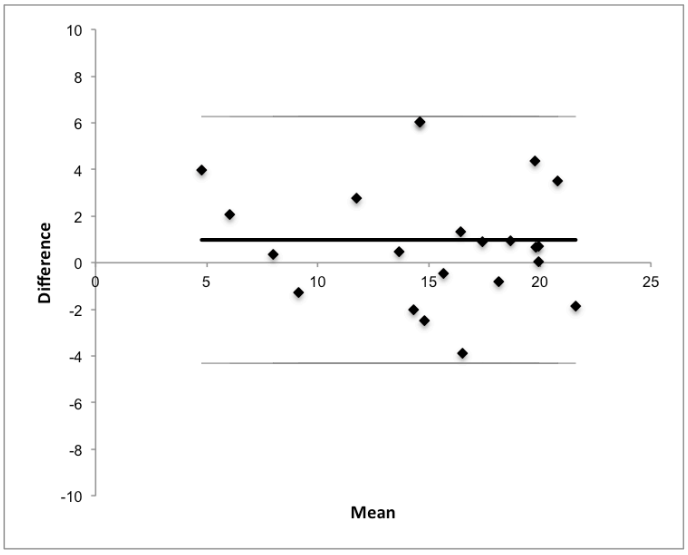


Figure 47. L1-NB Angle - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

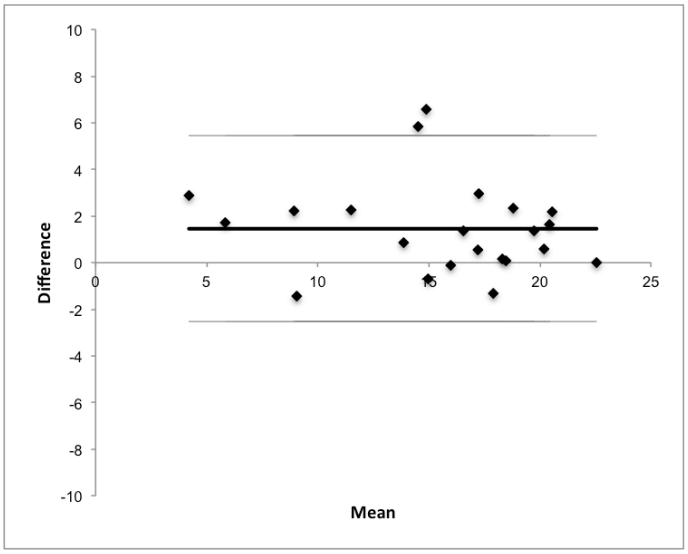
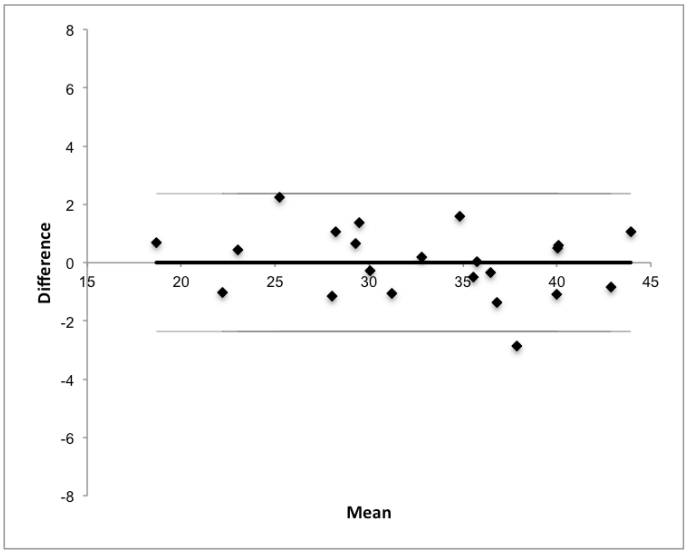
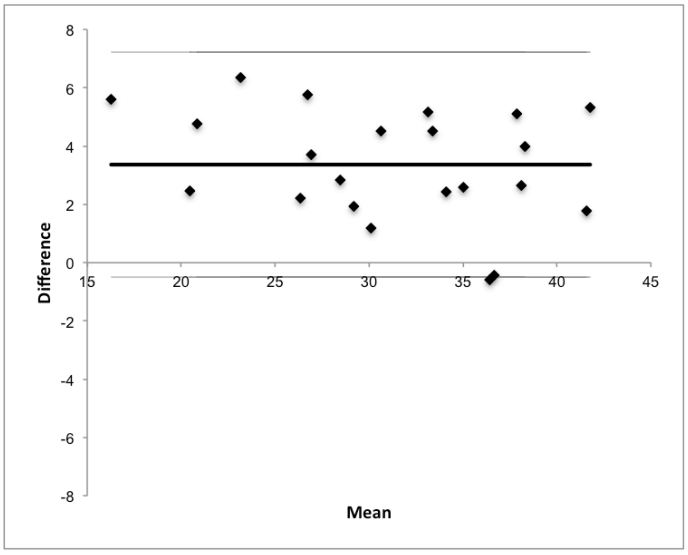


Figure 48. Occlusal Plane to SN - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

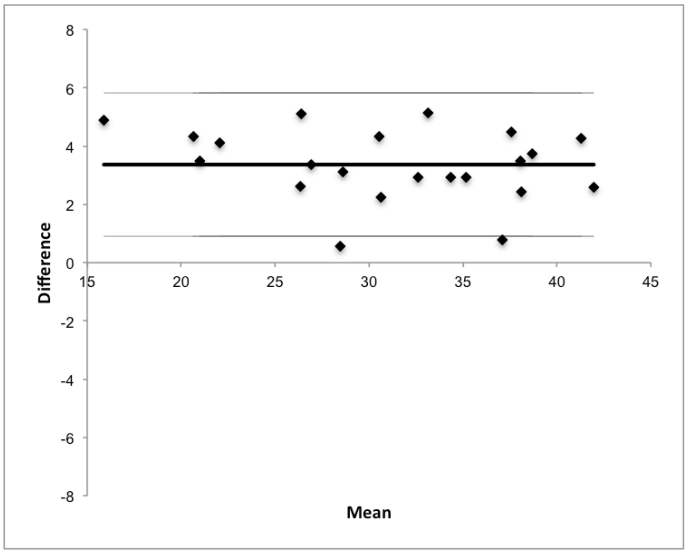
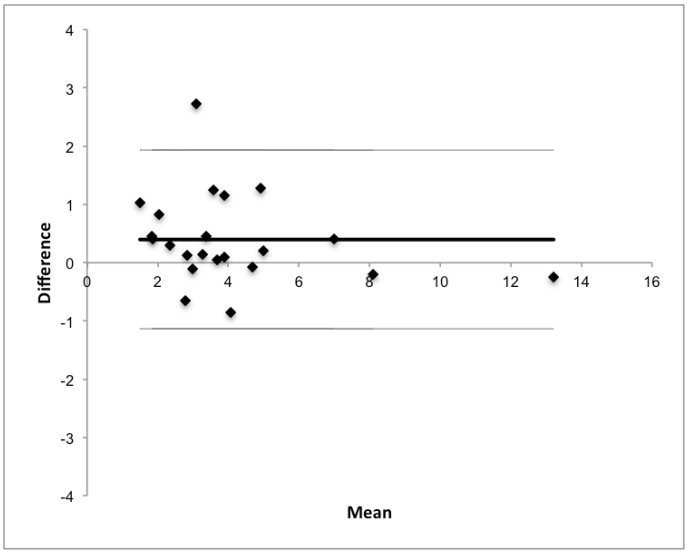
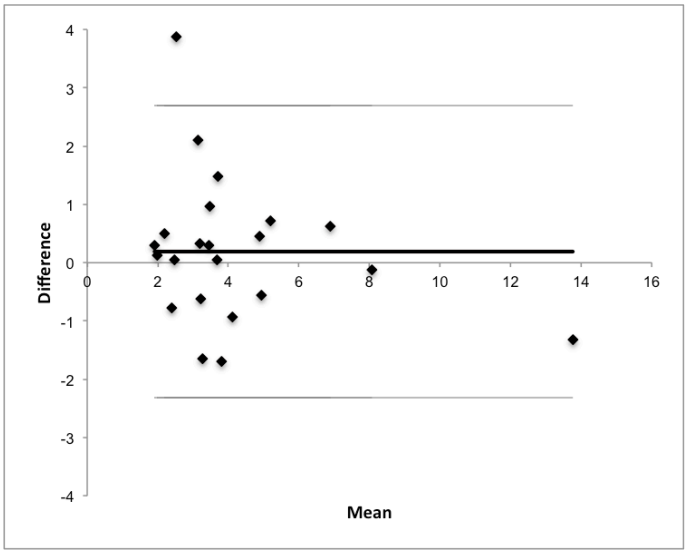


Figure 49. SN-MP - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

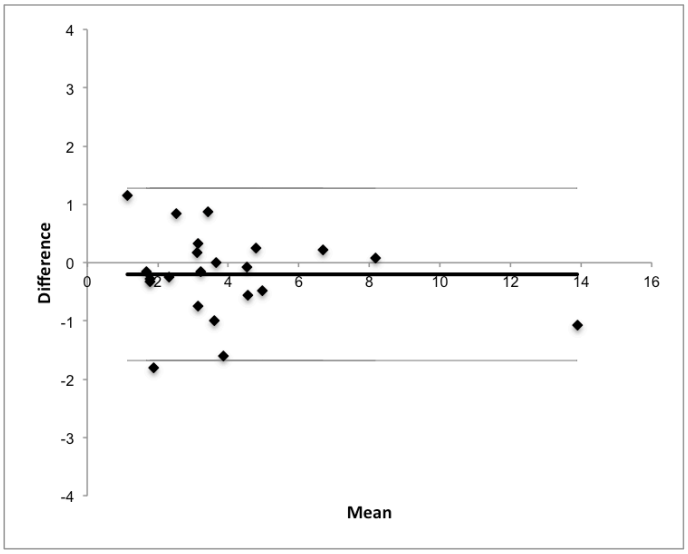
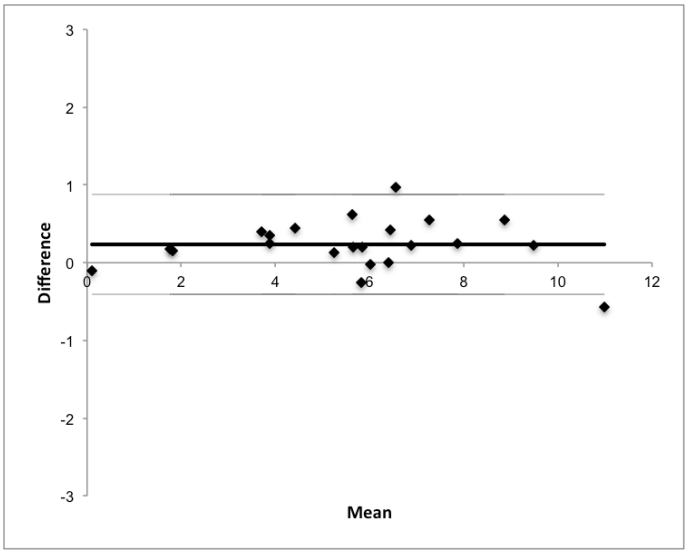
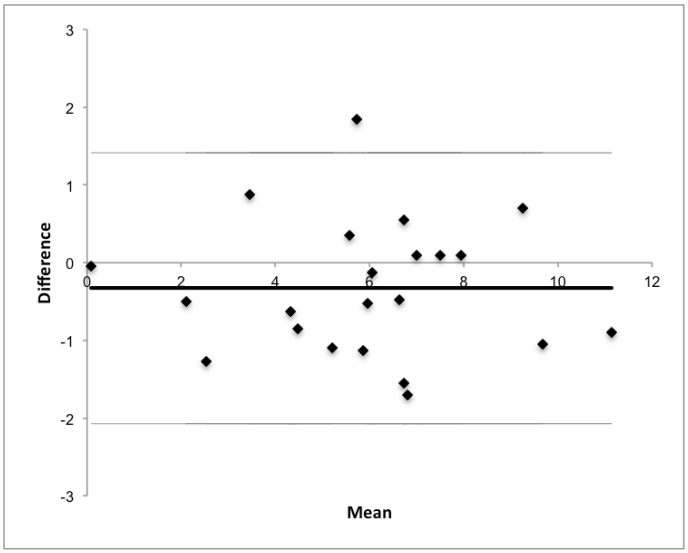


Figure 50. U1-NA Distance - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

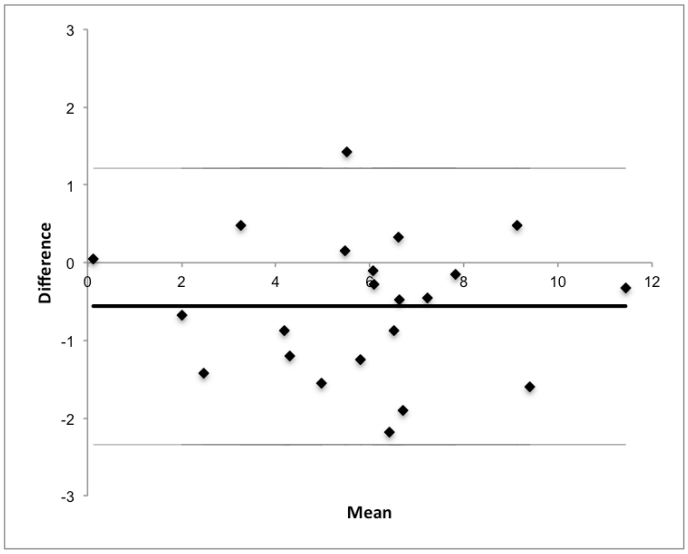
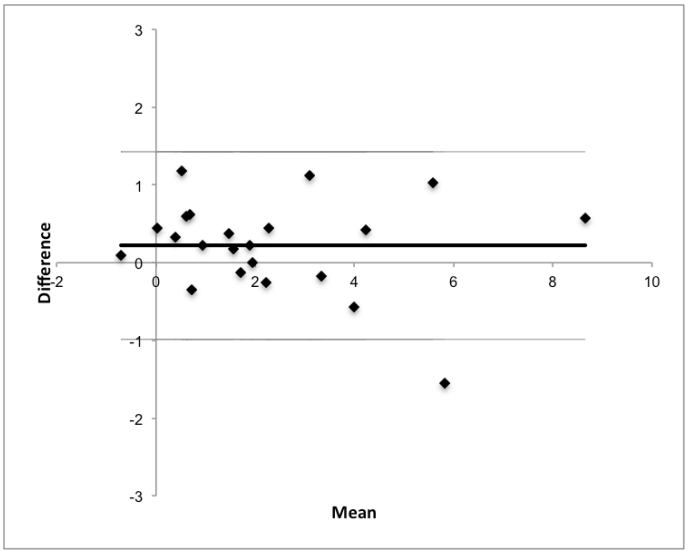
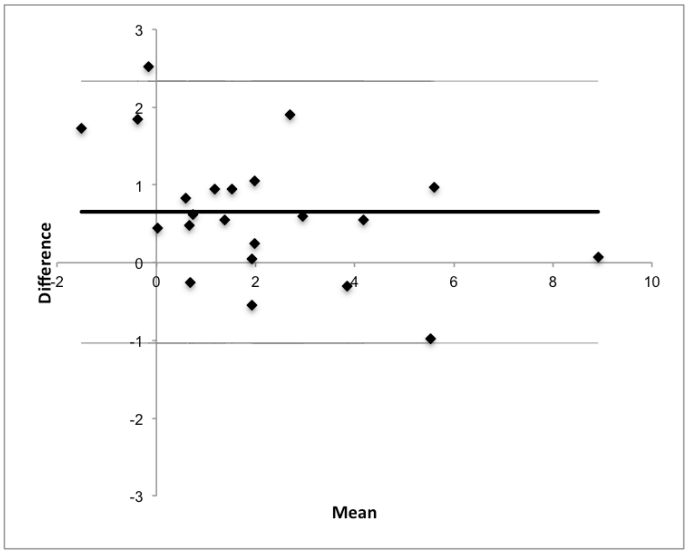


Figure 51. L1-NB Distance - 2 Readers

Lateral Ceph - CBCT



Lateral Ceph - MRI



CBCT-MRI

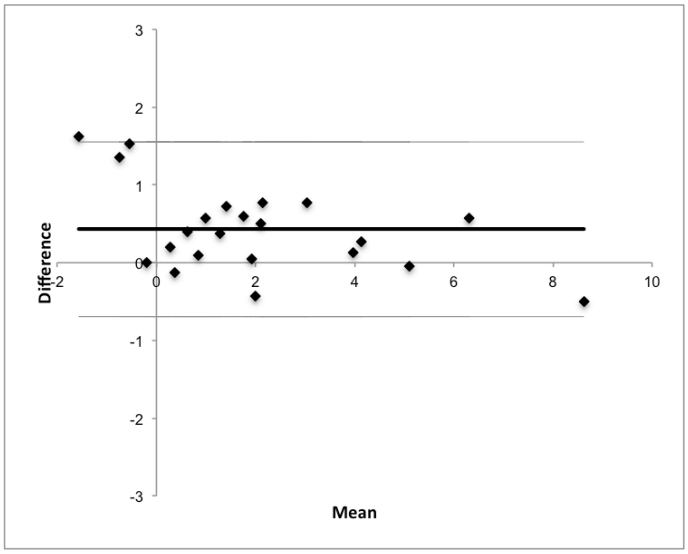


Figure 52. Pog-NB - 2 Readers

Table 8. Degree of Agreement – 3 Readers

Measurement	Clinical Norm	Clinical Deviation Range	Ceph-MRI Mean	CBCT-MRI Mean	Average Deviation	Deviation as Percentage Clinical Deviation Range	Degree of Agreement
(R)Facial Depth (FH-NPo) (º)	87.8 ± 3.0	6.0	-0.54	0.37	-0.08	1.4%	Very Good (0-10%)
(R)Facial Axis (NaBa-PtGn)(º)	90 ± 3.5	7.0	1.09	-0.82	0.13	1.9%	
(S)U1 - NA (mm)	4.3 ± 2.7	5.4	-0.02	-0.58	-0.30	5.5%	
(R)Lower Face Height (ANS-Xi-Pm)(º)	45.0 ± 4.0	8.0	-0.98	0.00	-0.49	6.1%	
(S)U1 - NA (º)	22.8 ± 5.7	11.4	0.99	-2.71	-0.86	7.5%	
(R)Cranial Deflection (º)	27.3 ± 3.0	6.0	-1.43	0.40	-0.51	8.5%	
(R)L1 Protrusion (L1-APo) (mm)	1.0 ± 2.3	4.6	-0.32	-0.59	-0.45	9.8%	
(R)Total Face Height (NaBa-Pm-Xi)(º)	60.0 ± 3.0	6.0	0.20	1.34	0.77	12.8%	Good (10-20%)
(R)Lower Lip to E-Plane (mm)	-2.0 ± 2.0	4.0	-0.28	-0.79	-0.53	13.3%	
(R)Maxillary Depth (FH-NA) (º)	90.0 ± 3.0	6.0	-1.45	-0.18	-0.81	13.6%	
(R)L1 to A-Po (º)	22.0 ± 4.0	8.0	-0.87	-1.36	-1.12	13.9%	
(S)Pog - NB (mm)	1.9 ± 1.7	3.4	0.57	0.39	0.48	14.1%	
(R)Mandibular Arc (º)	29.0 ± 4.0	8.0	-0.63	-1.73	-1.18	14.7%	
(S)ANB (º)	1.6 ± 1.5	3.0	-0.63	-0.42	-0.52	17.3%	
(S)L1 - NB (º)	25.3 ± 6.0	12.0	-2.13	-2.06	-2.10	17.5%	
(S)L1 - NB (mm)	4.0 ± 1.8	3.6	-0.55	-0.71	-0.63	17.5%	
(R)U-Incisor Protrusion (U1-APo) (mm)	3.5 ± 2.3	4.6	-0.71	-0.95	-0.83	18.0%	
(R)Convexity (A-NPo) (mm)	1.2 ± 2.0	4.0	-0.97	-0.59	-0.78	19.5%	
(R)U6 - PT Vertical (mm)	15.5 ± 3.0	6.0	-1.78	-0.76	-1.27	21.1%	Minor Bias (20-30%)
(R)FMA (MP-FH) (º)	24.7 ± 4.5	9.0	2.36	1.49	1.93	21.4%	
(S)SNB (º)	80.9 ± 3.4	6.8	-1.51	-1.48	-1.50	22.0%	
(S)MP - SN (º)	33.0 ± 6.0	12.0	3.02	3.20	3.11	25.9%	
(S)SNA (º)	82.0 ± 3.5	7.0	-2.14	-1.89	-2.01	28.7%	
(R)Interincisal Angle (U1-L1) (º)	130.0 ± 6.0	12.0	1.99	5.38	3.68	30.7%	Significant Bias (>30%)
(R)U-Incisor Inclination (U1-APo) (º)	28.0 ± 4.0	8.0	-1.12	-4.03	-2.57	32.2%	
(S)Occ Plane to SN (º)	14.4 ± 2.5	5.0	2.09	2.30	2.20	43.9%	

Table 9. Degree of Agreement – 2 Readers

Measurement	Clinical Norm	Clinical Deviation Range	Ceph-MRI Mean	CBCT-MRI Mean	Average Deviation	Deviation as Percentage Clinical Deviation Range	Degree of Agreement
(S)U1 - NA (mm)	4.3 ± 2.7	5.4	0.19	-0.21	-0.01	0.1%	Very Good (0-10%)
(R)Lower Face Height (ANS-Xi-Pm)(º)	45.0 ± 4.0	8.0	-0.47	0.58	0.06	0.7%	
(R)Facial Axis (NaBa-PtGn)(º)	90 ± 3.5	7.0	0.91	-0.80	0.06	0.8%	
(R)L1 Protrusion (L1-APo) (mm)	1.0 ± 2.3	4.6	-0.09	-0.33	-0.21	4.5%	
(S)U1 - NA (º)	22.8 ± 5.7	11.4	0.89	-2.11	-0.61	5.3%	
(R)Facial Depth (FH-NPo) (º)	87.8 ± 3.0	6.0	-0.77	0.04	-0.37	6.1%	
(R)Cranial Deflection (º)	27.3 ± 3.0	6.0	-1.33	0.27	-0.53	8.8%	
(R)L1 to A-Po (º)	22.0 ± 4.0	8.0	-0.83	-1.13	-0.98	12.2%	Good (10-20%)
(S)L1 - NB (mm)	4.0 ± 1.8	3.6	-0.33	-0.56	-0.45	12.4%	
(R)U-Incisor Protrusion (U1-APo) (mm)	3.5 ± 2.3	4.6	-0.56	-0.72	-0.64	13.8%	
(R)Lower Lip to E-Plane (mm)	-2.0 ± 2.0	4.0	-0.27	-0.93	-0.60	15.0%	
(R)Total Face Height (NaBa-Pm-Xi)(º)	60.0 ± 3.0	6.0	0.24	1.59	0.91	15.2%	
(R)Mandibular Arc (º)	29.0 ± 4.0	8.0	-0.67	-1.85	-1.26	15.8%	
(S)Pog - NB (mm)	1.9 ± 1.7	3.4	0.65	0.43	0.54	15.9%	
(R)U6 - PT Vertical (mm)	15.5 ± 3.0	6.0	-1.58	-0.67	-1.12	18.7%	
(S)L1 - NB (º)	25.3 ± 6.0	12.0	-2.38	-2.16	-2.27	18.9%	
(S)ANB (º)	1.6 ± 1.5	3.0	-0.65	-0.60	-0.62	20.8%	Minor Bias (20-30%)
(R)Maxillary Depth (FH-NA) (º)	90.0 ± 3.0	6.0	-1.80	-0.74	-1.27	21.1%	
(S)SNB (º)	80.9 ± 3.4	6.8	-1.59	-1.55	-1.57	23.1%	
(R)Convexity (A-NPo) (mm)	1.2 ± 2.0	4.0	-1.09	-0.83	-0.96	24.1%	
(S)Occ Plane to SN (º)	14.4 ± 2.5	5.0	0.97	1.46	1.21	24.3%	
(R)FMA (MP-FH) (º)	24.7 ± 4.5	9.0	2.92	1.91	2.41	26.8%	
(S)MP - SN (º)	33.0 ± 6.0	12.0	3.36	3.36	3.36	28.0%	
(R)Interincisal Angle (U1-L1) (º)	130.0 ± 6.0	12.0	2.11	4.81	3.46	28.8%	
(R)U-Incisor Inclination (U1-APo) (º)	28.0 ± 4.0	8.0	-1.28	-3.69	-2.49	31.1%	Significant Bias (>30%)
(S)SNA (º)	82.0 ± 3.5	7.0	-2.24	-2.15	-2.19	31.3%	

Table 10. Comparing Mean Differences for 2 and 3 Readers

Measurement	Ceph-CBCT		Ceph-MRI		CBCT-MRI	
	3 Readers	2 Readers	3 Readers	2 Readers	3 Readers	2 Readers
(R)Cranial Deflection (º)	-1.83	-1.60	-1.43	-1.33	0.40	0.27
(R)Maxillary Depth (FH-NA) (º)	-1.27	-1.06	-1.45	-1.80	-0.18	-0.74
(R)Facial Depth (FH-NPo) (º)	-0.90	-0.81	-0.54	-0.77	0.37	0.04
(R)Facial Axis (NaBa-PtGn)(º)	1.92	1.71	1.09	0.91	-0.82	-0.80
(R)Total Face Height (NaBa-PmXi) (º)	-1.14	-1.35	0.20	0.24	1.34	1.59
(R)Lower Face Height (ANS-Xi-Pm)(º)	-0.98	-1.05	-0.98	-0.47	0.00	0.58
(R)Mandibular Arc (º)	1.10	1.18	-0.63	-0.67	-1.73	-1.85
(R)FMA (MP-FH) (º)	0.87	1.01	2.36	2.92	1.49	1.91
(R)L1 to A-Po (º)	0.49	0.30	-0.87	-0.83	-1.36	-1.13
(R)U1 to A-Po (º)	2.91	2.41	-1.12	-1.28	-4.03	-3.69
(R)Interincisal Angle (U1-L1) (º)	-3.40	-2.70	1.99	2.11	5.38	4.81
(R)U6 - PT Vertical (mm)	-1.02	-0.90	-1.78	-1.58	-0.76	-0.67
(R)U1 Protrusion (U1-APo) (mm)	0.24	0.16	-0.71	-0.56	-0.95	-0.72
(R)L1 Protrusion (L1-APo) (mm)	0.27	0.24	-0.32	-0.09	-0.59	-0.33
(R)Convexity (A-NPo) (mm)	-0.38	-0.26	-0.97	-1.09	-0.59	-0.83
(R)Lower Lip to E-Plane (mm)	0.51	0.65	-0.28	-0.27	-0.79	-0.93
(S)SNA (º)	-0.25	-0.09	-2.14	-2.24	-1.89	-2.15
(S)SNB (º)	-0.03	-0.04	-1.51	-1.59	-1.48	-1.55
(S)ANB (º)	-0.21	-0.05	-0.63	-0.65	-0.42	-0.60
(S)U1 - NA (º)	3.70	3.00	0.99	0.89	-2.71	-2.11
(S)L1 - NB (º)	-0.08	-0.22	-2.13	-2.38	-2.06	-2.16
(S)Occ Plane to SN (º)	-0.21	-0.49	2.09	0.97	2.30	1.46
(S)MP - SN (º)	-0.18	0.00	3.02	3.36	3.20	3.36
(S)U1 - NA (mm)	0.56	0.40	-0.02	0.19	-0.58	-0.21
(S)L1 - NB (mm)	0.16	0.24	-0.55	-0.33	-0.71	-0.56
(S)Pog - NB (mm)	0.17	0.22	0.57	0.65	0.39	0.43

Table 11. Comparing Standard Deviations for 2 and 3 Readers

Measurement	Ceph-CBCT		Ceph-MRI		CBCT-MRI	
	3 Readers	2 Readers	3 Readers	2 Readers	3 Readers	2 Readers
(R)Cranial Deflection (º)	1.64	1.78	2.04	2.08	1.14	1.16
(R)Maxillary Depth (FH-NA) (º)	1.32	1.40	1.77	2.13	1.19	1.30
(R)Facial Depth (FH-NPo) (º)	1.09	1.31	1.56	1.84	1.06	1.22
(R)Facial Axis (NaBa-PtGn)(º)	1.02	1.05	1.19	1.33	0.95	0.88
(R)Total Face Height (NaBa-PmXi) (º)	1.15	1.19	1.26	1.54	1.35	1.19
(R)Lower Face Height (ANS-Xi-Pm)(º)	1.40	1.16	1.76	1.75	1.32	1.18
(R)Mandibular Arc (º)	2.61	2.85	2.58	2.92	2.39	2.29
(R)FMA (MP-FH) (º)	1.27	1.45	2.84	2.40	2.32	1.75
(R)L1 to A-Po (º)	2.31	2.44	3.22	3.38	3.03	2.67
(R)U1 to A-Po (º)	2.42	2.42	3.50	3.28	2.30	2.62
(R)Interincisal Angle (U1-L1) (º)	3.44	3.31	3.87	4.11	3.64	3.96
(R)U6 - PT Vertical (mm)	1.42	1.55	2.25	2.36	1.91	1.76
(R)U1 Protrusion (U1-APo) (mm)	0.44	0.46	0.78	0.87	0.63	0.61
(R)L1 Protrusion (L1-APo) (mm)	0.43	0.44	0.63	0.76	0.51	0.66
(R)Convexity (A-NPo) (mm)	0.54	0.49	1.15	1.25	0.99	1.02
(R)Lower Lip to E-Plane (mm)	1.15	0.68	1.13	1.12	1.20	0.93
(S)SNA (º)	0.96	0.91	1.51	1.59	1.32	1.48
(S)SNB (º)	0.83	0.82	1.05	1.10	0.94	0.95
(S)ANB (º)	0.46	0.38	0.93	1.03	0.88	0.93
(S)U1 - NA (º)	2.48	2.17	3.23	2.67	2.01	2.04
(S)L1 - NB (º)	2.25	2.56	3.15	3.49	3.42	3.38
(S)Occ Plane to SN (º)	1.42	1.48	2.62	2.64	2.07	1.99
(S)MP - SN (º)	1.13	1.18	2.38	1.93	2.21	1.23
(S)U1 - NA (mm)	0.77	0.77	1.26	1.25	0.88	0.74
(S)L1 - NB (mm)	0.35	0.32	0.69	0.87	0.75	0.89
(S)Pog - NB (mm)	0.46	0.60	0.73	0.84	0.53	0.56

CHAPTER FIVE

DISCUSSION

Analysis of Measures with Good Agreement or Minor Bias

A further examination of the Bland-Altman plots for each measurement reveals trends in error. The plots for cranial deflection, maxillary depth and facial depth show a bias where the cephalometric values obtained from the lateral cephs are less than that obtained from the CBCTs and MRIs. This would suggest that when the lateral cephs are traced, either Frankfort Horizontal is relatively the same and the NaBa plane, NA plane and NPog plane show a more clockwise position as shown in Figure 53, or that Frankfort Horizontal has a more counter-clockwise position as in Figure 54. Examining the plots for MPA shows that the values obtained when tracing lateral cephs are greater than that when tracing CBCTs or MRIs. This would also be indicative of a counter-clockwise rotation of Frankfort Horizontal.

The two points comprising Frankfort Horizontal are porion and orbitale. It was earlier identified in the methods and materials section that location of porion in a 3D volume was only possible by scrolling through the sagittal slices and selecting the most superior point along the roof of the bony external meatus. It is possible that this selected point is lower than the one selected when tracing a 2 dimensional ceph, thus creating a counter-clockwise rotation of Frankfort-Horizontal. The other possibility is that when scrolling to select orbitale the point chosen is too high.

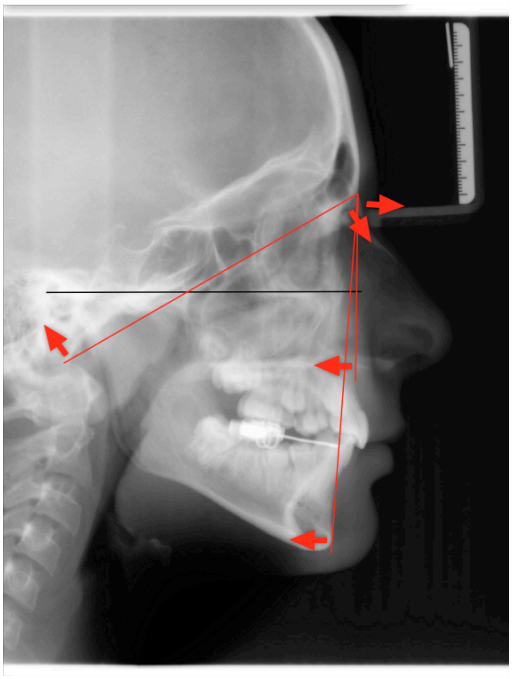


Figure 53. Frankfort-Horizontal Plane Constant

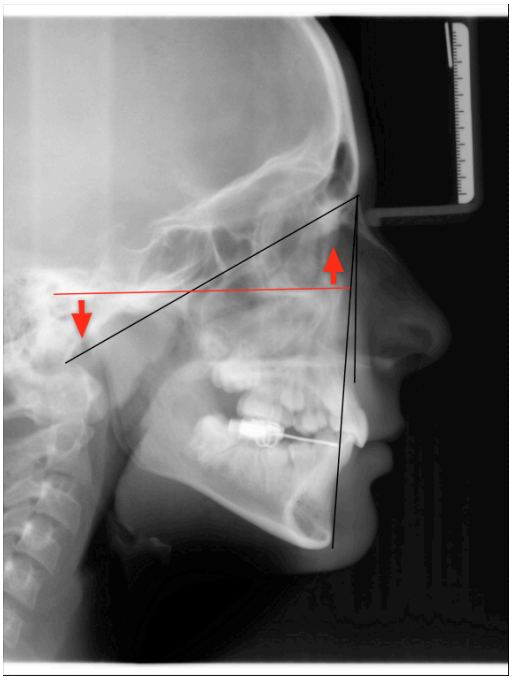


Figure 54. Frankfort-Horizontal Plane with Counter-Clockwise Rotation

An inspection of SNA and SNB reveals that the values obtained by tracing lateral cephs and CBCTs are similar, with the MRI values showing a bias to be greater than both. ANB shows good agreement among all 3 modalities. This would indicate either that the MRI landmarks for A and B point are both more anteriorly positioned as shown in Figure 55, or that the SN plane has a clockwise bias when tracing MRIs as shown in Figure 56. When comparing the Bland-Altman plots for occlusal plane angle and Steiner mandibular plane angle (GoGn-SN), the cephalometric values obtained from MRIs show a bias towards being lesser than both lateral cephs and CBCTs. This would be in agreement with a more clockwise SN plane when tracing MRIs.

When comparing the Ricketts analysis angular measurements for L1-APo, it is apparent that tracing the MRIs gives the largest angular measurement and tracing CBCTs the smallest measurement. Doing the same with U1-APo, MRI again gives the largest measurement and CBCT the smallest. This indicates that compared to a lateral ceph, the upper and lower incisors appear more flared when tracing an MRI and more upright when tracing a CBCT. This trend is shown in Figure 57. This helps to account for some of the other minor biases seen in other measurements, such as U1P, L1P, U1/NA and L1/NB, U1-NA and L1-NB.

Analysis of Measures with Significant Bias

There are several measurements that show a larger amount of bias. However, upon closer examination they could be due to the sum of a couple of the smaller biases. The largest bias was seen in the interincisal angle measurement. The plots reveal that the largest interincisal angle values come from CBCT, and the smallest from MRI. This is in

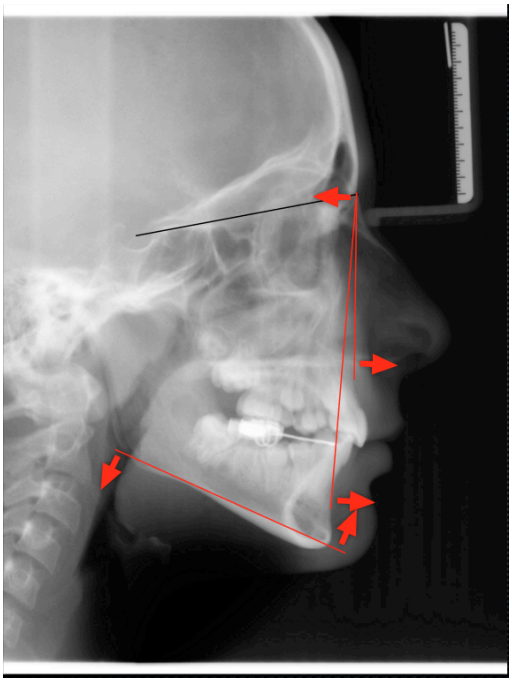


Figure 55. SN Plane Constant

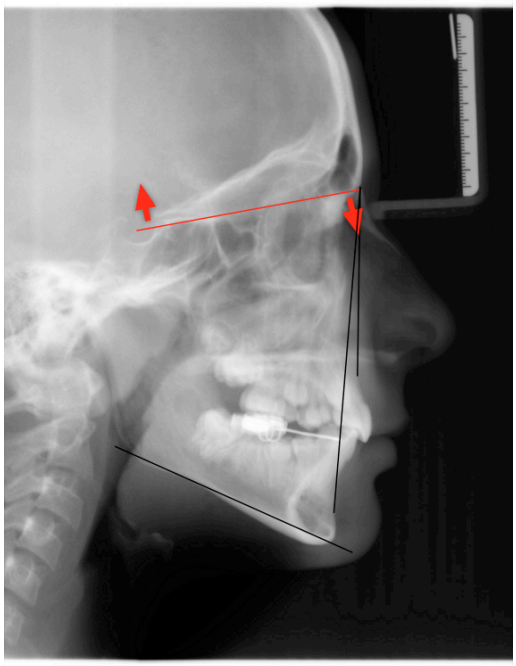
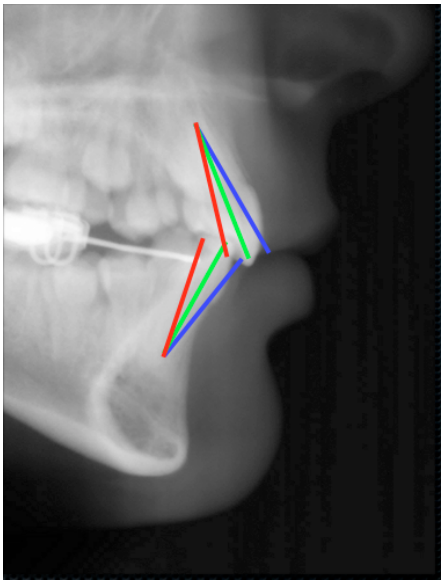


Figure 56. SN Plane with Clockwise Rotation



Legend	
Red	CBCT
Green	Ceph
Blue	MRI

Figure 57. Trends when Tracing Incisors

agreement with the earlier discussed minor biases of CBCT tracings indicating more upright incisors and MRI tracings showing more flared incisors. Compounding these two minor biases could account for the larger bias seen in interincisal angle measurements.

Comparing the Results from 3 Readers and 2 Readers

There were no significant differences noted when comparing the results between 3 readers and 2 readers. There were a few values that showed mildly better correlation when comparing mean difference, such as Steiner's U1-NA angle and occlusal plane to SN angle. However, there were also measurements that showed mildly worse correlation, such as Ricketts maxillary depth and FMA. When considering standard deviation, there were also cases of slightly better correlation (SN-MP, FMA) and slightly worse correlation (maxillary depth, facial depth). Overall, the trends of error were unchanged.

Cephalometric Error

A discrepancy between cephalometric values obtained when comparing different imaging modalities is not uncommon. Previous studies have shown statistically significant differences when comparing manually traced radiographs to digitally scanned and digitized images,[23,24] as well as between lateral cephs and 3D CBCT scans.[25] However, these studies have concluded that the differences were not clinically significant.

Another earlier study examining magnification in common digital lateral cephalometric machines showed 8.1% to 13.2% vertical magnification and 8.2% to 14.2% horizontal magnification. One machine in the study also displayed non-symmetric magnification characteristics. However, the study concluded that for clinical purposes all the machines evaluated in the study were adequate.[26]

The largest average error when comparing tracing lateral cephs to either CBCT or MRI in this study occurred when comparing interincisal measurements. The Bland-Altman plot for comparing lateral cephs to CBCTs for interincisal angle showed a bias of -3.39°. Compared to the clinical norm for Ricketts analysis for Caucasian patients (from Dolphin Imaging, 2013) of 130.0° ± 6.0°, this error is well within the roughly 8% to 14% error seen noted in common lateral cephalometric machines. It is also only about half the magnitude of the corresponding standard deviation.

Evaluation of Clinical Viability

This study suggests a good to very good agreement for almost half of the measurements evaluated. The rest appear to show a small to moderate degree of bias, but

the biases appear to be well within the limits of clinical acceptability. They also appear directional in most cases and can be adjusted for.

The larger issues at this time appear to be other limitations of practical MRI use for orthodontic diagnosis. The current cost of having an MRI taken both prior to and post orthodontic treatment is prohibitive in many cases. It would also likely not be covered by insurance at the time of this study. There would be difficulty in having young patients stay still for the duration of time required for an MRI to be taken. MRI is also not applicable for progress examinations during orthodontic treatment due to the presence of metal in most orthodontic appliances. However, some of the non-conventional modalities of treatment such as the use of clear aligners would allow for this. A previous study also noted that titanium brackets and some specific types of stainless steel brackets had no effect on MRI.[20] Lastly, most orthodontists are not familiar with reading MRIs and would need training in order to be able to trace MR scans.

If MRI is the chosen imaging modality of the treating orthodontist and the patient, this study suggests that with relatively quick training and the relevant software an orthodontist would be able to obtain clinically adequate cephalometric data from an MRI image.

Suggestions for Improvement

To improve the agreement between the imaging modalities, one suggestion would be to have each reader reorient the 3D volumes on their own. In a clinical practice setting, this would likely be the first action by an orthodontist tracing a 3D volume. In this study, the decision was made after the pilot experiment to leave the head orientations as is.

However, in retrospect the agreement may have been better if the images had been reoriented prior to landmark identification.

Another possible improvement would be to have a radiologist familiar with evaluating MR scans aid with calibration of the readers. There was some degree of debate during calibration as to the correct location of certain landmarks, and a radiologist with more experience dealing with such images would have aided in more correct and consistent landmark identification.

CHAPTER SIX

CONCLUSIONS

Conclusions

1. There are statistically significant differences in certain Ricketts and Steiner analysis cephalometric measurements when comparing data obtained from digital lateral cephalograms, cone beam computed tomography scans, and magnetic resonance imaging scans.
2. The differences in cephalometric measurements are within the limits of clinical variability and are adequate for clinical evaluation of a patient.
3. Under the conditions of this study, tracing magnetic resonance imaging scans can yield similar orthodontic cephalometric values to conventional lateral cephalograms and cone beam computed tomography scans.

REFERENCES

1. Parkin DM, Darby SC. Cancers in 2010 attributable to ionising radiation exposure in the UK. Br J Cancer 2011;105:S57-S65.

2. Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: A radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008;133:640.e1-640.e5.

3. Cattaneo PM, Bloch CB, Calmar D, Hjortshoj M, Melsen B. Comparison between conventional and cone-beam computed tomography–generated cephalograms. Am J Orthod Dentofacial Orthop 2008;134:798-802.

4. Ludlow JB, Gubler M, Cevidanes L, Mol A. Precision of cephalometric landmark identification: cone-beam computed tomography vs conventional cephalometric views. Am J Orthod Dentofacial Orthop 2009;136(3):312.

5. Gribel BF, Gribel MN, Frazäo DC, McNamara JA Jr, Manzi FR. Accuracy and reliability of craniometric measurements on lateral cephalometry and 3D measurements on CBCT scans. Angle Orthod 2011;81(1):26-35.

6. Suman S, Maniar M, Fornace AJ Jr, Datta K. Administration of ON 01210.Na after exposure to ionizing radiation protects bone marrow cells by attenuating DNA damage response. Radiat Oncol 2012;7:6.

7. De la Cal C, Fernández-Solari J, Mohn C, Prestifilippo J, Pugnaloni A, Medina V, Elverdin J. Radiation produces irreversible chronic dysfunction in the submandibular glands of the rat. Open Dent J 2012;6:8-13.

8. Williams PM, Fletcher S. Health effects of prenatal radiation exposure. Am Fam Physician 2010;82(5):488-93.

9. Rathnayaka K, Momot KI, Noser H, Volp A, Schuetz MA, Sahama T, Schmutz B. Quantification of the accuracy of MRI generated 3D models of long bones compared to CT generated 3D models. Med Eng Phys 2011;doi:10.1016/j.medengphy.2011.07.027.

10. Maizlin ZV, Nutiu N, Dent PB, Vos PM, Fenton DM, Kirby JM, Vora P, Gillies JH, Clement JJ. Displacement of the temporomandibular joint disk: correlation between clinical findings and MRI characteristics. J Can Dent Assoc 2010;76:a3.

11. Pirilä-Parkkinen K, Löppönen H, Nieminen P, Tolonen U, Paakko E, Pirttiniemi P. Validity of upper airway assessment in children: a clinical, cephalometric, and MRI study. Angle Orthod. 2011;81(3):433-9.

12. Plooij JM, Maal TJJ, Haers P, Borstlap WA, Kuijpers-Jagtman AM, Berge SJ. Digital three-dimensional image fusion processes for planning and evaluating orthodontics and orthognathic surgery. A systematic review. Int J Oral Maxillofac Surg 2011;40(4):341-52.

13. Terajima M, Yanagita N, Ozeki K, Hoshino Y, Mori N, Goto TK, Tokumori K, Aoki Y, Nakasima A. Three-dimensional analysis system for orthognathic surgery patients with jaw deformities. Am J Orthod Dentofacial Orthop 2008;134:100-11.

14. Ferretti F, Malventi M, Malasoma R. Dental magnetic resonance imaging: study of impacted mandibular third molars. Dentomaxillofac Radiol 2009;38(6):387-92.

15. Idiyatullin D, Corum C, Moeller S, Prasad HS, Garwood M, Mixdorf DR. Dental magnetic resonance imaging: making the invisible visible. J Endod 2011;37(6):745-52.

16. van Haute FRB, Taboada GF, Correa LL, Lima GAB, Fontes R, Riello AP, Dominici M, Gadelha MR. Prevalence of sleep apnea and metabolic abnormalities in patients with acromegaly and analysis of cephalometric parameters by magnetic resonance imaging. Eur J Endocrinol 2008;158(4):459-65.

17. Elison JM, Leggitt VL, Thomson M, Oyoyo U, Wycliffe ND. Influence of common orthodontic appliances on the diagnostic quality of cranial magnetic resonance images. Am J Orthod Dentofacial Orthop 2008;134(4):563-72.

18. Yilmaz S, Misirlioglu M. The effect of 3 T MRI on microleakage of amalgam restorations. Dentomaxillofac Radiol 2013;42:20130072

19. Hutton J, Walker LG, Gilbert FJ, Evans DG, Eeles R, Kwan-Lim GE, Thompson D, Pointon LJ, Sharp DM, Leach MO. Psychological impact and acceptability of magnetic resonance imaging and X-ray mammography: the MARIBS Study. Br J Cancer 2011;104(4):578-86.

20. McIsaac HK, Thordarson DS, Shafran R, Rachman S, Poole G. Claustrophobia and the magnetic resonance imaging procedure. J Behav Med 1998;21(3):255-68.

21. Williams WA. Cephalometric Analysis Using Magnetic Resonance Imaging: Unpublished Masters Thesis, Loma Linda University Graduate School, Department of Orthodontics 2008.

22. Sanders MA. Facial Type Analysis Comparison Between MRI, CBCT, and Lateral Cephalometrics: Unpublished Masters Thesis, Loma Linda University Graduate School, Department of Orthodontics 2010.

23. AlBarakati SF, Kula KS, Ghoneima AA. The reliability and reproducibility of cephalometric measurements: a comparison of conventional and digital methods. Dentomaxillofac Radiol 2012;41:11-17.

24. Naoumova J, Lindman R. A comparison of manual traced images and corresponding scanned radiographs digitally traced. Eur J Orthod 2009;31:247-253. Dentomaxillofac Radiol 2010;39:100-106.

25. Nalcaci R, Ozturk F, Sokucu O. A comparison of two-dimensional radiography and three-dimensional computed tomography in angular cephalometric measurements.

26. Schnepper GM. Magnification in Images Produced by Five Popular Digital Lateral Cephalometric Machines: Unpublished Masters Thesis, Loma Linda University Graduate School, Department of Orthodontics 2005.

APPENDIX A: Raw Data

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
Pt1	(R)Cranial Deflection (°)	25.9	26.1	26.25	23.9	26.15	26.05	26.4	26	26.3
	(R)Maxillary Depth (FH-NA) (°)	91.9	91.4	87.25	91.4	92.1	90.8	91.2	90.9	91.2
	(R)Facial Depth (FH-NPo) (°)	95.3	95	92.85	95.4	95.9	95.6	95.8	94.8	94.1
	(R)Facial Axis-Ricketts (NaBa-PtGn)(°)	100	99.7	99.75	103	100.8	102.35	101.1	99.45	100.8
	(R)Total Face Height (NaBa-PmXi) (°)	44.3	46.15	43.85	42.9	45.65	42.55	44.5	46.3	45.9
	(R)Lower Face Height (ANS-Xi-Pm)(°)	35.6	37.3	37.1	36.6	36.9	38.65	35.7	37.05	38.95
	(R)Mandibular Arc (°)	45.9	41.75	46	43.9	40.55	44.85	43.7	42.65	45.15
	(R)FMA (MP-FH) (°)	12.8	12.8	8.75	11.1	12.95	10.1	13.5	13.5	10.25
	(R)L1 to A-Po (°)	17.3	18.85	22.9	24.1	19.75	29.15	22	19.85	22.6
	(R)U1 to A-Po (°)	20.4	12.1	16.75	18.3	9.7	12.8	15.2	11	12.25
	(R)Interincisal Angle (U1-L1) (°)	142.3	149.05	140.25	137.6	150.5	138.05	142.8	149.15	145.2
	(R)U6 - PT Vertical (mm)	24.2	23.45	24.3	24.1	24.45	28.4	23.1	23.3	25.95
	(R)U1 Protrusion (U1-APo) (mm)	0.6	0.4	0.65	0.4	0.4	1.4	0.7	0.55	1.5
	(R)L1 Protrusion (L1-APo) (mm)	-2.4	-2.15	-2.7	-1.1	-1.7	-0.7	-1.5	-1.7	-0.7
	(R)Convexity (A-NPo) (mm)	-3.4	-3.5	-5	-3.9	-3.65	-4.55	-4.5	-3.9	-2.85
	(R)Lower Lip to E-Plane (mm)	-9.5	-9.2	-9.45	-8.3	-9	-10	-9.7	-9.65	-9.15
	(S)SNA (°)	86.2	86.1	83.75	86.7	86.3	86.8	85.1	85.8	86.9
	(S)SNB (°)	85.8	86.2	85.35	87.2	86.75	88.1	85.9	85.95	86.85
	(S)ANB (°)	0.4	-0.1	-1.7	-0.5	-0.4	-1.25	-0.8	-0.15	0.05
	(S)U1 - NA (°)	27.9	19.85	28.35	27.2	17.85	23.35	25.5	19.7	18.55
	(S)L1 - NB (°)	9.5	11.15	13	15.6	12.05	19.85	12.6	11.3	16.2
	(S)Occ Plane to SN (°)	7.2	6.85	6.45	4.8	6.85	0.3	6.9	6.55	3.55
	(S)MP - SN (°)	18.5	18.05	12.3	15.8	18.8	14.1	19.6	18.65	14.6
	(S)U1 - NA (mm)	2.9	2.95	4.65	3.1	3.1	4.85	2	3.25	3.55
	(S)L1 - NB (mm)	0	-0.15	-1.05	0.5	0.15	0.75	0.1	0.45	1.25
	(S)Pog - NB (mm)	6.8	6.4	6.85	6.2	6.1	6.1	3.3	6.8	5.2
Pt2	(R)Cranial Deflection (°)	30.7	31.35	33.6	28.1	33.85	32.8	28.5	31.8	32.3
	(R)Maxillary Depth (FH-NA) (°)	96.9	97.25	97	96.1	99.75	97.25	95.9	97.15	99.8
	(R)Facial Depth (FH-NPo) (°)	92.8	92.95	93.8	92.9	96.2	94.15	91.4	93.2	94.85
	(R)Facial Axis-Ricketts (NaBa-PtGn)(°)	88	89.35	87.3	91.7	88	89.45	88.6	87.7	89.4

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)Total Face Height (NaBa-PmXi) (º)	56	55.7	55.5	53.5	54.9	53.05	56.9	56.8	53.8
	(R)Lower Face Height (ANS-Xi-Pm)(º)	40.7	39.8	40.45	41.2	38.7	44.1	42.5	39.95	40
	(R)Mandibular Arc (º)	36.9	38.25	39.8	37.1	36.35	40.95	34.5	36	38.4
	(R)FMA (MP-FH) (º)	20.8	19.8	16.35	20.3	17.4	15.75	22.8	19.8	14.7
	(R)L1 to A-Po (º)	30.2	28.35	28.25	34.9	33.5	36.1	34.8	31.5	27.55
	(R)U1 to A-Po (º)	34.1	31	36.95	38.7	32.85	37.4	38.7	28.3	39.85
	(R)Interincisal Angle (U1-L1) (º)	115.7	120.65	114.75	106.4	113.7	106.55	106.5	120.15	112.6
	(R)U6 - PT Vertical (mm)	20.5	23.4	22.55	21.5	22.9	24.65	18.6	20.3	21.7
	(R)U1 Protrusion (U1-APo) (mm)	6.1	5.75	9.6	6.8	5.9	8.7	5.8	6.2	5.05
	(R)L1 Protrusion (L1-APo) (mm)	3.7	2.95	3.65	4.2	3.6	6.35	3.4	4.05	0.05
	(R)Convexity (A-NPo) (mm)	4.1	4.1	3.3	3.1	3.5	2.9	4.4	3.8	4.8
	(R)Lower Lip to E-Plane (mm)	-2.4	-2.4	-1.55	-2.6	-2.8	-1.6	-1.5	-2.3	-2.35
	(S)SNA (º)	84.9	84.55	83.45	85.9	84.5	84.3	85.8	84.1	87.7
	(S)SNB (º)	80.2	79.95	80	82.1	80.55	81.05	80.7	80.05	82.55
	(S)ANB (º)	4.7	4.6	3.5	3.9	3.95	3.3	5.1	4.05	5.15
	(S)U1 - NA (º)	24.7	21.5	29.2	31.6	24.65	30.7	28.6	19.55	28.65
	(S)L1 - NB (º)	34.9	33.3	32.55	38.1	37.7	39.5	39.8	36.2	33.6
	(S)Occ Plane to SN (º)	19.4	18.95	19.35	18.7	18.35	10.4	18.9	17.8	17.05
	(S)MP - SN (º)	32.9	32.55	29.9	30.5	32.65	28.7	32.9	32.85	26.85
	(S)U1 - NA (mm)	3.2	2.6	7.35	4.5	3.4	6.45	2.7	3.5	1.95
	(S)L1 - NB (mm)	6.7	5.85	6.2	6.7	6.3	8.3	6.6	6.6	3.4
	(S)Pog - NB (mm)	0.9	0.45	0.45	1	0.75	0.3	0.9	0.15	0.4
Pt3	(R)Cranial Deflection (º)	22.5	28	26.65	22.5	27.55	27.15	20.5	26.15	26.85
	(R)Maxillary Depth (FH-NA) (º)	85.5	88.05	88.4	84.2	88.05	87.3	83.6	86.25	88.7
	(R)Facial Depth (FH-NPo) (º)	85.4	87.45	84.75	84.5	87.85	85.6	83.4	85.75	84.8
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	93.1	88.5	88.6	93.9	89.85	90.85	93.5	89.45	88.2
	(R)Total Face Height (NaBa-PmXi) (º)	52	55.65	54.6	52.8	53.25	53	51.1	55.8	55.55
	(R)Lower Face Height (ANS-Xi-Pm)(º)	39.3	42	42.4	40.9	41.45	42.65	40.5	42.25	43.5
	(R)Mandibular Arc (º)	34.1	37.7	36.7	31.1	36.05	34.7	34.8	34.4	38.75
	(R)FMA (MP-FH) (º)	24.2	21.95	21.25	24.1	22.65	20.9	25.9	24.6	22.8
	(R)L1 to A-Po (º)	29.8	29.55	29.05	36.3	32.15	29.8	37.3	29.25	26.55
	(R)U1 to A-Po (º)	31.4	31.05	38	31.1	31	39.65	29.8	30.2	37.8

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)Interincisal Angle (U1-L1) (º)	118.8	119.35	112.95	112.5	116.85	110.55	112.9	120.55	115.7
	(R)U6 - PT Vertical (mm)	19	21.9	22.2	20.5	24.4	26.1	18.4	20.55	22.45
	(R)U1 Protrusion (U1-APo) (mm)	8.4	8.55	10.95	9	8.75	11.05	7.8	8.75	11.2
	(R)L1 Protrusion (L1-APo) (mm)	5.3	4.9	6.1	6.3	5.3	6.8	4.8	5.2	6
	(R)Convexity (A-NPo) (mm)	0.1	0.6	3.7	-0.3	0.25	1.65	0.2	0.5	4
	(R)Lower Lip to E-Plane (mm)	-2.5	-4	-0.3	-2.2	-4.05	-0.85	-2.8	-4	1.1
	(S)SNA (º)	82.3	81.8	85.1	83.4	82.25	83.85	82	81.9	85.65
	(S)SNB (º)	81.6	81.2	82.3	82.9	81.65	82.45	81.2	81.5	82.3
	(S)ANB (º)	0.7	0.65	2.8	0.4	0.55	1.4	0.8	0.4	3.35
	(S)U1 - NA (º)	31.2	29.85	30.35	31.9	30.5	35.95	29.2	29.2	29.45
	(S)L1 - NB (º)	29.2	30.15	33.9	35.2	32.15	32.05	37.1	29.9	31.5
	(S)Occ Plane to SN (º)	13.5	15.65	15.65	12.5	13.7	10.35	13.1	13.55	14.95
	(S)MP - SN (º)	27.4	28.2	24.6	24.9	28.5	24.35	27.5	29	25.85
	(S)U1 - NA (mm)	8.4	8	8.2	9.3	8.55	9.8	7.6	8.4	8.05
	(S)L1 - NB (mm)	6.2	5.25	7.35	7.2	5.85	7.45	5.7	5.4	7.65
	(S)Pog - NB (mm)	1.2	0.05	-1.65	1.4	0.6	-0.5	1	-0.2	-1.2
Pt4	(R)Cranial Deflection (º)	30.1	32.8	30.8	28.9	32.45	30.4	29.2	31.85	32.95
	(R)Maxillary Depth (FH-NA) (º)	92.9	96.6	96.1	95	96.35	95.2	91.8	95.65	97.35
	(R)Facial Depth (FH-NPo) (º)	89.3	92.3	89.95	90.8	92.25	90.2	88.1	91.25	91.75
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	87.7	85.9	86.2	89.8	86.1	88	88.3	86.7	85.9
	(R)Total Face Height (NaBa-PmXi) (º)	59.9	59.95	58.65	58.8	57.1	59.15	61	61.3	62.55
	(R)Lower Face Height (ANS-Xi-Pm)(º)	47.9	47.9	47.75	49.2	48.45	50.35	51	50.4	51.2
	(R)Mandibular Arc (º)	37.8	38.95	38.55	37.8	40.6	35.9	37.2	39.05	37.5
	(R)FMA (MP-FH) (º)	18.2	14.5	15.65	18.4	15.65	17.1	18.3	16.8	16.7
	(R)L1 to A-Po (º)	23.1	25.7	27.6	27	24.8	25.8	27.1	25.4	27.75
	(R)U1 to A-Po (º)	22.9	23.5	29.5	24.3	22.95	26.6	27.4	22.95	28.95
	(R)Interincisal Angle (U1-L1) (º)	133.9	130.8	122.9	128.6	132.25	127.6	125.4	131.75	123.3
	(R)U6 - PT Vertical (mm)	22.5	22.75	21.9	22.6	23.8	25.95	22.2	22.65	23.2
	(R)U1 Protrusion (U1-APo) (mm)	5.5	5.55	7.6	6	5.65	6.05	6.1	5.9	7.45
	(R)L1 Protrusion (L1-APo) (mm)	2.6	2.45	3.65	3.5	2.85	3.3	3	2.9	3.7
	(R)Convexity (A-NPo) (mm)	4.1	4.7	6.45	4.3	4.5	5.35	4	4.7	6.15
	(R)Lower Lip to E-Plane (mm)	-2	-3.4	-2.25	-1.8	-3.85	-1.8	-2.4	-3.55	-2.25

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(S)SNA (º)	80.6	82.6	84	84	83.5	85.85	80.3	83.4	85.45
	(S)SNB (º)	76.4	78.05	78.1	79.4	79.2	80.3	76.3	78.9	79.45
	(S)ANB (º)	4.2	4.55	5.95	4.6	4.3	5.55	4	4.55	6
	(S)U1 - NA (º)	15.4	14.75	17.55	16.1	14.6	16.4	20.2	14.2	17.7
	(S)L1 - NB (º)	26.5	29.9	33.6	30.7	28.85	30.4	30.4	29.55	33.05
	(S)Occ Plane to SN (º)	17.7	17.8	17.25	16.3	18	12.8	18	17.2	16.65
	(S)MP - SN (º)	30.5	28.55	27.8	29.4	28.5	26.45	29.8	29	28.6
	(S)U1 - NA (mm)	2.2	1.45	1.7	2.4	1.85	1.85	2.7	1.8	2.2
	(S)L1 - NB (mm)	6	5.55	7.2	6.8	5.85	7.45	5.9	5.95	8.1
	(S)Pog - NB (mm)	1.2	0.4	-0.45	1	0.45	1.1	0.8	0.35	0.8
Pt5	(R)Cranial Deflection (º)	29	28.5	27.45	29.3	28.7	28.4	30.9	28.95	28.75
	(R)Maxillary Depth (FH-NA) (º)	91.3	91.4	91.95	91.8	90.55	90.85	93.4	91.9	90.8
	(R)Facial Depth (FH-NPo) (º)	88.1	88	88.25	88.9	88.1	88.15	90.3	88.4	87.55
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	85.2	84.8	86.35	86.2	84.75	86.4	86.1	85.3	84.75
	(R)Total Face Height (NaBa-PmXi) (º)	60.4	60.45	58.05	60.2	61.85	61.4	60.4	60.75	60.65
	(R)Lower Face Height (ANS-Xi-Pm)(º)	44.6	46	44.55	44.8	49.65	49.85	44.8	46	45.85
	(R)Mandibular Arc (º)	34.7	34.95	35.85	36.1	30.15	30.25	35.5	35.4	36
	(R)FMA (MP-FH) (º)	24.6	24.2	23.2	22.4	24.75	19.5	24.1	24.9	23.2
	(R)L1 to A-Po (º)	19	27.6	28.3	24.3	26.55	32.1	28	26.25	27.4
	(R)U1 to A-Po (º)	25.2	26.7	30.35	27.8	21.95	37.65	28.8	24.25	28.75
	(R)Interincisal Angle (U1-L1) (º)	135.9	125.7	121.35	127.8	131.5	110.2	123.2	129.5	123.85
	(R)U6 - PT Vertical (mm)	20.5	20.5	20.9	22.3	21.8	23.3	21.6	20.8	18.65
	(R)U1 Protrusion (U1-APo) (mm)	5.5	5.65	6.05	6.2	5.65	7.8	5.8	5.8	6.7
	(R)L1 Protrusion (L1-APo) (mm)	3.1	3.85	4	4.2	4.8	6.25	4	4	4.15
	(R)Convexity (A-NPo) (mm)	3.5	3.5	3.9	3.1	2.55	2.85	3.4	3.75	3.65
	(R)Lower Lip to E-Plane (mm)	0.7	-0.15	0.6	1.6	-0.05	0.2	1.3	-0.25	0.7
	(S)SNA (º)	80.9	81.65	85.9	80.8	81.65	83.5	81.2	82.45	81.1
	(S)SNB (º)	77.5	78.25	82.2	77.7	79.5	78.9	78	79.25	78
	(S)ANB (º)	3.4	3.4	3.65	3.1	2.2	4.6	3.2	3.2	3.1
	(S)U1 - NA (º)	18.1	19.65	22.25	21.4	16.9	19.4	22	16.9	21.4
	(S)L1 - NB (º)	22.7	31.25	32.75	27.7	29.45	30.6	31.5	30.35	31.6
	(S)Occ Plane to SN (º)	22.4	21.55	17.4	21.7	18.05	14.4	22.7	19.25	20.7

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(S)MP - SN (º)	35	33.85	29.3	33.5	33.65	27.5	36.3	34.25	32.95
	(S)U1 - NA (mm)	2.7	2.7	3.1	3.6	3.7	4.2	3.1	2.85	3.95
	(S)L1 - NB (mm)	5.3	6	6.3	6.3	6	9.3	6.1	5.9	6.15
	(S)Pog - NB (mm)	0.3	0.1	-0.1	0.4	-0.5	1.3	0.2	-0.5	-0.3
Pt6	(R)Cranial Deflection (º)	25	23.9	24	22.6	25.75	26.25	16.7	23.45	22.1
	(R)Maxillary Depth (FH-NA) (º)	91.5	90.1	90.95	89.2	92.65	91.15	84.7	89.35	89.6
	(R)Facial Depth (FH-NPo) (º)	94.4	93.75	95.6	94.7	95.9	97.2	88.3	93.2	93.5
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	98.9	98.3	101.5	101.6	98.45	102.55	101.5	99.35	101.2
	(R)Total Face Height (NaBa-PmXi) (º)	47.9	47.2	44.85	45.7	47.2	46.05	46.8	48.7	45.9
	(R)Lower Face Height (ANS-Xi-Pm)(º)	40	42.4	40.55	42.9	42.35	43.65	43.1	43.9	43.35
	(R)Mandibular Arc (º)	42.2	39.9	39.5	41.5	36.7	39.75	39.7	36.65	40.8
	(R)FMA (MP-FH) (º)	20	17.95	14.9	19.9	16.2	12.4	26.4	19.8	17.95
	(R)L1 to A-Po (º)	37	34.05	38.1	39.2	34.55	40	41.9	37.4	39.25
	(R)U1 to A-Po (º)	32.6	33.95	34.95	34	36.5	35.3	33.4	32.35	36.3
	(R)Interincisal Angle (U1-L1) (º)	110.5	112	107	106.7	109	104.7	104.6	110.25	104.5
	(R)U6 - PT Vertical (mm)	31	25.55	31.7	31.5	32.05	38.8	14.8	23.95	29.8
	(R)U1 Protrusion (U1-APo) (mm)	10.2	10.35	11.45	11.4	10.35	11.4	11.1	10.6	11.25
	(R)L1 Protrusion (L1-APo) (mm)	9	8.9	9.45	10.6	9.1	10.05	9.7	9.5	9.7
	(R)Convexity (A-NPo) (mm)	-2.7	-3.3	-4.1	-4.8	-3	-5.2	-3.1	-3.55	-3.4
	(R)Lower Lip to E-Plane (mm)	4.6	4.25	4.95	6.1	4.25	4.6	5.4	4.25	4.75
	(S)SNA (º)	83.7	84.8	85.3	85.1	85.65	87.25	86.2	84.2	88.05
	(S)SNB (º)	86.3	87.95	89.4	90.3	88.6	91.65	89.5	87.6	91.6
	(S)ANB (º)	-2.6	-3.1	-4.15	-5.2	-2.9	-4.35	-3.2	-3.4	-3.55
	(S)U1 - NA (º)	38.4	41.05	43.85	44.6	42.75	45.85	40.3	39.8	43.75
	(S)L1 - NB (º)	33.7	30.1	33.25	33.9	31.15	33.8	38.3	33.3	35.35
	(S)Occ Plane to SN (º)	7.5	5.45	4.1	4.8	5.35	0.85	6	5.85	1.45
	(S)MP - SN (º)	27.8	23.25	20.5	24	23.2	17.65	24.9	24.95	19.5
	(S)U1 - NA (mm)	12.3	13.15	14.85	15.7	12.75	14.35	13.9	13.55	14
	(S)L1 - NB (mm)	7.7	7.55	7.7	8.3	7.75	7.8	8.3	7.95	8.1
	(S)Pog - NB (mm)	0.5	0.9	1.05	0.5	0.6	1.25	0.6	0.9	0.55
Pt7	(R)Cranial Deflection (º)	29.3	31.3	28.2	29.2	32.1	34.2	27.7	29.75	28.95
	(R)Maxillary Depth (FH-NA) (º)	93	93.25	90.5	91.7	94.05	94.75	91.4	92.45	92.6

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)Facial Depth (FH-NPo) (º)	91.4	91.7	88.1	91.2	92.95	94	90.1	90.8	90.85
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	88.2	86.25	86.55	88.3	86.45	86.9	90.1	87.35	88.9
	(R)Total Face Height (NaBa-PmXi) (º)	60.3	62.55	60.65	58.8	62.25	62.1	58.9	61.35	63.1
	(R)Lower Face Height (ANS-Xi-Pm)(º)	49.2	49	48.1	47	50.6	52.05	47.8	50.4	50.5
	(R)Mandibular Arc (º)	30.7	30.4	33.45	32.5	27.45	32.9	32.4	29.9	23.95
	(R)FMA (MP-FH) (º)	26.8	27.4	28.5	27.8	26.6	24.3	28	28.35	28.5
	(R)L1 to A-Po (º)	24.9	25.35	15.65	25.6	26.7	20.15	25.8	19.4	19.4
	(R)U1 to A-Po (º)	24.4	25.9	25.95	24.9	23.2	35.1	25.2	29.75	27.65
	(R)Interincisal Angle (U1-L1) (º)	130.6	128.75	138.4	129.5	130.1	124.7	129	130.9	133
	(R)U6 - PT Vertical (mm)	20.8	21.65	20.8	21.2	22.75	24.9	20.3	21.15	22.45
	(R)U1 Protrusion (U1-APo) (mm)	5.9	6.3	7.25	6.2	6.3	6.7	5.8	6.65	6.4
	(R)L1 Protrusion (L1-APo) (mm)	3.7	3.6	3.15	4.8	4.55	4.4	3.8	2.9	3.9
	(R)Convexity (A-NPo) (mm)	1.6	1.6	2.4	0.6	1.1	0.75	1.3	1.65	1.7
	(R)Lower Lip to E-Plane (mm)	-0.4	-1.65	-1.75	0	-1.65	-1.45	0.1	-2.3	-1.8
	(S)SNA (º)	80.5	81.05	82.6	80.3	81.3	82.2	79.8	81.2	83.9
	(S)SNB (º)	78.1	78.45	79.25	78.7	79.05	80.35	77.3	78.7	81.2
	(S)ANB (º)	2.4	2.6	3.35	1.6	2.25	1.8	2.5	2.45	2.7
	(S)U1 - NA (º)	21.2	22.7	21.2	23.8	20.95	33.6	22.5	19.9	24.3
	(S)L1 - NB (º)	25.7	25.9	17.1	25.2	26.65	19.85	26	26.65	20.1
	(S)Occ Plane to SN (º)	18.5	17.6	12.65	18.5	18.15	6.35	16.7	18.7	10.5
	(S)MP - SN (º)	39.3	39.65	36.4	39.2	39.35	36.9	39.6	41.4	37.2
	(S)U1 - NA (mm)	4.6	4.85	5.3	5.7	5.3	6.25	4.7	4.6	5.1
	(S)L1 - NB (mm)	5.8	5.9	6	6.6	6.8	6.3	6.2	6.15	6.25
	(S)Pog - NB (mm)	1.6	2	1.9	2.1	2.25	2.1	2.3	1.9	1.9
Pt8	(R)Cranial Deflection (º)	30.4	31.8	32.9	27.6	33.35	34	28.5	33.1	34.05
	(R)Maxillary Depth (FH-NA) (º)	93.4	94.05	96.15	92.7	95.35	96.25	92.8	95	96.3
	(R)Facial Depth (FH-NPo) (º)	92.1	93.1	94.1	92.7	94.1	95.45	91.3	94	94.25
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	90.8	88.8	89.95	93.8	88.05	91.2	91.4	88.75	88.5
	(R)Total Face Height (NaBa-PmXi) (º)	56.3	58.1	54.6	54.8	57.2	52.7	55.4	56.7	57.25
	(R)Lower Face Height (ANS-Xi-Pm)(º)	44.1	46.85	44.25	45.1	45.6	45.05	44.5	44.4	45.35
	(R)Mandibular Arc (º)	38.6	40.2	43.85	34.9	37.25	39.7	38.5	42.8	42.75
	(R)FMA (MP-FH) (º)	21.8	20.65	18.6	20.2	21.85	16.55	26.2	22.65	20.3

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)L1 to A-Po (º)	22.7	23.3	24.75	28.4	26.45	26.95	25.7	24.55	25.45
	(R)U1 to A-Po (º)	25	24.25	28.3	25.3	26.05	34.45	25	23.6	28.55
	(R)Interincisal Angle (U1-L1) (º)	132.3	132.45	126.95	126.3	127.5	118.6	129.4	131.75	125.95
	(R)U6 - PT Vertical (mm)	25.7	26.95	29.45	27.3	29.05	32.7	23.1	27.75	28.05
	(R)U1 Protrusion (U1-APo) (mm)	5	5.2	6.1	5.8	5.15	7.7	4.7	5.35	6.25
	(R)L1 Protrusion (L1-APo) (mm)	2.3	2.8	3.5	4.3	3.75	5.85	2.8	3.35	4.45
	(R)Convexity (A-NPo) (mm)	1.5	1	2.2	0	1.35	0.75	1.6	1.05	2.2
	(R)Lower Lip to E-Plane (mm)	-0.4	-1.25	-0.7	-0.4	-1.1	0	-0.5	-1.2	-1.35
	(S)SNA (º)	80.4	79.7	81.65	80.2	79.95	81.95	81.2	79.3	82.3
	(S)SNB (º)	77.8	77.7	78.65	79.1	77.55	80.4	78.5	77.45	79.7
	(S)ANB (º)	2.6	1.95	3.05	1.2	2.4	1.6	2.7	1.9	2.6
	(S)U1 - NA (º)	22.1	22.3	24.1	25.3	23.4	32.95	21.9	21.65	24.25
	(S)L1 - NB (º)	23	23.3	25.95	27.3	26.65	26.85	26.1	24.65	27.2
	(S)Occ Plane to SN (º)	13.4	12.75	11.6	13.9	14.1	5.1	12.8	12.5	9.1
	(S)MP - SN (º)	34.8	34.95	33.1	32.7	37.25	30.85	37.8	38.35	34.35
	(S)U1 - NA (mm)	3.9	4.45	4.45	5.8	4.15	7.2	3.4	4.55	4.7
	(S)L1 - NB (mm)	5.1	4.95	6.25	6	6.35	7.45	5.5	5.4	6.6
	(S)Pog - NB (mm)	2.6	2.15	1.9	2.4	2.5	1.6	2.4	1.95	1
Pt9	(R)Cranial Deflection (º)	31.5	32.75	30.2	30.8	34.4	31.35	31	32.2	32.2
	(R)Maxillary Depth (FH-NA) (º)	91.9	91.1	90.6	88.3	93.15	90.55	90.2	90.4	92.05
	(R)Facial Depth (FH-NPo) (º)	94.6	93.95	93	94	96.25	93.95	93.8	93.25	93.9
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	92.7	89.45	91.65	91.9	90.2	91.8	94	90.75	91.35
	(R)Total Face Height (NaBa-PmXi) (º)	57.8	60.75	56.8	57.9	58.6	57.3	56.8	60.65	57.85
	(R)Lower Face Height (ANS-Xi-Pm)(º)	41.1	43	42.75	43.4	43.8	45.3	41.5	43	42.05
	(R)Mandibular Arc (º)	37.2	35.4	38.3	38.5	32	36.95	44.9	30.3	38.95
	(R)FMA (MP-FH) (º)	18.2	18.15	19.05	19.7	16.3	18.6	19.4	19.3	17.35
	(R)L1 to A-Po (º)	24.1	23.95	26.95	29.1	22.95	33.45	27.1	23.05	26.35
	(R)U1 to A-Po (º)	19.7	14.45	14.75	22.8	13.2	16.05	14.2	13.65	15.7
	(R)Interincisal Angle (U1-L1) (º)	136.3	141.6	138.35	128.1	143.8	130.45	138.7	143.3	137.95
	(R)U6 - PT Vertical (mm)	19.2	27.05	26.8	28.5	31.35	27.85	28.4	27.55	26.1
	(R)U1 Protrusion (U1-APo) (mm)	0.5	0.65	0.95	2.7	0.85	3.5	1.3	0.95	1.5
	(R)L1 Protrusion (L1-APo) (mm)	-2.2	-2.1	-1.6	0.4	-1.35	1.15	-1.4	-1.8	-1.3

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)Convexity (A-NPo) (mm)	-3.1	-3.35	-2.7	-6.5	-3.65	-3.85	-4.1	-3.4	-2.2
	(R)Lower Lip to E-Plane (mm)	-6.2	-7.15	-6.3	-6.3	-7.2	-6.3	-6.5	-7	-6.6
	(S)SNA (º)	79.6	77.6	79.55	76.2	78.5	80	78.7	77.95	80.5
	(S)SNB (º)	78.2	76.45	77.4	77.5	77.4	79.2	78	77	78.7
	(S)ANB (º)	1.4	1.1	2.15	-1.4	1.05	0.8	0.7	0.95	1.85
	(S)U1 - NA (º)	25.7	20.7	19.7	35.1	20.05	23.3	21.9	20.1	19.8
	(S)L1 - NB (º)	16.7	16.6	19.8	18.1	15.1	25.4	18.7	15.65	20.45
	(S)Occ Plane to SN (º)	13.9	15.6	16.8	13.6	14.65	15.65	13.2	16.25	15.25
	(S)MP - SN (º)	30.5	31.7	30.15	31.8	31	29.2	30.9	31.8	28.85
	(S)U1 - NA (mm)	2.5	3	2.95	7.1	3.5	5.95	4.2	3.4	3.1
	(S)L1 - NB (mm)	1.6	1.65	3.45	2.4	2.45	4.7	2.2	1.85	2.9
	(S)Pog - NB (mm)	8.7	8.5	9.85	9.1	8.95	8.95	9.2	8.25	7.9
Pt10	(R)Cranial Deflection (º)	31.1	31.15	28.35	29.4	30.95	30.15	23.2	31.35	30.95
	(R)Maxillary Depth (FH-NA) (º)	95.4	94.85	94.8	95.2	94.45	96.35	88.1	95.25	96.4
	(R)Facial Depth (FH-NPo) (º)	92.2	91.1	89.4	91.5	91.05	92.15	84.1	91.5	92
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	85.8	84.1	84.6	87	85.7	88.8	87	84.75	85.2
	(R)Total Face Height (NaBa-PmXi) (º)	59.1	60.25	57.15	56.3	60.55	54.95	59.7	60.35	57.9
	(R)Lower Face Height (ANS-Xi-Pm)(º)	47.3	49.75	48.85	47.6	50.65	45.35	49.7	49.25	48.2
	(R)Mandibular Arc (º)	30.5	30.95	29.6	35.6	27.35	32	27.7	30.35	32.25
	(R)FMA (MP-FH) (º)	21.6	22.1	20.8	21.3	22.55	17.95	31.4	23.15	20.35
	(R)L1 to A-Po (º)	18.1	23.35	22.75	24	25	22.55	25.1	26.75	26.15
	(R)U1 to A-Po (º)	30.3	26.45	32.2	33.2	31.4	30.65	31.7	30.2	31.6
	(R)Interincisal Angle (U1-L1) (º)	131.6	130.2	125.05	122.8	123.55	126.85	123.2	123	122.3
	(R)U6 - PT Vertical (mm)	21.6	19	17.8	23	22.3	25.25	16.6	19.1	19.25
	(R)U1 Protrusion (U1-APo) (mm)	6.9	6.25	7.85	6.6	7.15	7.8	6.7	6.7	7
	(R)L1 Protrusion (L1-APo) (mm)	4.4	4.35	5.75	4.9	5.65	5.1	5.1	5.1	5.5
	(R)Convexity (A-NPo) (mm)	3.4	3.95	5.45	4	3.65	4.25	4.1	4	4.65
	(R)Lower Lip to E-Plane (mm)	0.1	-0.45	0.85	0	-0.2	0.25	0.7	-0.3	0.1
	(S)SNA (º)	82.3	81.65	84.45	82.9	82.05	84.75	82.7	82.3	86.75
	(S)SNB (º)	79.3	78.2	80.35	79.5	79.25	81.7	79.2	79.1	83.4
	(S)ANB (º)	3	3.5	4.1	3.4	2.8	3.1	3.6	3.2	3.35
	(S)U1 - NA (º)	23.5	18.65	21.25	25.1	24.25	22.1	23.5	22.2	22.3

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(S)L1 - NB (º)	21.9	27.65	29.55	28.6	29.35	27.95	29.8	31.55	32.15
	(S)Occ Plane to SN (º)	17.7	19.65	17.55	18.7	17.4	11.9	16.5	17.8	14
	(S)MP - SN (º)	34.7	35.35	31.15	33.6	34.9	29.3	36.8	36.1	30
	(S)U1 - NA (mm)	4	2.85	3.25	3.4	4.25	4.65	3.2	3.45	3.35
	(S)L1 - NB (mm)	5.9	6.2	7.1	6.6	6.85	6.4	6.9	6.6	6.65
	(S)Pog - NB (mm)	-0.5	-0.45	-2.5	-0.7	-1.3	-1.8	-0.8	-1.05	-2.25
Pt11	(R)Cranial Deflection (º)	30.8	30.6	31.9	30.2	31.85	32.5	29.3	30.75	30.7
	(R)Maxillary Depth (FH-NA) (º)	92.5	91.8	94.95	92.5	92.05	95.45	91.7	92.1	94.7
	(R)Facial Depth (FH-NPo) (º)	86.8	85.9	87.3	86.2	86.8	87.05	85.7	86.1	87.05
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	83.8	82.65	83.55	83.7	82.3	79.85	84.4	83	83.95
	(R)Total Face Height (NaBa-PmXi) (º)	62.8	65.4	62.8	63.4	67.9	65.75	64.3	65.5	64.25
	(R)Lower Face Height (ANS-Xi-Pm)(º)	43.6	47.1	45.3	44.3	50.05	50.15	45.2	46.9	45.65
	(R)Mandibular Arc (º)	34.4	28.2	31.7	31.6	22.9	28	30.4	28.4	28.6
	(R)FMA (MP-FH) (º)	30.5	30.95	25.95	30.2	29.2	54.25	32.8	32.2	29.35
	(R)L1 to A-Po (º)	25.3	22.5	29.05	22.9	24.2	22.75	25.3	23.1	26.6
	(R)U1 to A-Po (º)	34.2	27.5	29.25	33.2	26.05	33.2	29.9	25.7	32
	(R)Interincisal Angle (U1-L1) (º)	120.5	130	121.7	123.9	129.85	124.1	124.8	131.15	121.45
	(R)U6 - PT Vertical (mm)	17.9	18.7	21.1	19.1	20.25	22	17.6	17.9	18.7
	(R)U1 Protrusion (U1-APo) (mm)	8.6	8.3	8.4	9.2	9.45	9.05	9.4	8.1	8.05
	(R)L1 Protrusion (L1-APo) (mm)	3.6	3.3	4.2	4.4	4.75	5.2	3.9	3.3	3.45
	(R)Convexity (A-NPo) (mm)	5.5	5.8	7.3	6	5.05	8.05	5.8	5.75	7.3
	(R)Lower Lip to E-Plane (mm)	0.3	-0.15	0.7	0.5	0.75	1.7	0.8	0.25	0.65
	(S)SNA (º)	83.3	83.4	85.65	83.8	83.4	86.1	83.5	84.1	88.5
	(S)SNB (º)	77.4	77.25	78.65	77.3	78.1	78.3	77.1	78.2	81.75
	(S)ANB (º)	5.9	6.2	7	6.4	5.35	7.8	6.4	5.95	6.8
	(S)U1 - NA (º)	22.3	15.5	14.2	20.6	15.9	17.1	17.6	13.85	16.9
	(S)L1 - NB (º)	31.3	28.3	37.15	29.1	29	31.05	31.3	29.05	36.25
	(S)Occ Plane to SN (º)	17.2	18.05	19.95	17.4	16	15.55	18.3	16.45	17.15
	(S)MP - SN (º)	39.7	39.35	35.25	38.9	37.85	63.6	41.1	40.25	35.35
	(S)U1 - NA (mm)	3.9	3.1	2.35	4.1	5.05	3.05	4.5	2.8	1.85
	(S)L1 - NB (mm)	7.1	7.25	7.9	8.3	8	9.85	8	6.75	7
	(S)Pog - NB (mm)	0.4	0.55	-1.25	0.2	0.1	-1.15	0.7	-0.1	-1.35

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
Pt12	(R)Cranial Deflection (°)	34.1	34.65	33.1	34.8	34.3	30.7	33.1	34.05	34.4
	(R)Maxillary Depth (FH-NA) (°)	91.9	91.45	93.3	91.4	90.85	88.25	91.3	91.35	93.8
	(R)Facial Depth (FH-NPo) (°)	90.3	89.9	89.6	90.8	89.8	87.7	89.4	89.5	90.1
	(R)Facial Axis-Ricketts (NaBa-PtGn)(°)	79.9	78.75	80.2	81	79.8	82.4	81.3	79.4	79.15
	(R)Total Face Height (NaBa-PmXi) (°)	71.2	72.75	70.25	69.5	70.15	69.45	71.7	71.9	70.8
	(R)Lower Face Height (ANS-Xi-Pm)(°)	53.6	54.65	52.1	56.6	55.15	56	54.5	53.95	53.05
	(R)Mandibular Arc (°)	29.5	29.8	34.15	33	32.4	31.6	28.5	30.55	33.9
	(R)FMA (MP-FH) (°)	27.1	27.4	28.15	25.6	27.15	28.95	28.2	29.2	28.45
	(R)L1 to A-Po (°)	26.3	24.5	28.2	27.4	25.2	30.85	27.3	24.4	26.85
	(R)U1 to A-Po (°)	29.4	26.9	36.05	32.9	27.2	30.65	30.9	27.85	33.65
	(R)Interincisal Angle (U1-L1) (°)	124.3	128.65	115.7	119.7	127.6	118.5	121.9	127.75	119.55
	(R)U6 - PT Vertical (mm)	18.7	18.45	20.3	22.6	20.6	20.15	18.9	18.15	19.4
	(R)U1 Protrusion (U1-APo) (mm)	8.7	8.35	10.55	9.6	8.95	12.4	8.6	8.25	8.85
	(R)L1 Protrusion (L1-APo) (mm)	6.3	6.05	6.85	7.6	6.65	8.9	6.6	6.2	6.6
	(R)Convexity (A-NPo) (mm)	1.8	1.8	4.25	0.7	1.2	0.6	2.3	2.15	4.4
	(R)Lower Lip to E-Plane (mm)	0.1	0.05	0.85	0.4	0.55	2.9	0.7	0.05	1.2
	(S)SNA (°)	76.8	76	80.8	75.2	76	79.45	76.9	76.85	81.6
	(S)SNB (°)	74.4	73.6	76.4	73.7	74.05	78.3	73.9	74.4	77.6
	(S)ANB (°)	2.4	2.4	4.4	1.5	1.85	1.2	2.9	2.5	3.95
	(S)U1 - NA (°)	26.1	23.75	28.5	31.7	25.1	29.55	26.8	24.1	25.85
	(S)L1 - NB (°)	27.3	25.2	31.35	27.1	25.35	30.8	28.4	25.65	30.65
	(S)Occ Plane to SN (°)	20.3	22.4	21.1	22.4	21.05	16.15	20	20.9	17.85
	(S)MP - SN (°)	42.2	42.8	40.65	41.7	41.95	37.75	42.7	43.75	40.7
	(S)U1 - NA (mm)	7.4	6.95	7.5	9.1	8.05	11.85	7	6.65	5.65
	(S)L1 - NB (mm)	8.8	8.6	10.6	9.4	8.8	10.25	9.5	8.6	9.8
	(S)Pog - NB (mm)	1.8	2.05	1.6	2	2	1.35	2.2	1.5	0.5
Pt13	(R)Cranial Deflection (°)	29.4	31.95	29.9	31.2	32.85	26.4	27.7	31.2	31.05
	(R)Maxillary Depth (FH-NA) (°)	86.8	89.25	91	87	91.25	85.1	85.7	90.05	91.85
	(R)Facial Depth (FH-NPo) (°)	85.3	86.35	85.9	86.9	88.8	82	84	86.7	86.8
	(R)Facial Axis-Ricketts (NaBa-PtGn)(°)	85.8	83.85	85.85	86.4	85	86.3	86.5	85.2	85.05
	(R)Total Face Height (NaBa-PmXi) (°)	64.9	66.4	62.85	65.2	65	64.3	65	65.1	64.4
	(R)Lower Face Height (ANS-Xi-Pm)(°)	48.3	48.6	45.5	50.6	49.9	49.75	50.5	48.8	49.2

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)Mandibular Arc (º)	29.6	28.55	30.85	28.2	26.8	28.2	26.5	27.15	30.35
	(R)FMA (MP-FH) (º)	23.3	22.7	23.4	21	20.8	25.3	24.9	23.65	22.7
	(R)L1 to A-Po (º)	27.8	27.8	26.5	32.3	27.95	31.8	30.5	28.1	26.05
	(R)U1 to A-Po (º)	20.9	20.2	24.65	25.3	18.8	21	19	19.1	23.65
	(R)Interincisal Angle (U1-L1) (º)	131.3	132	128.8	122.4	133.25	127.25	130.4	132.75	130.3
	(R)U6 - PT Vertical (mm)	21.2	24.75	23.55	23.5	26.65	20.5	20.2	23.25	21.45
	(R)U1 Protrusion (U1-APo) (mm)	6.1	4.55	5.35	7.2	5.1	6.25	5.7	4.65	4.95
	(R)L1 Protrusion (L1-APo) (mm)	3.4	1.9	2.45	4.3	3	4.25	3.4	2.25	2.1
	(R)Convexity (A-NPo) (mm)	1.6	3.3	5.65	0.2	2.65	3.4	1.9	3.7	5.5
	(R)Lower Lip to E-Plane (mm)	-4.7	-5.2	-2.3	-4.6	-5.35	-2.85	-4.9	-4.95	-3.2
	(S)SNA (º)	73.3	72.25	77.05	70.5	74.6	76.75	74.5	74.9	78.2
	(S)SNB (º)	70.3	68.05	70.9	68.6	70.65	72.2	70.8	70.45	72.4
	(S)ANB (º)	3.1	4.15	6.25	1.9	4	4.6	3.6	4.45	5.75
	(S)U1 - NA (º)	17.8	13.9	13.55	24.9	13.7	14.4	15.5	12.05	12.85
	(S)L1 - NB (º)	27.9	29.9	31.45	30.8	29.05	33.75	30.4	30.7	31
	(S)Occ Plane to SN (º)	21	22.95	23.85	24.1	21.2	16.4	20.4	22.15	21.25
	(S)MP - SN (º)	36.7	39.75	37.35	37.6	37.4	33.65	36.2	38.85	36.4
	(S)U1 - NA (mm)	4.7	1.8	0.7	7	2.9	3.65	4.2	1.65	0.45
	(S)L1 - NB (mm)	6.8	5.95	7.45	7	6.95	8.5	7.3	6.2	6.45
	(S)Pog - NB (mm)	3.3	2.75	2.15	3.7	3.3	3.1	4	2.3	1.35
Pt14	(R)Cranial Deflection (º)	28.2	30	29.4	27.8	27.75	31.3	28.9	30.55	29.1
	(R)Maxillary Depth (FH-NA) (º)	88.8	90.35	90.3	91.2	88.3	90	90	90.65	90.65
	(R)Facial Depth (FH-NPo) (º)	88.1	89.65	89	89.8	87.85	90.3	89.2	90	88.95
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	89.6	88.3	88.75	92	88.95	88.5	89.8	88.75	89.25
	(R)Total Face Height (NaBa-PmXi) (º)	57.5	58.45	55.05	55.8	56.55	55.9	57.6	58.8	55.8
	(R)Lower Face Height (ANS-Xi-Pm)(º)	44.2	45.15	44.05	41.1	45.8	44.7	42.4	45.55	44.7
	(R)Mandibular Arc (º)	33.8	35.6	40.75	34	35.8	38.45	34.5	33.4	40.25
	(R)FMA (MP-FH) (º)	21.1	19.4	18.65	19.5	22.5	16.85	22	21.4	20.05
	(R)L1 to A-Po (º)	24	24.25	29.8	22.9	25.1	30.75	26.1	21.95	27.9
	(R)U1 to A-Po (º)	24.7	23.85	24.85	31.5	23.9	26.7	29.6	22.8	25.7
	(R)Interincisal Angle (U1-L1) (º)	131.3	131.9	125.4	125.6	131	122.6	124.3	135.25	126.45
	(R)U6 - PT Vertical (mm)	18	18.65	19.85	21.9	18.7	22.05	18.1	19.3	18.2

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)U1 Protrusion (U1-APo) (mm)	4.2	4	4.9	3.9	4.7	6.45	4.4	4.4	4.75
	(R)L1 Protrusion (L1-APo) (mm)	1.3	0.75	2.05	0.7	1.6	4	1.2	1.3	1.75
	(R)Convexity (A-NPo) (mm)	0.7	0.65	1.25	1.4	0.45	-0.3	0.8	0.65	1.6
	(R)Lower Lip to E-Plane (mm)	-5.7	-6.15	-5.5	-5.4	-5.95	-5.95	-5.9	-6.35	-5.7
	(S)SNA (º)	80.6	80.5	82.2	83.3	81	80.25	81.6	81	83.4
	(S)SNB (º)	78.3	78	79.3	80.3	78.75	78.75	78.7	78.6	80.35
	(S)ANB (º)	2.2	2.5	2.95	3	2.3	1.5	2.9	2.35	3.05
	(S)U1 - NA (º)	23.2	22.5	22.25	28.4	22.95	27.3	27.9	21.5	22.2
	(S)L1 - NB (º)	23.2	23.1	29.5	23	23.8	28.65	25	20.85	28.4
	(S)Occ Plane to SN (º)	14.9	15.85	15.4	13.7	13.05	16.05	12.9	12.75	11.45
	(S)MP - SN (º)	29.4	29.25	26.75	27.4	29.8	26.6	30.4	31.1	27.35
	(S)U1 - NA (mm)	3.6	3.45	3.85	3	4.35	6.65	3.8	3.85	3.45
	(S)L1 - NB (mm)	3.7	3.55	4.85	3.6	4.25	6.25	4.3	3.95	4.4
	(S)Pog - NB (mm)	2.8	3.5	3	3	3.4	3.45	3.7	3.35	2.3
Pt15	(R)Cranial Deflection (º)	31.2	26.7	26.05	28.5	29	28.4	27.5	27.05	27.45
	(R)Maxillary Depth (FH-NA) (º)	94	91.9	93.45	93.5	93.6	91.75	91.9	91.75	93.05
	(R)Facial Depth (FH-NPo) (º)	94.3	91.2	90.35	93.1	93.4	90.45	91.1	91.4	92
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	91.9	92.25	92.75	94.8	92.8	91.65	94.6	93.2	93.75
	(R)Total Face Height (NaBa-PmXi) (º)	55.9	54.8	54.05	56.6	54.85	55.1	54.1	54.45	53.55
	(R)Lower Face Height (ANS-Xi-Pm)(º)	41.8	43.75	42.15	43.5	43.45	43.75	43.9	43.2	44.15
	(R)Mandibular Arc (º)	39	36.7	35.1	34.9	34.35	38.35	43.4	37.45	36.65
	(R)FMA (MP-FH) (º)	17.9	20.85	19.85	21	18.6	18.05	22.1	21.35	17.45
	(R)L1 to A-Po (º)	25.1	22.4	28.45	21.5	28.25	27.2	22.7	24.3	28.75
	(R)U1 to A-Po (º)	23.4	23.8	33	25.1	25.35	28.2	26.3	25.35	30.25
	(R)Interincisal Angle (U1-L1) (º)	131.5	133.75	118.5	133.4	126.4	124.55	131	130.3	120.95
	(R)U6 - PT Vertical (mm)	19.9	18	16.8	19.9	21.25	19.95	19.5	17.85	18.55
	(R)U1 Protrusion (U1-APo) (mm)	5.4	5.2	5.95	5.1	5.8	6.5	5.2	5.45	6.45
	(R)L1 Protrusion (L1-APo) (mm)	3.3	2.5	3.25	2.8	3.55	4	3.3	2.7	2.55
	(R)Convexity (A-NPo) (mm)	-0.2	0.65	2.95	0.4	0.2	1.2	0.7	0.3	1
	(R)Lower Lip to E-Plane (mm)	-0.6	-1.05	-0.7	-0.3	-0.9	-1.05	1.2	-0.6	-1
	(S)SNA (º)	82.5	84.1	88	83.9	84.3	85.2	84.2	83.9	88.15
	(S)SNB (º)	81.8	82.4	83.8	82.5	83.15	83.05	82.6	82.5	85.6

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(S)ANB (º)	0.7	1.6	4.2	1.5	1.15	2.1	1.6	1.4	2.6
	(S)U1 - NA (º)	23.9	22.35	26.1	24.2	24.9	25.5	24.7	24.65	27.95
	(S)L1 - NB (º)	23.8	22.2	31.2	20.9	27.6	27.8	22.7	23.65	28.5
	(S)Occ Plane to SN (º)	17.7	18.75	13.9	16.3	15.35	13.7	17.5	16.1	9.25
	(S)MP - SN (º)	29.4	28.7	25.3	30.5	27.9	24.6	29.8	29.2	22.4
	(S)U1 - NA (mm)	5.6	4.6	3.65	4.8	5.65	5.55	4.6	5.2	5.65
	(S)L1 - NB (mm)	4.4	4.15	6.4	4.4	4.9	5.7	4.9	4.25	5.1
	(S)Pog - NB (mm)	1.8	1.7	1.8	1.9	1.65	1.4	1.5	1.85	2.6
Pt16	(R)Cranial Deflection (º)	27.6	27.6	27.2	27.3	29.8	28.45	21.4	27.2	26.55
	(R)Maxillary Depth (FH-NA) (º)	93.4	92.45	92.25	90.3	95.1	93.15	86.6	91.95	93.45
	(R)Facial Depth (FH-NPo) (º)	94.1	92.5	92.4	92.8	95.15	94.25	87.6	92.2	93.25
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	98.6	95.45	97.65	98.5	96.2	97.25	99.2	96.5	99.6
	(R)Total Face Height (NaBa-PmXi) (º)	45.9	48.75	45.4	47	48.2	45.05	43.6	46.6	43.7
	(R)Lower Face Height (ANS-Xi-Pm)(º)	33.4	36.55	37.05	35.6	36.15	37.1	35.2	35.55	36.1
	(R)Mandibular Arc (º)	42.1	39.75	42.9	40.2	40.4	42.4	44.1	41.75	43.9
	(R)FMA (MP-FH) (º)	11.9	13.05	10.7	13.6	11.35	10	18.9	15.4	12.15
	(R)L1 to A-Po (º)	19.2	22.75	22.5	26	21.85	29.5	22.8	22.75	26.05
	(R)U1 to A-Po (º)	23.2	18.85	19.7	24.5	17.2	16.7	22.3	18.45	18.95
	(R)Interincisal Angle (U1-L1) (º)	137.6	138.35	137.8	129.5	140.9	133.85	134.9	138.85	134.95
	(R)U6 - PT Vertical (mm)	24.9	24.45	25.9	24.4	28.35	27.25	21.6	24.7	25.8
	(R)U1 Protrusion (U1-APo) (mm)	1.5	1.5	2.55	2.5	2.05	2.7	1.6	1.55	1.4
	(R)L1 Protrusion (L1-APo) (mm)	-2.2	-1.8	-0.75	-0.2	-1.15	0.75	-1.2	-1.6	-1.65
	(R)Convexity (A-NPo) (mm)	-0.7	-0.05	-0.1	-2.4	-0.05	-1	-1	-0.3	0.2
	(R)Lower Lip to E-Plane (mm)	-5.8	-5	-4.1	-5.3	-4.65	-5.05	-6	-5.35	-5.05
	(S)SNA (º)	84.2	83.9	83.8	81.9	84.6	85.95	83.1	83.5	86.35
	(S)SNB (º)	81.4	81.4	81.25	81.1	81.25	83.9	80.9	80.85	83.05
	(S)ANB (º)	2.8	2.5	2.5	0.8	3.35	2.1	2.3	2.65	3.25
	(S)U1 - NA (º)	24.7	18.95	20	29.9	17.3	18.95	24.7	19	18.5
	(S)L1 - NB (º)	14.9	20.2	19.75	19.9	18.4	25.15	18.2	19.5	23.25
	(S)Occ Plane to SN (º)	9.4	8.55	10.7	9	8.15	5.85	7.6	8.1	8.85
	(S)MP - SN (º)	21	21.6	19.2	22	21.85	17.25	22.4	23.85	19.3
	(S)U1 - NA (mm)	1.9	1.55	2.6	4.2	2.05	3.55	2.2	1.75	1.25

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(S)L1 - NB (mm)	1.6	1.45	2.45	2.2	3.05	3.9	2.1	1.9	2.25
	(S)Pog - NB (mm)	6.3	4.75	4.75	6	6.25	5.65	5.9	5.4	5.5
Pt17	(R)Cranial Deflection (º)	29.1	30.5	28.6	28.9	30.2	29.9	28.2	30.25	32
	(R)Maxillary Depth (FH-NA) (º)	89	89.85	89.5	86.8	89.25	90.1	87.9	89.5	91.3
	(R)Facial Depth (FH-NPo) (º)	87.5	88.1	87.35	87.2	87.9	87.85	86.4	87.9	89.25
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	86.7	84.8	86.65	88.7	85.55	87.45	88	85.6	85.55
	(R)Total Face Height (NaBa-PmXi) (º)	62.4	63.65	61.85	60.8	63.05	62.2	61.8	64.15	64.05
	(R)Lower Face Height (ANS-Xi-Pm)(º)	49.8	50.5	51.3	50.2	50.55	50.5	48.7	51	52.05
	(R)Mandibular Arc (º)	33.6	32.55	32.9	32.8	31.6	29.05	32.9	32.45	32.7
	(R)FMA (MP-FH) (º)	27.4	27	27.5	26	27.45	23.5	29	28.65	25.25
	(R)L1 to A-Po (º)	16.6	19.3	22.7	19.1	18.85	20.65	18.8	19.6	20.85
	(R)U1 to A-Po (º)	17	17.35	23.5	20.1	16.7	27.95	18.5	13.9	16.4
	(R)Interincisal Angle (U1-L1) (º)	146.4	143.35	133.8	140.8	144.4	131.4	142.7	146.5	142.7
	(R)U6 - PT Vertical (mm)	19	21.35	21.05	22	22.85	22.95	20.3	21.25	22.2
	(R)U1 Protrusion (U1-APo) (mm)	3.8	3.75	4.85	5.1	4.2	3.9	3.7	3.75	3.7
	(R)L1 Protrusion (L1-APo) (mm)	1.7	1	2.5	2.5	1.6	0.55	1.6	1.2	2.2
	(R)Convexity (A-NPo) (mm)	1.5	1.75	2	-0.4	1.35	2.2	1.5	1.6	2.05
	(R)Lower Lip to E-Plane (mm)	-4.7	-5.8	-4.65	-5	-5.9	-4.35	-4.1	-5.65	-4.8
	(S)SNA (º)	80.6	80	79.95	77.6	79.95	81.55	80.2	80	80.05
	(S)SNB (º)	78.3	77.1	76.75	76.8	77.3	77.85	77.5	77.3	77.3
	(S)ANB (º)	2.3	2.9	3.3	0.8	2.6	3.7	2.7	2.65	2.75
	(S)U1 - NA (º)	14	13.95	19.45	20.9	14.1	23.65	15.5	10.8	12.5
	(S)L1 - NB (º)	17.4	19.8	23.45	17.4	18.9	21.3	19	20	22.05
	(S)Occ Plane to SN (º)	14.6	18.35	20.5	16.2	18	12.7	14.5	18.7	16.4
	(S)MP - SN (º)	35.7	36.85	37	35.2	36.7	32	36.6	38.15	36.45
	(S)U1 - NA (mm)	2.5	2.15	3	5.5	3.05	2.25	2.5	2.25	1.9
	(S)L1 - NB (mm)	3.8	3.65	5.35	4	4.2	4	4.3	3.75	4.45
	(S)Pog - NB (mm)	1.6	2.4	2.3	2.5	2.6	3.05	2.6	2.3	1.4
Pt18	(R)Cranial Deflection (º)	31.5	30.5	27.95	28.4	32.3	29.55	28.8	28.6	28.85
	(R)Maxillary Depth (FH-NA) (º)	92.5	91.45	88.5	89.7	92.5	87.4	89.9	89.7	89.8
	(R)Facial Depth (FH-NPo) (º)	91.4	90.15	88.4	89.2	91.5	88.75	88.5	87.9	89.05
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	90.9	89.05	91.6	93	88.65	89.75	91.7	89.25	91.65

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)Total Face Height (NaBa-PmXi) (º)	53.2	53.35	51.95	53.5	54.25	53.3	54.1	54.5	52
	(R)Lower Face Height (ANS-Xi-Pm)(º)	38.3	38.9	40.3	39.1	39.8	45.2	39.8	40.6	39.95
	(R)Mandibular Arc (º)	41.5	40.85	43.7	37.9	39.95	37.4	43.5	41	43.35
	(R)FMA (MP-FH) (º)	15.4	15.2	12.2	16.9	13.75	13.45	17.4	19.05	14.95
	(R)L1 to A-Po (º)	25.7	28.55	29.25	28.1	27.9	24.45	27.7	27.4	25.25
	(R)U1 to A-Po (º)	25.1	21.8	22.2	24.5	20.1	23.85	27.7	22.2	22.2
	(R)Interincisal Angle (U1-L1) (º)	129.1	129.7	128.55	127.4	132	131.7	124.6	130.45	132.6
	(R)U6 - PT Vertical (mm)	24.2	22.3	22.65	24.9	24.55	23.65	23.2	20.15	21.9
	(R)U1 Protrusion (U1-APo) (mm)	3.1	2	3.5	3.3	2.95	5.3	3	2.55	2.65
	(R)L1 Protrusion (L1-APo) (mm)	0.5	-1.1	1	0.9	0.25	1.4	0.5	-0.1	-1
	(R)Convexity (A-NPo) (mm)	1.1	1.4	0.1	0.5	1.1	-1.4	1.5	1.95	0.75
	(R)Lower Lip to E-Plane (mm)	-4.4	-6.7	-5.5	-5.5	-6.7	-5.8	-5.6	-6.55	-6.35
	(S)SNA (º)	84.1	84.85	83.35	83.8	84.55	82.05	84.7	84.95	85.2
	(S)SNB (º)	81	81.15	81.35	81.1	81.35	81.35	81.3	81.1	82.2
	(S)ANB (º)	3.1	3.7	2	2.7	3.2	0.7	3.4	3.8	2.95
	(S)U1 - NA (º)	22.7	18.9	22	23.3	17.95	26.7	24.6	18.25	20.55
	(S)L1 - NB (º)	25.1	27.7	27.4	26.5	26.9	20.85	27.4	27.55	23.85
	(S)Occ Plane to SN (º)	8.3	9.6	7.45	8.7	10.3	7.6	8.1	10.5	8.2
	(S)MP - SN (º)	23.8	21.8	17.4	22.8	21.7	18.8	22.7	23.8	19.55
	(S)U1 - NA (mm)	2.2	0.9	3.45	2.8	2.05	6.35	1.8	1.05	2.1
	(S)L1 - NB (mm)	3.8	3.1	3.6	4.2	3.9	3.25	4	3.9	2.45
	(S)Pog - NB (mm)	3.7	4.65	3.65	4.1	4.2	4	3.7	3.9	4.35
Pt19	(R)Cranial Deflection (º)	31	33.15	32.55	29.9	33.4	32.25	31.4	33.65	33.3
	(R)Maxillary Depth (FH-NA) (º)	91	92.2	91.2	93	93.5	93.25	91.5	92.5	93.1
	(R)Facial Depth (FH-NPo) (º)	89.5	90.55	88.6	90.6	91.65	89.7	90.3	90.75	90.55
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	84.1	81.75	81.85	85.6	82.45	82.5	85.3	82	82.45
	(R)Total Face Height (NaBa-PmXi) (º)	62.9	63.3	65.8	63.3	61.9	62.2	62.2	63.95	62.9
	(R)Lower Face Height (ANS-Xi-Pm)(º)	46.8	47.15	47.8	48.4	48.65	48.2	48.3	47.7	46.35
	(R)Mandibular Arc (º)	38.6	39.75	37.85	34.6	38.8	36.4	40.6	39.55	42.65
	(R)FMA (MP-FH) (º)	24.8	22.65	23.2	23.4	21.95	21.15	23.6	24	21.4
	(R)L1 to A-Po (º)	26.5	28.25	28.05	27.2	27.45	27.3	23.5	25.7	24.4
	(R)U1 to A-Po (º)	22.2	21.8	23.2	23.5	21.3	25.95	22.1	21.75	22.85

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(R)Interincisal Angle (U1-L1) (º)	131.3	129.9	128.75	129.3	131.25	126.75	134.4	132.5	132.75
	(R)U6 - PT Vertical (mm)	18.9	19.35	18.95	19.6	21.6	20.75	19.8	19.7	18.25
	(R)U1 Protrusion (U1-APo) (mm)	4.9	5.5	5.65	5.7	5.7	6.6	5.6	5.55	5
	(R)L1 Protrusion (L1-APo) (mm)	1.5	1.9	0.55	2.3	1.95	3.15	1.8	1.25	1.1
	(R)Convexity (A-NPo) (mm)	1.7	1.8	3	2.5	2	3.85	1.4	2	2.9
	(R)Lower Lip to E-Plane (mm)	-0.3	0.1	1.1	0.2	10.8	1.25	0.6	0.15	0.75
	(S)SNA (º)	80.8	80	80.05	84.7	81	84.95	79.5	79.75	83.2
	(S)SNB (º)	77.1	76.35	75.6	80.5	77.2	80.05	76.1	76.25	78.8
	(S)ANB (º)	3.7	3.65	4.45	4.2	3.8	4.9	3.4	3.5	4.35
	(S)U1 - NA (º)	18.9	18.55	17.65	18.5	17.5	18.55	19.5	18.1	17.4
	(S)L1 - NB (º)	26.1	27.9	29.2	28	27.45	29.75	22.7	25.9	25.5
	(S)Occ Plane to SN (º)	15.7	17.25	18.55	13.1	16.5	11	15.1	17.25	13.2
	(S)MP - SN (º)	35	34.85	34.4	31.7	34.45	29.5	35.6	36.75	31.35
	(S)U1 - NA (mm)	3.5	3.9	3.3	3.7	3.85	3.5	4.4	3.8	2.65
	(S)L1 - NB (mm)	5.6	6	5.2	6.5	6.15	7.45	5.9	5.1	5.6
	(S)Pog - NB (mm)	4.4	4.35	3.95	3.7	4.2	2.65	4.5	3.7	3.85
Pt20	(R)Cranial Deflection (º)	28.9	28.15	28.8	25.2	26.65	29.4	25.6	28.3	29.35
	(R)Maxillary Depth (FH-NA) (º)	90.2	90.55	90.45	86.3	89.8	90.35	88.7	90.75	92.65
	(R)Facial Depth (FH-NPo) (º)	83.6	83.8	83.5	81.4	83.85	82.7	81.4	83.8	85.25
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	80.8	79.9	80.05	82.6	81.6	78	83.7	81.3	81
	(R)Total Face Height (NaBa-PmXi) (º)	68	69.25	66.65	68	64.95	64.5	66.1	69.8	65.85
	(R)Lower Face Height (ANS-Xi-Pm)(º)	46.5	49.15	48.6	46.5	49.1	50.05	45.6	49.45	47.45
	(R)Mandibular Arc (º)	32	26.5	34.05	28.4	32.4	42.2	35.6	27.4	33.25
	(R)FMA (MP-FH) (º)	33	32.55	29.55	34.3	33.65	29.3	34.2	34	30.4
	(R)L1 to A-Po (º)	22.3	23.15	24.9	30	27.5	33.55	25.1	24.1	24.9
	(R)U1 to A-Po (º)	30	26.6	30.7	28.8	26.15	30.7	34.7	26.3	30.75
	(R)Interincisal Angle (U1-L1) (º)	127.8	130.3	124.4	121.2	126.35	115.7	120.1	129.6	124.25
	(R)U6 - PT Vertical (mm)	14.4	12.9	13.45	11.9	15.6	15	12.3	13.85	12.9
	(R)U1 Protrusion (U1-APo) (mm)	8.2	7.65	7.7	9.9	9.05	10.75	8.4	7.9	7.6
	(R)L1 Protrusion (L1-APo) (mm)	3.7	2.95	2.75	5.7	5.05	5.8	3.3	3.45	2.7
	(R)Convexity (A-NPo) (mm)	7.6	7.7	7.95	5.4	6.35	8.3	8.1	7.9	8.45
	(R)Lower Lip to E-Plane (mm)	0.8	0.75	1.7	0.8	1	1	0.9	0.65	1.25

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(S)SNA (º)	81.1	83.65	84.15	81.9	85.85	84.7	84.4	84.6	86.3
	(S)SNB (º)	73.6	76.05	76.75	76.2	78.8	76.8	76.3	77	78.25
	(S)ANB (º)	7.5	7.6	7.4	5.8	7.05	7.85	8.1	7.6	8.05
	(S)U1 - NA (º)	15	11.3	14.4	17.8	13.4	14	18.5	10.85	13.5
	(S)L1 - NB (º)	29.8	30.85	33.75	35.2	33.25	42.4	33.3	31.95	34.2
	(S)Occ Plane to SN (º)	20.9	20.35	21	19.6	19.85	20.6	19	20.6	18.8
	(S)MP - SN (º)	42.1	39.45	35.9	38.7	37.55	34.9	38.5	40.15	36.7
	(S)U1 - NA (mm)	2.2	1.6	2	5.5	3.65	4.35	1.9	1.6	1.5
	(S)L1 - NB (mm)	9.8	9.25	8.65	10.2	10.5	11.4	9.4	9.5	9.15
	(S)Pog - NB (mm)	1.8	1.65	0.95	1.6	2.15	0.6	1.5	1.3	1.25
Pt21	(R)Cranial Deflection (º)	27.7	27.55	24.4	28.5	26.2	25.8	27.2	28.55	28.95
	(R)Maxillary Depth (FH-NA) (º)	94.2	93.9	96.6	94.7	94.8	92.5	93	94.45	93.3
	(R)Facial Depth (FH-NPo) (º)	88.5	87.95	88	89.5	88.8	87.25	88.2	88.6	87.25
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	86.6	86.25	89	86.4	88.7	87.2	87.8	86.95	84.6
	(R)Total Face Height (NaBa-PmXi) (º)	55.5	55.65	52.35	56.2	51.1	56.45	52.8	56	59.85
	(R)Lower Face Height (ANS-Xi-Pm)(º)	42.2	43.15	41.7	42.7	42.3	50.8	40.9	43.1	44.2
	(R)Mandibular Arc (º)	39.5	38.35	39.7	40.3	43.35	39.7	44.2	39.6	36.25
	(R)FMA (MP-FH) (º)	18.3	15.85	16.05	15.1	17.55	15.5	18.1	18.05	18.45
	(R)L1 to A-Po (º)	30.7	37.5	36.45	32.9	38.1	27.9	34.6	37.3	35.65
	(R)U1 to A-Po (º)	31.1	32.25	37.9	33.2	30.4	30.9	35.2	31.1	35.7
	(R)Interincisal Angle (U1-L1) (º)	118.2	110.25	105.65	114	111.5	121.2	110.2	111.55	108.65
	(R)U6 - PT Vertical (mm)	18.8	19.45	19.95	19.8	21.9	22.05	18.1	21.25	19
	(R)U1 Protrusion (U1-APo) (mm)	8.2	8.4	8.6	8.7	8.65	8.85	8.8	8.55	8.95
	(R)L1 Protrusion (L1-APo) (mm)	5.7	6.15	5.55	6.1	6.8	5.85	6.3	6.5	6.55
	(R)Convexity (A-NPo) (mm)	6.3	6.65	9	5.6	6.2	5.4	5	6.55	7.05
	(R)Lower Lip to E-Plane (mm)	1.4	2.9	4.55	0.6	2.05	5.05	2.2	2.05	3.75
	(S)SNA (º)	83.7	83.25	91.5	83.5	86.95	87.85	82.4	83.6	82.75
	(S)SNB (º)	77.1	76.35	82.5	77.3	80.15	81.75	76.9	77.45	76.45
	(S)ANB (º)	6.6	6.9	9	6.2	6.85	6.15	5.5	6.15	6.25
	(S)U1 - NA (º)	19	19.5	19.8	22.3	18.15	20.35	24.6	18.7	22.5
	(S)L1 - NB (º)	36.1	43.3	45.6	37.5	43.55	32.3	39.7	43.5	42.55
	(S)Occ Plane to SN (º)	19.7	21	17.75	21.2	18.65	15.15	20.9	21.5	21.45

Pt/Reader	Measurement	R1_Ceph	R1_CBCT	R1_MRI	R2_Ceph	R2_CBCT	R2_MRI	R3_Ceph	R3_CBCT	R3_MRI
	(S)MP - SN (º)	28.8	26.5	21.15	26.2	25.3	20.1	28.7	28.85	28.95
	(S)U1 - NA (mm)	3.7	3.15	2	4.4	3.9	4.85	5.2	3.45	3.95
	(S)L1 - NB (mm)	11	11.55	11.85	11.1	11.95	10.6	10.4	11	11.35
	(S)Pog - NB (mm)	1.9	1.9	0.8	2.1	1.8	1.9	1.4	0.65	0.6
Pt22	(R)Cranial Deflection (º)	32.2	34.35	32.8	31.6	35.3	34.85	31.4	32.75	40.75
	(R)Maxillary Depth (FH-NA) (º)	89.9	91.95	91.2	90.6	92.5	91.55	89.3	90.95	98.65
	(R)Facial Depth (FH-NPo) (º)	86.5	88.3	87.8	87.7	89.8	88.65	86.7	87.6	95.6
	(R)Facial Axis-Ricketts (NaBa-PtGn)(º)	78.3	77.7	80.2	80.8	79.05	79.55	79.6	79.15	80.1
	(R)Total Face Height (NaBa-PmXi) (º)	66.6	66.1	64.25	65.6	65.95	67.65	65.4	66.4	65
	(R)Lower Face Height (ANS-Xi-Pm)(º)	56.4	56.35	50.8	58.4	55.6	56.9	56.7	56.15	52.85
	(R)Mandibular Arc (º)	32	34.5	32.85	31.5	32.45	28.5	32.7	32.4	35.1
	(R)FMA (MP-FH) (º)	31.1	28.4	28.35	29.8	27.9	24.6	32.7	30.85	18.9
	(R)L1 to A-Po (º)	26.4	27.05	29.25	26.5	25.8	28	30.5	28.6	27.15
	(R)U1 to A-Po (º)	28.9	27.35	26.75	29.4	24.7	28.55	29.2	26.55	28.35
	(R)Interincisal Angle (U1-L1) (º)	124.7	125.6	123.95	124.1	129.5	123.45	120.3	124.9	124.5
	(R)U6 - PT Vertical (mm)	20.2	22	22.7	21.4	24.15	27.45	21.6	22.05	30.1
	(R)U1 Protrusion (U1-APo) (mm)	7.9	7.5	7.1	8.2	8.05	11.05	8.7	7.55	8.4
	(R)L1 Protrusion (L1-APo) (mm)	4.1	3.85	3.7	3.8	4.9	7.55	4.8	4.25	4.65
	(R)Convexity (A-NPo) (mm)	3.6	3.85	3.55	3	2.8	3.05	2.7	3.5	3.25
	(R)Lower Lip to E-Plane (mm)	3.4	2.05	2.8	4.3	2.15	3.4	2.8	2	2.9
	(S)SNA (º)	77.7	77.4	80.25	77.4	77.55	80.2	76.4	77.85	78.5
	(S)SNB (º)	73.8	73.4	76.2	74	74.15	77.25	73.3	74.15	75.65
	(S)ANB (º)	3.9	4	4.1	3.4	3.3	2.95	3.1	3.7	2.8
	(S)U1 - NA (º)	22.3	20.3	19.65	23.7	19.5	22.7	24.1	20.05	22.2
	(S)L1 - NB (º)	29.2	30.05	32.3	28.9	27.65	30.85	32.5	31.35	30.45
	(S)Occ Plane to SN (º)	22.1	20.45	19.4	24.5	19.65	15.6	21.8	19.45	15.8
	(S)MP - SN (º)	43.3	42.9	39.2	43	42.85	35.95	45.6	43.9	39.05
	(S)U1 - NA (mm)	4.8	4.1	3.9	5.5	5.6	8.45	6.3	4.45	5.75
	(S)L1 - NB (mm)	6.9	6.65	6.65	6.2	7.55	9.45	7.1	6.9	6.25
	(S)Pog - NB (mm)	1.1	0.8	1.35	1	1.5	0.1	1	0.85	-0.5