# Establishing Age, Race/ethnicity, and Gender-Specific Dentofacial Reference Values for Children and Adolescents; a 3D Orthodontic Diagnostic Analysis

# Establishing Age, Race/ethnicity, and Gender-Specific Dentofacial Reference Values for Children and Adolescents; a 3D Orthodontic Diagnostic analysis

A Thesis Presented by

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# I. Acknowledgments

"Strive always to excel in virtue and truth" Proph. Mohammad (PBUH)

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## II. Abstract

***Background:*** Orthodontic diagnosis and treatment planning relies heavily on 2D imaging. Currently 2D lateral cephalograms, which expose the entire skull to ionizing radiation to reveal cranial reference structures, are the most commonly used tool. A novel diagnostic protocol suggested the Natural Head Position, NHP, and the Maximum Convexity of the Cornea (MCC) as clinically visible replacements of the radiographically visible cranial reference planes. Based on that, adult average norms have been established and validated; however, we fall short of providing dentofacial norms that are age, race/ethnicity, and gender specific for the population of interest (4-18yr). ***Aims:*** **a)** Establish the reliability of orthodontic measurements generated via 3D diagnosis and analysis. **b)** Establish age, race/ethnicity, and gender specific dentofacial reference values in the form of means, standard deviations, and 3D mesh composites via 3D diagnostic analysis. ***Materials & Methods:*** **a)** 3D records of 25 subjects were analyzed by 2 calibrated orthodontic residents to generate dentofacial orthodontic measurements and report intra- and inter-operator reliability values of images superimposition, landmarking, and use of multiple facial images. **b)** 3D dental and facial images of 240 healthy subjects with symmetrical faces and near ideal occlusion were obtained and analyzed by a single experienced operator to generate age, race/ethnicity, and gender specific reference values while using NHP and MCC as references. ***Results:*** **a)** Average ICC (intra-class correlation) values for the measurements generated during the three different registration steps (registration of facial and dental images, landmarks digitization, use of different facial images) were (0.941, 0.906), (0.916, 0.905), and (0.87, 0.90) respectively. **b)** 960 reference values, their standard deviations, and twelve 3D meshes were generated to describe dentofacial structures of children and adolescents. Significant shape differences were noted in all 3 planes of the dentofacial complex. Maxillary and Mandibular sagittal and vertical position, as well as angulation of upper and lower incisors were distinct between groups *(p-value <0.01)* and showed an increasing trend with age. There is a significant difference in the overall shape between adolescent males and females *(p-value <0.01)*. ***Conclusion:*** 80% of orthodontic measurements created via 3D landmark based registration and analysis are reliable; however, some facial landmarks would benefit from physical palpation and marking to improve its reliability. Dentofacial significant shape differences exist in all 3 planes due to age, race/ethnicity, and gender in individuals below 18 years. This radiation free diagnostic method can be supplemented with a limited field low dose CBCT of the maxilla and mandible to eliminate the need of irradiating the entire cranial complex in children and adolescents.

## III. Literature review:

- ***Background***

Orthodontics, established in 1901 by Edward Angle, is a branch of dentistry that initially focused on moving the dentition to achieve ideal alignment[1]. As with all branches of medical sciences, technology and research allowed the science of orthodontics to evolve by incorporating newly developed techniques and tools such as panoramic radiographs and lateral cephalograms. In 1931, the Lateral Cephalometric radiograph (LCR), was introduced to us by Broadbent [2]. Since then, LCR's have been heavily utilized in orthodontics as a tool of clinical diagnosis, treatment planning, treatment progress evaluation, growth prediction, and research [3]. It is usually obtained by exposing the entire cranium including the cranial base and facial skeleton to radiation, then utilized to place landmarks and extrapolate measurements. These describe the dental and skeletal proportions and relations of a patient compared to a previously established set of norms with the goal of making diagnostic and treatment planning decisions [4]. It is a popular tool because majority of the orthodontic analyses rely on radiographically visible cranial structures (Fig1) such as the anterior cranial base (Sella-Nasion, SN) and the Frankfort Horizontal line (Orbital-Porion, FH) as reference planes (Fig2) [4] . However, controversies have surrounded the use of LCR's since the early longitudinal studies of craniofacial growth, such as the Broadbent Bolton Standards of Dentofacial Developmental growth studies, and the Burlington Growth studies [3]. Literature shows that LCR's are also associated with a significantly large range of linear and angular measurements variability that is often not corrected [5]. According to Hahn et al [6], errors associated with 2D cephalometric radiographs have been recognized to affect our diagnosis and treatment planning decisions. Baumrid and Frantz described landmark identification and X-rays projection (a two-dimensional representation of a 3-dimensional object) as the two major sources of error[7,8] . It has been indicated several times in the literature that LCRs might not be as necessary as advocated for in certain cases[9-12].

In the United States, the orthodontic diagnostic records and their resultant radiation exposure have been considered to possess a public health significance, particularly as the prevalence of orthodontic treatment increases [13]. Although the effective doses of ionizing radiation associated with an LCR or a Panoramic radiograph (2-10 and 6-38μSv) are significantly lower than X-rays for medical purposes, they should be obtained only after clinical examination and whenever justified [14]. The International Commission on Radiological Protection (ICRP) in 2007 released a report stating that the estimated dose from dental radiography is substantially greater than reported in 1990[15]. It is important to also mention the increasing number of individuals starting orthodontic treatment exceeded 5.75 million individuals in 2004 (North America); 81% of those were children and adolescents[16-17]. Interestingly, a systematic review of the literature reported the minimum records required for orthodontic diagnosis and treatment planning remains unidentified[18]. Therefore, the use of LCR's in children should be better justified as the scientific evidence is lacking[19]. In Europe, the new guidelines of the British Orthodontic Society states that there is no orthodontic indication for an LCR in monitoring growth or treatment completion, nor a consensus on the set of routine radiographs required for all orthodontic patients[20]. Hahn et al, reported that study models of the teeth provided adequate information in 55.6% of the cases studied (Class II) and only minor increase was noted with the use of a LCR [6].

Lately cone beam computed tomography (CBCT), a three-dimensional radiograph, started to gain popularity over 2D radiographs. Studies have shown that CBCT can provide clinically significant information in cases of craniofacial anomalies, severe dentofacial discrepancies, impacted permanent teeth, and Temporomandibular joint skeletal malformations. However, recent systematic reviews indicated that CBCT provides only limited evidence that does not justify the increased radiation dose in most cases[21-22]. CBCT is known to introduce a higher radiation dose when compared to LCRs. Therefore, the decision to obtain one when the patient is a child is more critical, as the biological effects of ionizing radiation exposure are greater due to the highly radiosensitive tissue, the greater number of actively dividing cells, and the longer life span for carcinogenesis development [23]. Children are estimated to be 2 – 10x more prone to radiation-induced carcinogenesis than mature adults[14]. Since it is difficult to quantify the damage, the American Academy of Oral and Maxillofacial Radiology, stated that there is neither convincing evidence for radiation induced carcinogenesis at the level of dental exposure nor absence of evidence of such effect[24]. There are growing concerns about the increasing radiation doses within dentistry and medicine, from a public health perspective, which led to the establishment of multiple organizations whose primary objective is to reduce children's exposure to ionizing radiation [25]. Therefore, it is our role as health care providers to regulate our use and administration of ionizing radiation as they are considered a potential health hazard particularly in children and adolescents below 18 years.

Over the past three decades, there has been an increased focus on non-radiographic three-dimensional diagnostic imaging technology that captures the soft tissue; Stereophotogrammetry is considered to be the most popular (Fig 3) [26]. It is a non-invasive method that is designed to rapidly capture multiple images of the soft tissue through combining photographs taken from various angles using synchronous digital cameras[27]. Its advantages include the absence of ionizing radiation, lack of motion artifacts due to its speed, high color resolution, quick image configuration, and ease of archiving and storage [27]. It has been shown that orthodontic soft tissue measurements completed on 3D stereophotogrammetric images are consistent with those completed via standard anthropometry and 2D photography [28]. Anthropometry, the gold standard, is less commonly used now since it is a lengthy process that demands subject to remain still during the data acquisition process, which not all children can tolerate. Laser scans on the other hand, can capture images faster yet it is still slow enough to introduce motion artifacts[29]. Plooij and his colleagues studied stereophotogrammetry to show that it is reliable, accurate, and can be implemented in growth studies [30]. According to a systematic review completed in 2014, 3D stereophotogrammetry is the most versatile method for longitudinal assessment of external cranial dimension and shape in children[31]. Additionally, Ghoddousi showed that facial measurements recorded using 3D systems are sufficiently accurate and reliable for clinical purposes[32]. 3D stereophotogrammetry was also capable of recovering dense surface point maps and facial landmarks with an accuracy of 0.5mm when using high resolution cameras[33].

3D stereophotogrammetry has been researched extensively in anthropometric, medical, and dental literature, in particular maxillofacial surgery and orthodontics[34-42] . Researchers in different countries have used 3D stereophotogrammetry to generate average 3D facial composite images of different populations, to facilitate comprehensive medical and dental diagnosis [38-41]. The digitization of 3D maxillary images, generated by intra-oral scanners, to their corresponding 3D facial images creates a virtual 3D patient which offers clinical and research benefits in longitudinal monitoring of children and adolescents[42]. The ultimate goal is to create a 3D virtual patient although, orthodontic diagnosis and treatment planning still depends on the traditional 2D based method since a 3D soft tissue based alternative is not readily available [43].

Reliable alternatives to the radiographically visible reference planes, SN and FH, have been suggested in literature. Moorrees, introduced the concept of using the Natural Head Position (NHP) and the True Horizontal Plane (THP), as a clinically visible reference plane (Fig 4) that can be reproduced reliability over time [44-47] . Recently, the Maximum Convexity of the Cornea, MCC, a clinically visible structure, (Fig 5) has been studied and suggested as an adjunct to the THP in LCR orientation and analysis [48]. In fact, measurements of the maxilla-mandibular relationship, mandibular divergency, and incisors orientation generated using Steiner's orthodontic analysis (SN plane) had a strong positive correlation with their analogues when using MCC and THP as references [48]. Based on the suggested references, a novel radiation free diagnostic protocol was suggested and used to generate average dentofacial measurements and 3D composite images of adult males and females (Fig 6) [49] . The protocol described the steps needed to superimpose 3D dental images to 3D facial images creating a virtual patient via a landmark based registration technique (Fig 7). In a later study, a positive correlation was found between measurements created with the 3D radiation free method and their corresponding traditional cephalometric measurements e.g maxilla-mandibular relation, incisors angulation, and incisors position [50]. Results from previous studies indicate that the clinically visible references (NHP & MCC) could facilitate the use of 3D soft tissue imaging in orthodontics and eventually modify our x-rays to a low dose limited field CBCT confined to the area of orthodontic interest (maxilla and mandible) to avoid direct cranial exposure. A recent study has shown that a limited field CBCT (17*6cm) using low dose feather mode setting of 0.4 Voxel could produce less radiation (9.17 microSv) compared to a standard panoramic radiograph (29.30 microSv) [51] (Fig 8). Therefore, the implementation and use of this method in orthodontic care has potential benefits in terms of potential harm reduction since the number of children exposed to ionizing radiation for orthodontic treatment is increasing.

- ***Innovation:***

Currently, the previously discussed method is not yet adopted nor utilized in routine orthodontic practice because we lack age, race/ethnicity, and gender reference values that describe the dentofacial complex in our population of interest (4-18yr). Additionally, the reliability of the orthodontic measurements created using the landmark based 3D diagnosis and analysis has not been explored yet.

## IV. Aims:

1- Measure and report the intra and inter-operator reliability of orthodontic measurements generated via 3D diagnosis and analysis while using the NHP and the Maximum Convexity of the Cornea as reference planes.

2- Generate and report age, race/ethnicity, and gender specific non-radiographic reference average values, standard deviations, as well as 3D mesh composite images for children and adolescents between the ages of 4 and 18 years in the Greater Boston Area.

## V. ***Clinical and Scientific significance***

- Non-radiographic dentofacial reference values for children and adolescents can be implemented in various dental and medical specialties e.g orthodontics, prosthodontics, maxillofacial surgery, plastic surgery, and dermatology to aid in:
  - Diagnosis
  - Treatment planning, virtual simulation, and monitoring of treatment progress
  - Assessment of treatment outcomes
  - Monitoring, simulating and predicting dentofacial growth

- Radiation free alternative diagnostic records would allow more frequent monitoring of facial and dental changes in growing patients as the cranium is spared from the harmful effects of ionizing radiation.

- 3D dentofacial norms could facilitate the use of a low dose limited field CBCT for orthodontic diagnosis and treatment planning to create a 3D virtual patient.

- The generated norms can also be utilized in the future for a more personalized diagnosis and treatment approach in combination with techniques such as genetic mapping to create a biological basis that justifies our stratification of the population based on facial and dental characteristics more objectively and scientifically.

- The 3D virtual patient that this method generates maybe used with current orthodontic technology associated with clear aligner therapy to customize aligners with the patients dental and facial needs.

## VI. <u>***Materials and Methods:***</u>

- ***Aim 1:***

After the approval of the research protocol by the Harvard Medical School institutional review board (#IRB 14-1347 and #H-31863), 3D records of 25 subjects, 12 females and 13 males, between the ages of 18 and 35 were obtained from the 3D adult database previously collected, Masoud et al, 2016 [49]. Subjects included satisfied the following inclusion criteria: crowding or spacing less than 3mm, full complement of permanent dentition, overbite and Overjet between 1-3mm, Class I molar and canine relationship, and less than 1mm CR-CO shift. The data included 3D dental images and 3D facial images both in smile and repose while maintaining Natural Head Position (Fig 7). The 3D Facial images were captured in NHP using Vectra M3 imaging system (Canfield Scientific, Fairfield, NJ, USA) and an adjustable mirror. Dental images were obtained via scanning dental impressions and bite registration using a desk-top scanner (Motion View Software, LLC, Hixon, Tennessee, USA). Two orthodontic residents were recruited, trained, and calibrated by a senior orthodontist and a software engineer to follow the digitization steps needed to perform the analysis of the 3D records using a customized version of the Ortho-Insight software (Motion view, LLC). The calibration process included five sessions (2hr/session) where 3D records of 4 subjects were used to train the recruited residents on the digitization and analysis. All the records were oriented in (X,Y,Z) of (0,0,0) to be a half way point between the eyes (iris center). After importing the 3D data into the software, the digitization steps were followed as indicated below to generate Dentofacial linear and angular measurements used in orthodontic diagnosis:

1. **Superimposition of 3D dental image to the 3D repose facial image via landmark based registration (Fig9):**

The first step is to superimpose the 3D dental image to the smiling face image using at least 6 pairs of common horizontal and vertical landmarks confined to the anterior teeth. Landmarks are classified into primary landmarks such as, incisal and gingival embrasures of maxillary central and lateral incisors and canines, and secondary landmarks such as interdental papilla and zenith points of the previously mentioned teeth on both dental and facial images. Then the 3D repose facial image is superimposed to the smiling image using landmarks specific to the forehead and the eyes e.g. pupils, moles, lateral end and apices of the eyebrows on both facial images. The built-in algorithm in the software will allow images superimposition to the best fit using the Landmark based registration. The registration landmarks will be discarded as they are not needed. By using the smile face image as a superimposition medium, the teeth will be now be registered to the repose facial image

2. **Landmarking of 3D facial and dental images (Fig10):**

After superimposition, soft tissue/dental landmarks were digitally and individually placed on the facial and dental 3D images. Dental and Facial landmarks used (Table 1,2) were based on Huanca Ghislanzoni study [52] and on Plooij[53] and Farkas[54] research. After the completion of images orientation, superimposition, and landmarking (Fig.10), dentofacial measurements (Table 3) were calculated using a customized 3D analysis that relies on creating 3 planes (Mid-Coronal, MC, Mid-Sagittal, MS, and Mid-Axial, MA) that intersect at point (0,0,0) between the eyes (Fig 11).

To test the intra- and inter-operator reliability coefficients of the measurement created, the 2 residents completed the following steps maintaining a 2-4 weeks buffer period:

1- Export the dentofacial measurements after repeating the 1st step only (superimposition) (Fig 9)
2- Export the dentofacial measurements after repeating the 2nd step only (landmarking) (Fig 10)
3- Export the dentofacial measurements after replacing the 3D repose facial image with a new image (same day acquisition) of the same subject (Fig 12) then repeating steps 1 and 2.

The measurements produced from both operators were then compared and contrasted to measure and report the reliability of orthodontic measurements during superimposition, landmarking, using a different image of the same subject in the form of ICC values.

**Statistical analysis:**

To assess the intra and inter-operator reliability, two trained and calibrated orthodontic residents were recruited. Then, 3D records of 25 subjects (44 measurement per subject/step) were included to produce statistically significant results of a 95% confidence interval and satisfy a 95% power (type I error 0.05). Cronbach's alpha statistical test (intra-class correlation coefficients) was used as a statistical measure to report intra- and inter-operator reliability. According to Cicchetti (Table 4), if ICC values ranges between 0.60 and 0.74, it indicates good clinical significance; while if it was between 0.75 and 1.00, the level of clinical significance is excellent [55]. Additionally, Cicchetti and Sparow stated that a reliability measure of 0.90 or above is considered to have an excellent level of clinical significance [56]. All statistical tests were conducted using IBM SPSS Version 25.0 software (IBM Corp, NY) [57].

- ***Aim 2:***

After research protocol approval by the Harvard Human Research Administration (IRB16-1457), children and adolescents between the ages of 4 and 18 years were recruited from dental clinics in the greater Boston area. Initially, potential subjects were screened by their pediatric dentists/hygienists, then final eligibility was determined by an orthodontic resident based on the following criteria (Fig 14):

**Inclusion criteria**

- ***General inclusion criteria:***

  1- Less than 4mm upper/lower incisors irregularity.

  2- Spacing of 2mm or less excluding physiological spacing in primary dentition.

  3- Overbite and overjet between 2-3mm.

  4- Absence of deep bites, open bites, cross bites.

  5- Absence of missing teeth except for third molars.

- ***Age specific inclusion criteria (±6months is applied to each group due to chronological age variation in dental development)***

  **1- Primary dentition (Males and Females), 20 subjects**

  - Chronological age of 4 to 7 yr.
  - Full complement of primary teeth with or without the first molars.
  - End-on or mesial step primary molar relationship.

  **2- Early mixed dentition (Males and females), 20 subjects**

  - Chronological age of 6 to 10 yr.
  - At least one permanent first molar in each arch.
  - At least one lower permanent incisor and one upper central incisor present.

- Primary canine, first molar, and second molar at least in one quadrant.
- Molar relationship ranging between ¼ cusp Class III and ½ cusp Class II.

**3- Late mixed dentition (Males and Females), 20 subjects**

- Chronological age of 9 to 12 yr.
- All the permanent incisors are present, as well as the lower canines and upper first premolars in at least one quadrant. (partial eruption acceptable).
- At least one second primary molar is present and at least one un-erupted second permanent molar.
- Molar relationship ranging between ¼ cusp Class III and ¼ cusp Class II.

**4- Late adolescent, Permanent dentition (Females), 20 subjects**

- Females between the ages of 12 and 18 yr.
- All the permanent teeth are present (at least two permanent second molars accepted).
- Molar relationship ranging between ¼ cusp Class III and ¼ cusp Class II.

**5- Late adolescent Permanent dentition (Males), 20 subjects**

- Males between the ages of 12 and 18 yr.
- All the permanent teeth are present (at least two permanent second molars accepted).
- Molar relationship ranging between ¼ cusp Class III and ¼ cusp Class II.

**Exclusion criteria:**

1- Active caries or large restorations or stainless steel crowns.

2- Overjet or overbite >4mm or <1mm.

3- Abnormalities or conditions affecting the eyes, e.g. exophthalmos.

4- Excessive facial hair growth that masks facial structures.

5- Facial asymmetry or any eye abnormality or malformation.

6- Previous surgeries or scar tissue on the face.

7- Current orthodontic treatment.

8- >2mm Dental midline discrepancy

Once final eligibility is determined, participants and their parents or legal guardians were provided with consent and assent forms as well as a facial image release form; additionally, a short questionnaire was delivered to determine subjects' gender, age, and race/ethnicity based on family history, self-identification, and ancestral (grandparents) geographical location. Although a total of 350 subjects were screened, only 240 male and female participants (4-18yr) from the Black or African American (non-Hispanic), White (non-Hispanic), and Hispanic American descent were included in the final sample. 90% of the subjects in the White (non-Hispanic) male and female groups had previous orthodontic history with no extractions, expansion, functional appliances, or surgical correction. Sample size calculation was completed with the aid of data from the U.S. Census Bureau, Population Estimates Program (PEP) and the American Community Survey (ACS) [58] that reported the number of children between 4 and 18yr in Boston; A minimum of 225 subjects were needed in total to achieve a 95% confidence interval and satisfy a 95% power (type I error 0.05). However, in order to have proportionate stratum sampling between the subgroups and assuming subjects drop out, the final sample size was increased to 240 [59]. Data was collected in the form of 3D intra-oral images (upper and lower arches) obtained via the 3Shape Trios® scanner

(3Shape, Copenhagen, Denmark and Warren, NJ) and the iTero® scanner (Align tech, Amsterdam The Netherlands and San Jose, CA) as well as a repose and smile 3D facial image obtained via the Vectra H1 portable 3D camera. None of the tools used or images obtained produced ionizing radiation. The validity and the reliability of the scanners and camera were reported in previous studies [60-63] . All facial images were obtained in Natural Head Position, NHP, which was achieved by using an adjustable mirror placed at a 7 feet distance to accommodate size and height variation within our sample. Younger children were often instructed to place their heels together and let their arms swing or walk for a few steps and stop, or raise then drop their shoulders to ease any tension to guide them into natural head orientation[64]. After data collection, processing, and de-identification, data was stored in an encrypted, password protected, research computer only accessible to the research members. Images were then superimposed, landmarked, and analyzed through a customized version of the Canfield 3D analysis software "Vectra" (Canfield, Parsippany, NJ) and Ortho-Insight software (Motion view, LLC). Superimposition of the dental and facial images to each other was completed via both landmarked based registration (see aim 1 for details) and surface based registration to achieve the best three dimensional fit [65]. Surfaces selected for superimposition were limited to the upper face (forehead). Facial and dental Landmarks then were placed as described earlier (Tables 1,2) to facilitate further analysis and extrapolation of orthodontic measurements for each subject. A total of 80 measurements were exported per individual.

**Statistical analysis**

Means (averages/norms) and standard deviations of 80 metric variables (x12 groups) as well as their corresponding 95% confidence intervals were calculated based on a Student's t-distribution, with the degree of freedom equal to (n) in each tested subgroup (n=20). Student's t-test was then implemented to measure and report significant differences between subgroups due to age, gender, and racial background. Analysis of variance, ANOVA test, was also used to test for significant difference among multiple groups in terms of each metric. Linear discriminant analysis (LDA) was adopted to test for shapes differences. The Principal component analysis (PCA) was then implemented to choose 14 metric variables that accounted for 80% of the total variance between groups to answer questions related to the overall shape differences. Hotelling's t-test was then conducted to compare the overall difference between males and females in each race/ethnicity, between age groups within race/ethnicity, and between racial groups of the same age/gender. All statistical analyses were completed using R statistical computing environment (R version 3.6.0 2019, Vienna, Austria) [66]. Additionally, within each of the 12 subgroups, the mean position of facial and dental landmarks in the form of CSV files (Comma Separated Value) where generated in Python using the vtk-python library.  240 CVS files were uploaded and assembled into VTK [67].  A generalized Procrustes analysis, GPA, was then carried out to yield the average location of each dental and facial landmark after eliminating variation in scale, translation, and rotation [67-68]. Then 3D dentofacial composite of the individual closest to the average in each subgroup was then morphed to create twelve 3D average meshes.

# VII. <u>Results</u>

- **Aim 1**:

3D facial and dental records of 25 adults, 12 females and 13 males, between the ages of 18 and 35 were included in the final sample size. Two trained and calibrated orthodontic residents analyzed the records according to the 3D diagnosis protocol yielding 44 measurements per subject in each step (n= 176 /resident, total n= 1100 comparisons /resident per step). The Intra-class Correlation Coefficient (ICC) values were generated through the Cronbach's alpha statistical test. Intra- and inter-operator reliability coefficients for the three different steps are shown in Table 5 while the clinical significance of the ICC values is shown in Table 4. During superimposition of dental and facial images (Step 1. Fig 9) the intra and inter-operator consistency values ranged between (0.72-0.99) and (0.68-0.99); the average ICC value was 0.941 for intra and 0.906 for inter-operator reliability. Secondly, Intra and inter-operator consistency during landmarks digitization (Step2, Fig 10) ranged between (0.734-0.955) and (0.0.467-0.997) respectively. When testing for the effects of landmarking the images, the average consistency within measurements exported was 0.916 for a single operator and 0.905 between operators. The least consistent measurement was the mandibular plane angle MPMA (0.467,0.771) (Fig 13). Lastly, when using a different repose facial image, consistency ranged between (0.639-0.997) and (0.697-0.999) within and between operators respectively; and the average was 0.87 for intra and 0.90 for inter-operator consistency. MPMA measurement was one of the least consistent measurements during this step too (0.63 and 0.69).

- **Aim 2:**

A total of 240 subjects (112 Males: 128 Females), who satisfied inclusion and exclusion criteria, were included in the final sample size (Fig 14). Subjects were assigned based on age, dental developmental stage, gender, and their self-identification of racial background, into one of 12 groups (Table 6). Nine hundred and sixty dentofacial average measurements (norms) and their standard deviations were created for the 12 subgroups. The results are shown in Tables 8-13. Additionally, 3D dentofacial meshes were created to morphometrically represent the orthodontic norms in the 3 planes of space for each group (Fig 15-26). The plus sign in between the eyes (iris) represents point (0,0,0) on the (X, Y, Z) coordinates system when NHP and the Maximum Convexity of the Cornea are used as reference planes. According to the linear discriminative analysis, LDA and the principle component analysis, PCA, significant overall shape differences were found due to gender in the permanent dentition stage (Hotelling's T test *p-value 0.01*), due to age (MANOVA test *p-value <0.001*), and due to racial background (MANOVA test *p-value <0.001*) (Fig26 & 27). Specific results and differences of/ between groups are as follow:

- **Differences between dentofacial measurements across age groups (dental developmental stage) among Black or African American (non-Hispanic) individuals (Table 8):**

Average values (means), standard deviations of dentofacial measurements, and their differences are reported in Table 8. In the Maxilla, measurements of the Subnasale sagittal position (SnMC), Maxillary apical base sagittal position (SAMC), Upper lip sagittal position (LsMCP), Maxillary vertical position (SnMA), Upper lip length (StuSn), and upper face width (Zy-Zy) were higher in older subjects (*p-value <.05*). A similar pattern was seen in the mandible with regards to Mandibular sagittal position and angulation to MC (SBMC, SBP-

MC), chin sagittal position and angulation (PG-MC, SPGP-MCP), Anterior and lower face heights (STME-MA, SN-STME), lower face width (STGOL-STGOR) *(p-value <.01).* Dentally, upper and lower incisors sagittal position, angulation to the MC plane, and vertical position (U1-MA,L1-MP) significantly increased with age (*p-value* <*.05*). Upper and lower Inter-canines and Inter-molars widths were larger in older subjects (*p-value* <*.01*). Also, canines and 1st molars vertical position (U3-MA & U6-MA) significantly increased with age (*p-value* <*.01).* On the other hand, both the Intermaxillary angle(ACP-STPGP) and facial taper ratio(STZY-STGO) decreased with age (*p-value* <*.01).*

- **Differences between dentofacial measurements across age groups (dental developmental stage) among Hispanic American individuals (Table 9):**

Reference values (means), standard deviations of dentofacial measurements, and their differences are reported in Table 9. Individuals in the permanent dentition stage had significantly larger measurements of Subnasale sagittal position (SnMC), Maxillary apical base sagittal position (SAMC), Upper lip sagittal position (LsMCP), Maxillary vertical position (SnMA), Upper lip length (StuSn), and upper face width (Zy-Zy) (*p-value* <*.01*). On the other hand, Maxillary apical base angular position (ACP-MCP) decreased slightly with age *(p-value 0.03).* In the Mandible, a significant increase in the Mandibular sagittal position to MC (SBMC), chin sagittal position and angulation (PG-MC, SPGP-MCP), Anterior and lower face height (STME-MA, SN-STME), lower face width (STGOL-STGOR) (*p-value* <*.01).* Dentally, upper and lower incisors vertical position significantly increased with age (*p-value* <*.01*). Upper and lower Inter-canines and Inter-molars width has increased with age as well (*p-value* <*.01*). The canines and 1st molars vertical position were significantly higher during the permanent dentition stage (U3-MA & U6-MA) (*p-value* *<.01). The Intermaxillary angle(ACP-STPGP) decreased with age* (*p-value* <*.01).*

- **Differences between dentofacial measurements of Males and Females in the permanent dentition stage (Table 10):**

Averages values (means), standard deviations of dentofacial measurements, and their differences are reported in Table 10.

**White Non-Hispanic Males vs Females**

Measurements of the Sagittal position of Subnasale (SnMC), Sagittal and angular position of the Maxillary apical base (SAMC, SAPMCP), upper lip sagittal position (LsMCP), Upper lip length (StuSn), Upper face width (ZY-ZY), Lower lip sagittal position (LiMCP), anterior and lower face heights (STME-MA, SN-STME), and Lower face width (STGOR-STGOL) are significantly higher in males (*p-value <.05).* Females have significantly more tapered faces (STYZ-STGO) (*p-value <.05).* Measurements that reflect the vertical position of upper incisors, canines, and 1st molars are significantly higher in males *(p-value <.05*). Additionally, Males have wider inter-canine and inter-molar widths in both arches (Maxillary and Mandibular) (*p-value <.05*).

**Black or African American (non-Hispanic) Males vs Females**

Soft tissue measurements of the Sagittal position of the Maxilla, Mandible (SAMC, SBMC, SPB-MC), upper and lower lips (UsMCP, LiMC), and Chin (PgMC, SPgP-MCP) are significantly higher in males (*p-value <.05).* Males have more protrusive soft tissue Pogonion in comparison to females (PG-ALR) (*p-value <.01).* Additionally, the lower right and left face heights (STGO-MA) were higher in males (*p-value <.05)*. Dentally, males have more proclined upper incisors to MC (U1LA-MCP), proclined lower incisors to the mandibular plane (L1-MP), and wider maxillary and mandibular inter-canine and inter-molar distances (*p-value <.05)*.

**Hispanic American Males vs Females**

Soft tissue measurements of the Sagittal and angular position of the Maxilla and Mandible (ACMC, SAMC, SAPB-MC, SBMC, SPB-MC), Maxillary vertical position (SnMC), upper and lower lip sagittal position (UsMCP, LiMC), and Chin sagittal position (PgMC) were significantly higher in males (*p-value <0.05)*. Females have more tapered faces compared to males (STYZ-STGO) (*p-value <0.01)*. Dentally, males have wider maxillary inter-molar distance, and more protrusive lower incisors to MC (L1MC) (*p-value <0.05)*.

- **Differences between dentofacial measurements of Females in the permanent dentition stage from 3 different racial backgrounds (Table 11):**

Means and standard deviations of dentofacial measurements, and their differences are reported in Table 11. There is a significant difference between White non-Hispanic, Black or African (non-Hispanic) American, and Hispanic American females with regards to Maxillary apical base position (SAPMCP), Upper lip position and length (LsMCP, STUSN), lower lip position (LiMC), anterior face height (STME-MA), lower face height (SN-STME), and Intermaxillary Apical base angle (SAP-SBP) (*p-value <0.05)*. White non-Hispanic females have narrower maxillary and mandibular inter-canine widths compared to African American and Hispanic American females (UR3C-UL3C, LL3C-LR3C) (*p-value <0.05)*.

- **Differences between dentofacial measurements of Males in the permanent dentition stage from 3 different racial backgrounds (Table 12):**

Average values, standard deviations of Male dentofacial measurements, and their differences are reported in Table 12. There is a significant difference between White non-Hispanic, Black or African (non-Hispanic) American, and Hispanic American males with regards to upper face width (ZY-ZY), lower lip sagittal position (Li-MC), anterior face height (STME-MA), lower face height (Sn-STME), and face taper (STZY-STGO) (*p-value <0.05*). African American Males have more proclined upper incisors (U1LA-MCP), wider maxillary and mandibular inter-canine and inter-molar widths *(*UR3C-UL3C, UR6mp-UL6mp) (LR3C-LL3C, LR6cf-LL6cf) (*p-value <0.05).*

- **Differences between dentofacial measurements of Black or African (non-Hispanic) American vs Hispanic subjects in each age subgroups (Table 13):**

Means, standard deviations of dentofacial measurements, and their differences are reported in Table 13.

**Primary dentition stage (Black or African American vs Hispanic)**

African American measurements during the primary dentition stage are significantly higher for upper lip position (LsMCP), soft tissue mandibular sagittal position (SBMC), lower lip position (LiMC), face taper (STZY-STGO) (*p-value <0.05).* Both upper and lower Inter-canine widths are significantly larger in African Americans vs Hispanic American (*p-value <0.01).*

**Early mixed dentition stage (Black or African American vs Hispanic)**

The upper and lower lips (LsMCP, LiMC) are significantly more protrusive in African American children in comparison to Hispanic children (*p-value* $<0.05$). Lower face width measurement (STGOL-STGOR) is larger in Hispanic children (*p-value* $<0.01$). The sagittal distance between Subnasale and Soft tissue Pogonion (Sn-STPG) is larger in Hispanic individuals (*p-value* $<0.05$).

**Late mixed dentition stage (Black or African American vs Hispanic)**

The upper and lower lips (LsMCP, LiMC) are significantly more protrusive in African American children in comparison to Hispanic children (*p-value* $<0.01$). Upper incisors are more proclined (U1LA-MCP) and Lower incisors are more protrusive (L1IMC) in African American individuals (*p-value* $<0.05$).

# VIII. Discussion

- **Aim1:**

Advances in the digital age of orthodontics and soft tissue based diagnosis and treatment requires the development of an objective and reliable soft tissue assessment tool. Currently, the standard of care includes two dimensional records: 2D lateral cephalometric radiographs, 2D photographs, and 3D dental models. Many orthodontic clinicians use the lateral skull cephalogram and the 2D photographs to quantify the soft tissue. The is a need to develop a 3-dimensional objective method to assess the soft tissues relative to the underlying dental and skeletal components. With the advent of 3D stereophotogrammetry, it is possible to capture the soft tissue quickly and reliably. This has a potential for orthodontic diagnosis, treatment planning, and virtual treatment forecasting. The aim of this section in our study was to focus on reporting the reliability values for orthodontic measurement generated using a novel orthodontic registration protocol that utilizes 3D dentofacial records. The registration process was recently implemented in developing adult 3D soft tissue orthodontic norms [49]. Assessing the reliability of such a protocol is expected to improve, refine and use it later in developing age, race/ethnicity, and gender specific orthodontic norms using 3D dentofacial records. Three steps were included in this process, superimposition of dental and facial images, landmarking, use of multiple images of the same subject. High reliability existed for the majority of facial and dental measurements across the 3 different steps (70% of the measurements ICC>0.88). Plooij et al previously reported similar results when testing for facial landmark reliability with intra-observer ICC values of (0.97 (0.90 – 0.99)) and inter-observer ICC values (0.94 (0.69 – 0.99) [69]. During dental and facial images superimposition, we reported high correlation coefficient (0.941, 0.906) which is consistent with what Rossati et al has reported when they tested for the Integration of facial stereophotogrammetric images and dental laser scans [70]. A study by Ceinos et al tested the reliability of landmarking when multiple facial images are used.

They reported ICC values for facial measurements between (0.732-0.976) and (0.598-0.914) for dental measurements [71]. Another study reported that even with using two different 3D facial images of the same individual, results are still reliable and valid [72]. Maal quantified the mean variation when multiple images were taken of the same individual at different time points to be 0.25mm; thus, 3D images can be reproduced accurately over time with minimal variation [73]. Interestingly, the mandibular plane angle was found to be the least consistent measure during landmarking and using a 2nd facial image. The mandibular plane angle is defined as the angle between the mandibular plane (soft tissue menton and soft tissue Gonion) and the Mid-Axial (Fig 13). Soft tissue Gonion is difficult to locate on the 3D facial image as it is primarily considered a bony landmark, with low reliability values relative to Mandibular plane angle. Extraoral tissue palpation over the mandibular angle may be indicated to locate and mark Gonion before capturing the 3D facial image. The 3D diagnostic method may be reliable once the user is trained and calibrated. Acceptance and adoption of the 3D diagnostic technique is anticipated once age, race/ethnicity, and gender specific norms are developed.

- **Aim 2:**

The objective of this section in the study was to develop age, race/ethnicity, and gender specific dentofacial reference values with a 3D radiation free diagnostic analysis that uses Natural Head Position and the Maximum Convexity of the Cornea as references. The diagnosis and treatment planning of orthodontic patients can be individualized by comparing their own diagnostic measurements to the standard values using radiation free 3D facial and dental images. Currently, there is no consensus regarding the minimum set of diagnostic records needed for orthodontics diagnosis and treatment [18]; hence it is arguable that all patients especially growing children will need to be exposed to radiation of the cranium multiple times during the course of care. As a new method of diagnosis is available [49], there will be a need to modify our routine orthodontic x-rays to a limited field low dose CBCT that is confined to the area of interest (maxilla and mandible) with appropriate shielding of the eyes and thyroid gland [51] . The limited field CBCT may also be digitized and superimposed on the 3D facial and dental images using surface based registration (Fig 29)[74]. The suggested radiation free diagnostic method is not utilized in routine orthodontic practice for multiple reasons; the main one being the lack of age, race/ethnicity, and gender specific reference values for children and adolescents. Therefore, with the results of this study may encourage a wider adoption of three-dimensional orthodontic care. In the context of this study, we defined our norms/normal as the average numerical values and their standard deviations that describe the soft tissue and dental component of the face in the form of linear and angular quantitative measurements, as well as visual mesh diagrams for a previously defined sample. It is important to reiterate that the sample in this study has been selected according to certain inclusion and exclusion criteria placing heavy emphasis on the occlusion and dental relationships as well as absence of facial abnormality and asymmetry. It is not based on the most pleasing facial proportions or esthetics since the definition of beauty is subjective. Hellman who was one of the first orthodontists to study the face on a large group of living adult males to develop soft tissue average measurements reported that variation is the normal [75] . According to published scientific literature, normal or average is considered more pleasing and esthetic than the atypical; and soft tissue measurements that are within one standard deviation of the average are considered attractive or esthetic too[75-76] . It is important to emphasize that the reference values generated here (average and standard deviations) are merely a guiding tool and not necessarily a treatment goal for every patient.

Historically, most skeletal, facial, and dental norms reported in anthropology, plastic surgery, or orthodontic literature are categorized based on age, dental developmental stage, gender, and racial background. That is because significant differences were seen in previous averages reported based on these distinctive characteristics. It is imperative to note that the reference values generated keep changing with time due to global immigration trends and the mass media impact on the definition of average or beautiful [77]. Therefore, the 3D Dentofacial norms developed and reported here are based on age, dental developmental stage, gender, and racial background of children and adolescents in the greater Boston area. In our definition of age, we used dental developmental stages supplemented with their corresponding chronological age range since chronological age by itself can be misleading; some children mature earlier compared to other in terms of dental development. When it comes to gender, the literature reports a clear distinction in soft tissue facial forms between males and females around puberty which is defined as a developmental stage characterized by the capability of sexual reproduction, attainment of secondary sexual characteristics, and increase in height growth spurt [78-80]. It has been reported by the longitudinal National Heart, Lung, and Blood institute growth and health study that the mean age of menarche is 12.7 years in Whites and 12.1 years in African-Americans females [81]. Generally, the onset of puberty occurs earlier in females (12-14yr) vs males (13-15 yr) [82]. Most adolescents at that age are in their permanent dentition stage. Therefore, we decided to report gender specific norms for the permanent dentition groups only. With regards to race/ethnicity, the literature fails to reach an agreement that objectively defines race/ethnicity especially in our era of globalization, international migration, and racial washout. In the 18$^{th}$ century, several historians and taxonomists such as John Ray, Blumenbach, George Cuvier, and Carlos Linnaeus started exploring and categorizing human differences in their work under the name of race/ethnicity [83]. A hundred years later, race/ethnicity was considered more of a highly-charged network of stances with sociopolitical, cultural, theological, and scientific overtone rather than a biological term. Race/ethnicity has also been defined based on geographical location where a group of people are united by language, cultural values, history, behavior, religion, and appearance [84]. In the early orthodontic works of

Moorrees, Down, Arnett, Steiner, and McNamara, the norms reported were race/ethnicity specific; however, there was a lack of scientific definition of race/ethnicity. Scientifically race/ethnicity is not a stratum or a classification criteria as it is hard to define objectively. Within the context of this thesis we use race/ethnicity as a term to describe geographical ancestry based on self-reports by individuals, their parents, and legal guardians. We are not suggesting that race/ethnicity is a morphology or a facial pattern.

In our definition of race/ethnicity, we rely on the U.S Census Bureau guidelines that classify race and ethnicity based on individual self-report to the following categories [85]:

**Race:**

- **White** – A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

- **Black or African American** – A person having origins in any of the Black racial groups of Africa.

- **American Indian or Alaska Native** – A person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment.

- **Asian** – A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.

**Ethnicities:**

- **Hispanic** – Hispanic, Mexican, or Latino in origin.

Our results which indicate significant differences in the overall dentofacial structures between the groups studied (Fig 27 & 28) are comparable to results from other studies that used anthropometry, cephalometric radiographs, and stereophotogrammetry [38-41].

1. **Dentofacial differences between different age groups (Fig 27)**

   In both the African American and Hispanic American sample, an overall increase in shape and size was noted with age. The largest values of sagittal, vertical, and transverse measurements of the maxilla, upper lip, and upper face width were seen in the older age groups (13-18yr). Soft tissue mandible and chin grew forward and downward as the lower face height continued to increase. Longitudinal growth studies have reported similar phenomena [86-87]. Interestingly, faces became narrower and the relation of the maxilla and mandible shifted towards a Class I relation in the permanent dentition stage. A possible explanation is the mandibular sagittal and vertical growth attained during the growth spurt (12-14yr). We have noted a significant increase in upper and lower incisors inclination with age which can be attributed to multiple factors including incisal liability and muscular forces of the tongue; Gütermann, Bhatia, and Leighton demonstrated similar results on cephalograms[86-87] . In conjunction to facial vertical growth, molars, canines, and incisors showed a continuous increase in their vertical position across the age groups. This phenomenon was reported in the early work of Bjork and Skieller [88] . Additionally, the width of the dental arches measured at the canines and molars increased which could be attributed according to Moyer to eruption pattern and location, as well as growth [89] . The age specific norms present would facilitate comparison of children and adolescents to their peers of the same age and racial background using 3D facial and dental images thus reducing the need of radiation exposure during childhood.

2. **Dentofacial differences between males and females (Fig 28)**

Within each racially distinct group, Adolescent males had more protrusive, longer and wider faces in comparison to females; while females demonstrated narrower more tapered faces. As males had wider and longer faces, their teeth tended to follow a similar pattern as the inter-molar width, inter-canine width, and vertical molars and canine position were all increased in comparison to females. It has to be brought up to the reader's attention that the White Non-Hispanic adolescent (males and females) sample was drawn from a population that had a history of orthodontic treatment; therefore, the actual average values need careful interpretation; We expect the ratios and relations between structures to be less affected and still valid. The African American and Hispanic American samples on the other hand were drawn from a population that didn't receive orthodontic treatment hence reference values are more representative of their true average. Only within the African American adolescent group, males have shown more proclined upper and lower incisors to the mandibular plane in comparison to females. The dentofacial measurements of Hispanic American females vs males displayed less significant differences so one could argue that they should be distinguished based on dental and facial features.

3. **Dentofacial differences between racially distinct individuals within each age groups (Fig 28)**

During the primary dentition stage (4-5yr), African American children showed more protrusive lips and chin position in comparison to Hispanic American Children. However, the Hispanic groups had wider and less tapered faces. In the next age group (6-10yr), a similar facial pattern continued , but the soft tissue chin (Pogonion) was more prominent in the Hispanic American group. This could indicate that facial patterns are established as early as 4 years old as reported by Kesterke et al [78]. Although a significant increase in the proclination of the upper the lower incisors in African American individuals between the aforementioned age groups was not apparent, it was evident during pre-adolescence (9-12yr) as the permanent incisors fully erupt by age of 7-8. As individuals become older, it becomes interesting to compare reference values of females/males to their peers from other racial backgrounds. Although there has not been an established biological base for the term race/ethnicity, we have noticed facial and dental morphological differences between the racial groups studied. Since the majority of growth is completed by 15-16yr of age (permanent dentition stage), distinct racial differences become more evident. White non-Hispanic adolescent females had relatively more retrusive soft tissue position of the maxilla, shorter lower anterior faces, retrusive upper lip, as well as shorter upper and lower lips. Since they had more retrusive faces, the difference between the apical sagittal of the maxilla and mandible was less in comparison to their African American and Hispanic American peers. These results are in agreement with their cephalometric counterparts [90]. Although, the maxillary and mandibular inter-canine width was less in White non-Hispanic females, this might not be influenced by the females in this sample had a history of orthodontic treatment with no extraction of teeth which might have altered arch width and morphology. In males, differences due to racial background were even more distinct than in between females. African American adolescent males had more tapered faces, and protrusive lips while White non-Hispanic males had increased anterior and lower faces. As with all age groups, African American males have the most proclined upper and lower incisors as well as the widest inter-canine and inter-molar widths. Using the reference values as a guide should help us understand the distinct features of every age, gender, and racial background. With further research to extensively study the dentofacial changes using 3D stereophotogrammetry in children and adolescents, we anticipate a wider adoption of radiation free diagnostic tools in orthodontics and dentistry in general.

## IX. Limitations of the studies

This study was a cross-sectional study to develop reference values for children and adolescents in Boston, MA. Although statistically significant results were reported based on our 240 subjects sample size, results should be interpreted with caution for multiple reasons. Each one of the 12 subgroups had 20 subjects only as we faced difficulty locating individuals who satisfied the inclusion and exclusion criteria. Majority of the sample was recruited from 2 large pediatric practices that are confined to 2 specific geographical locations in the greater Boston area, which might do not represent all areas of Boston equally. A wide multi-centered study is recommended for more representative results. Due to the difficulties we encountered in recruiting White non-Hispanic adolescents, we have included subjects who had previous orthodontic treatment with no history of teeth extraction, expansion, functional appliances, or surgical corrective therapy in order to achieve an adequate sample size. Specifically, 90% of the White non-Hispanic adolescents had history of brace/ethnicitys which might have affected the dental but not the facial measurements such as incisors angulations, inter-canine and molar widths, or overjet. Lastly, we strongly recommend carrying out future studies that include subjects with no history of orthodontic therapy to eliminate bias.

## X. Future studies

1. A study exploring the reliability and the validity of the developed reference values, standard deviations, and 3D meshes is recommended to measure and report the consistency in the clinical decision making process between 2D vs 3D orthodontic records.

2. A larger scale multi-center longitudinal study utilizing the previously described protocol is recommended to create more representative norms of children and adolescents in the United States of America.

3. Combining 3D soft tissue orthodontic studies with basic sciences methodologies to develop a scientific objective classification system instead of our current use of racial background.

4. A cross sectional study that develops skeletal norms based on a limited field CBCT in conjunction with the radiation free 3D images with the goal of creating a skeletal data base of maxillary and mandibular measurements.

5. Development of an artificial intelligent system that utilizes the normative database to predict growth, treatment outcomes, and surgical corrections facially, skeletally, and dentally.

6. Exploring the use of the palatal rugae area as a method of superimposition of 3D radiation free facial and dental records in order to compare and contrast treatment progress or growth.

# XI. Conclusion

1. Dentofacial Orthodontic measurements generated while using the eyes and NHP as references when analyzing 3D records is highly reliable for most measurements.

2. Consistency of Mandibular plane angle can be improved by physically palpating and marking the Gonial angle.

3. Age, race/ethnicity, and gender specific significant differences exist in all three planes of the dentofacial complex necessitating an individualized diagnosis and treatment approach in orthodontics.

4. The reported norms could facilitate the use of a limited field CBCT combined with 3D non-invasive records to limit radiation exposure of the entire cranium in orthodontic diagnosis and care.

5. Validation of the developed reference values and 3D meshes is necessary to determine its us and effect in orthodontic diagnosis.

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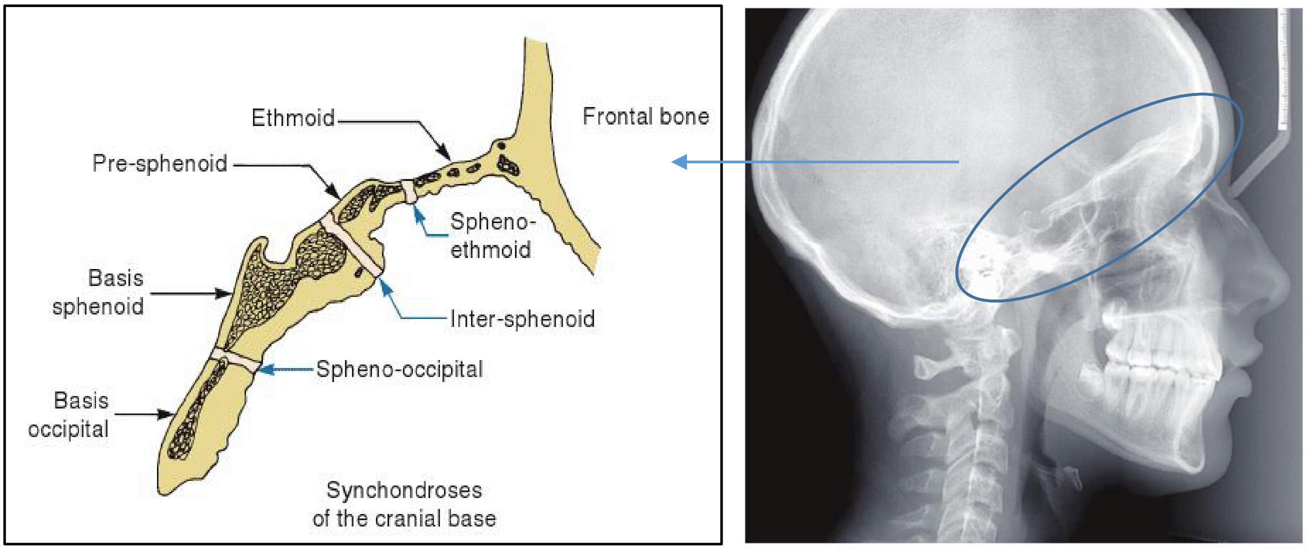
# XIII. Figures

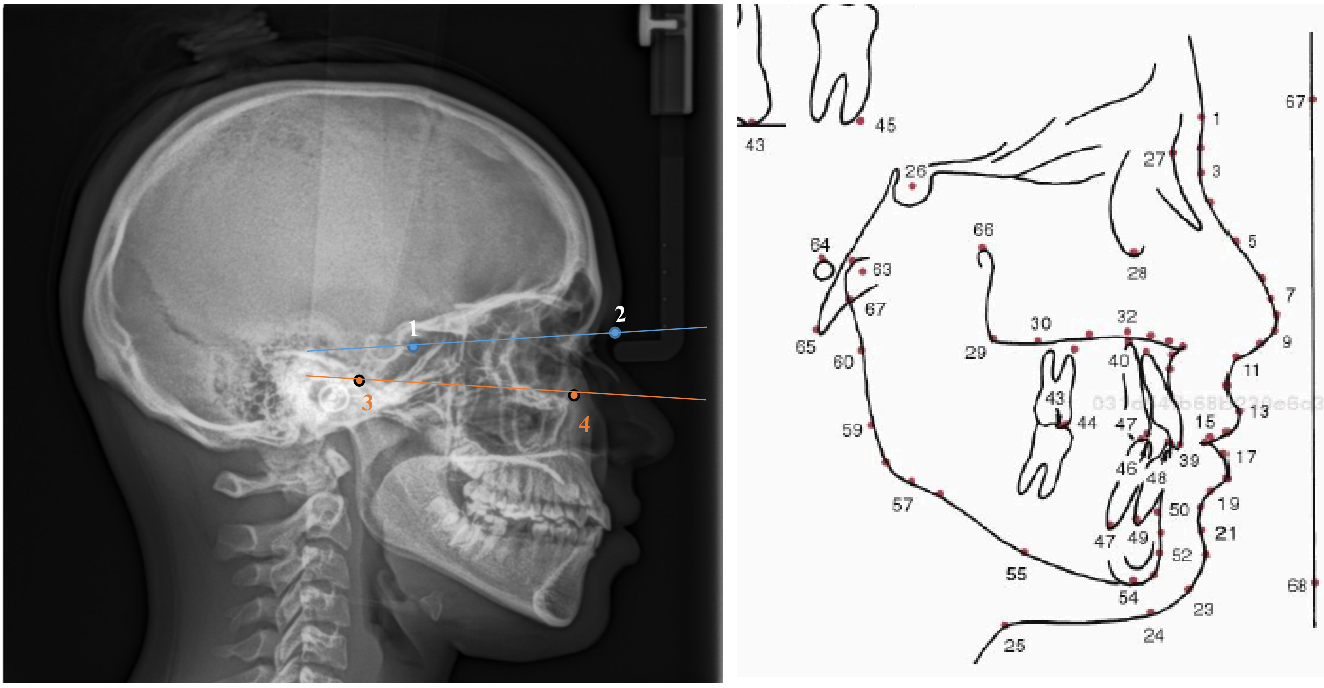
**Fig1**: Cranial base completes growth by the age of 6 or 7 years. (Proffit, Fields & Sarver, Contemporary Orthodontics by Mosby, 2012)




a. Visual illustration of the cranial base

b. A lateral Cephalometric radiograph, LCR

**Fig2:** Cephalometric analysis; Sella-Nasion plane (SN) and Frankfort Horizontal (FH, Orbital-Porion)(Proffit, Fields & Sarver, Contemporary Orthodontics 2013, Pg 206)




a. Blue, 1/Sella 2/Nasion, SN plane
Orange, 3/Porion 4/Orbitale, FH plane

b. Example of the dental, skeletal, and facial landmarks placed on an LCR

**Fig3:** Multiple 2D views of a three-dimensional image of the face in its repose position taken by the Vectra H1 3D stereophotogrammetric camera

**Fig4:** Moorrees diagnostic mesh and the use of NHP in children as a reference for orientation and standardization.

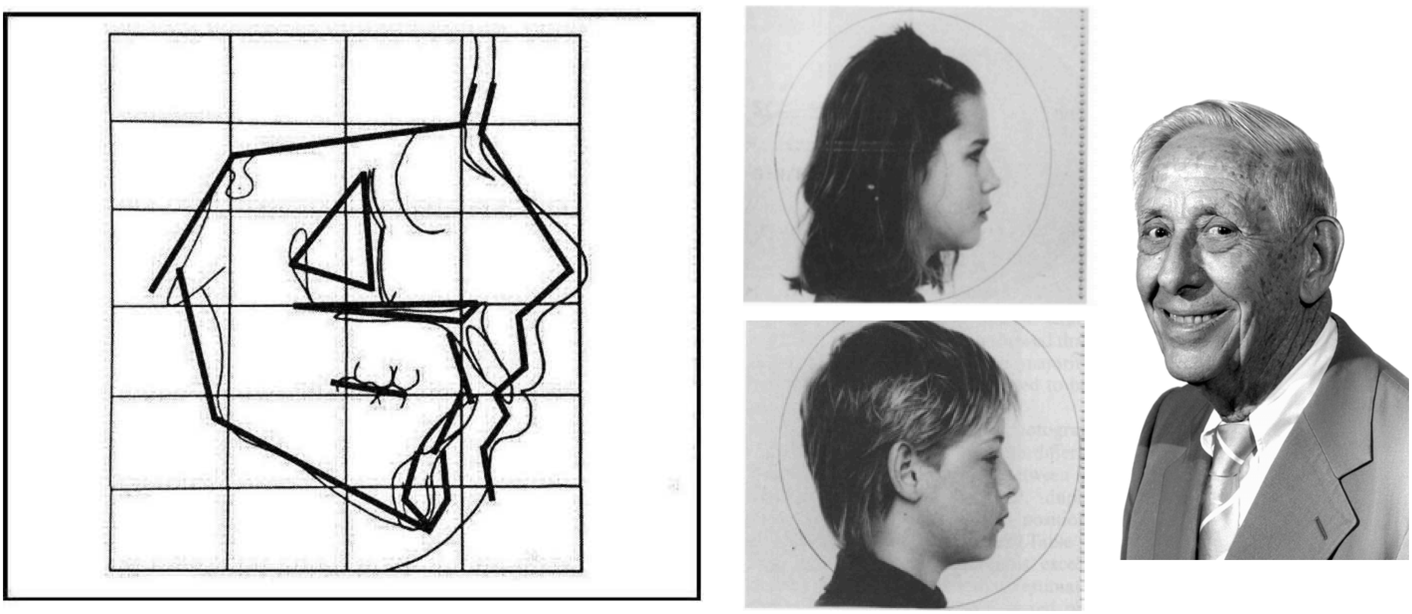
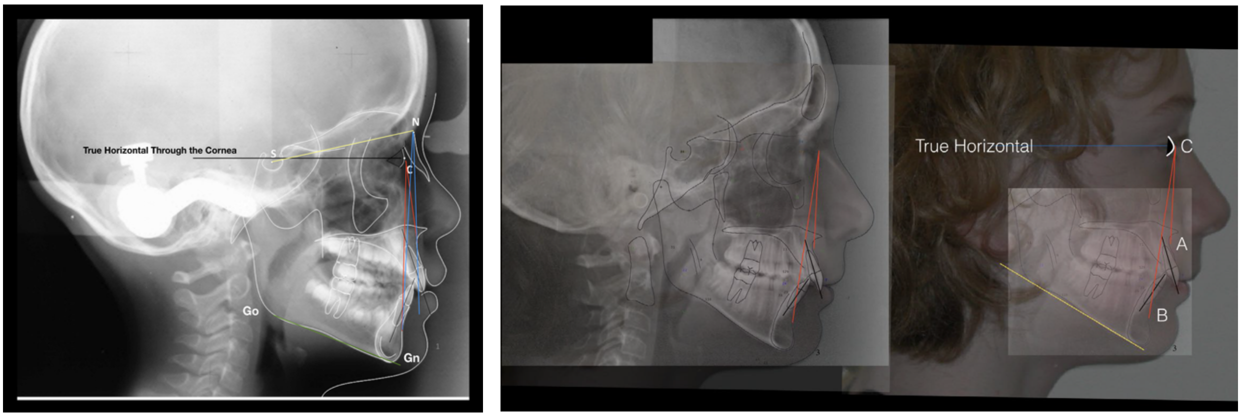


**Fig 5:** Lateral cephalogram oriented in NHP showing the two different methods (Stiener's analysis that uses SN reference plane vs the True Horizontal Plane drawn through the Maximum Convexity of the Cornea (Finn et al,2019)




a. A lateral cephalogram showing the SN plane and the THP that goes through the Maximum Convexity of the Cornea,MCC.

b. Superimposition of a lateral cephalogram on a 2D facial image when the NHP and MCC are used as references.

**Fig 6:** A 3D composite mesh representation of the average standard measurements created for a female adult using 3D records (Masoud et al,2016)

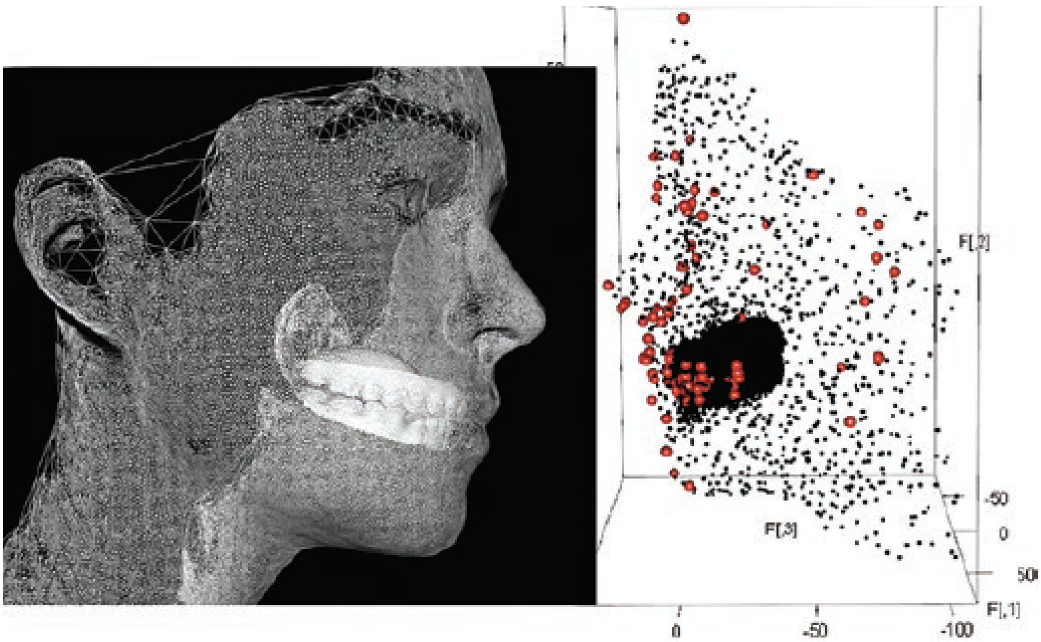


**Fig 7:** Digitizing a 3D dental scan to an adult male 3D facial image using landmark based registration through a customized software (Masoud et al, 2016).

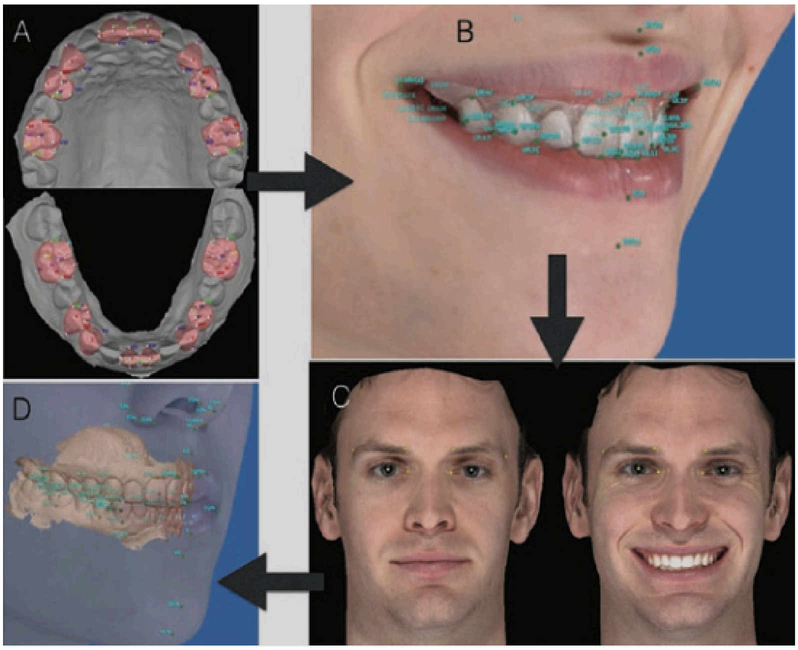
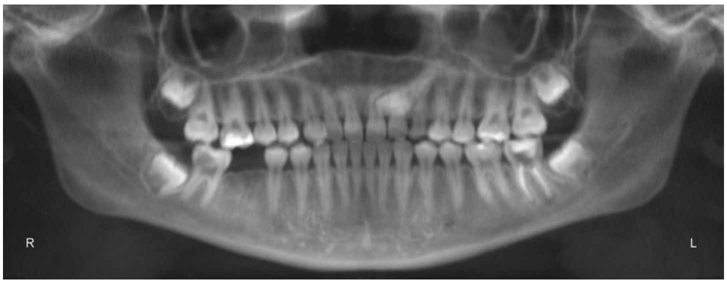
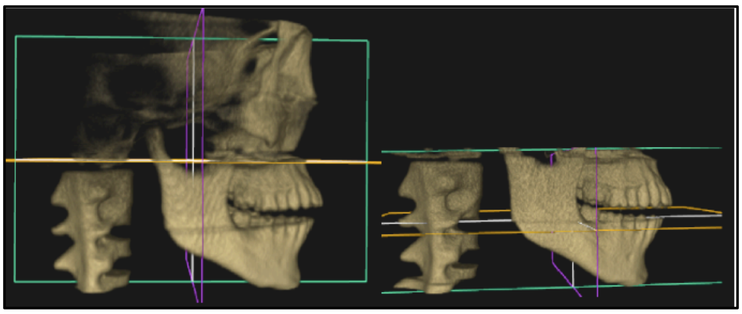



**Fig 8:** Comparing effective doses of a CBCT in standard mode, a feather mode, and a panoramic radiograph delivered to a child's phantom head using the CS9300 and the Orthophose SL dental radiation units.




a. A panoramic radiograph (29.30 microSv)



b. Left large filed CBCT in feather mode (17x11 cm) (9.17 microSv) vs Right limited field standard mode CBCT(17x6 cm) (51.3 microSv)

**Fig 9:** Superimposition (indexing) of facial and dental images via landmark based registration

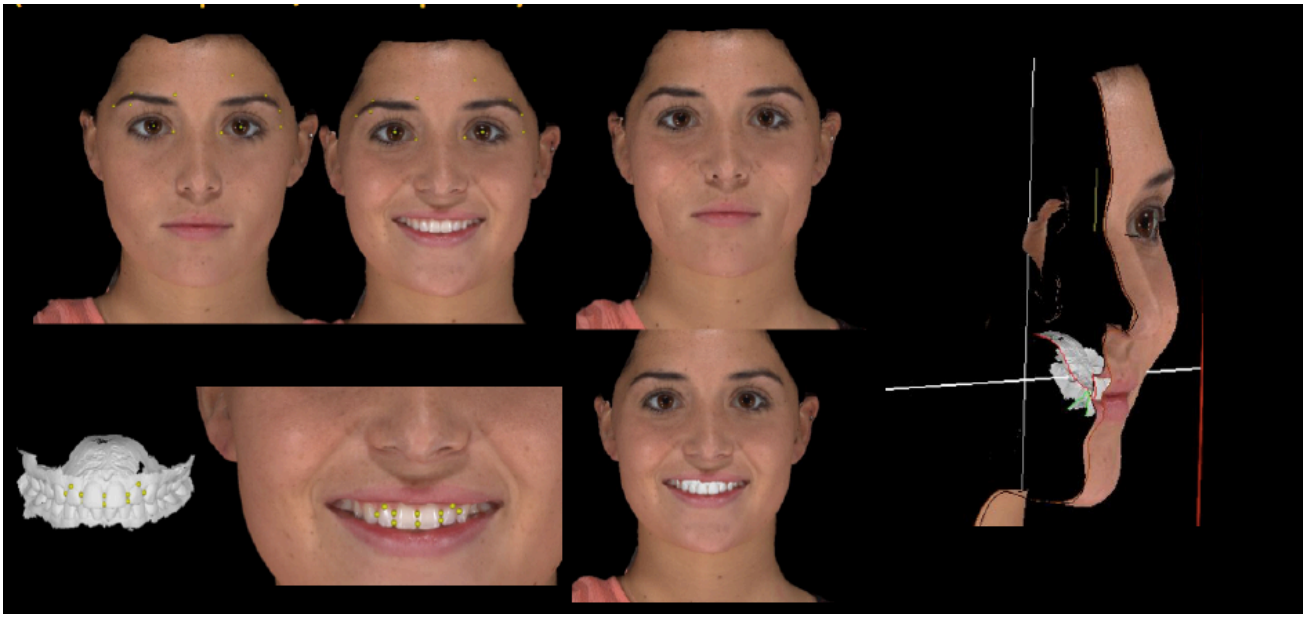


**Fig 10:** Digitizing the landmarks on the facial and the dental 3D images. 3D dental landmarks were derived from Huanca Ghislanzoni et al. while facial landmarks were previously described by Plooij et al and Farkas et al

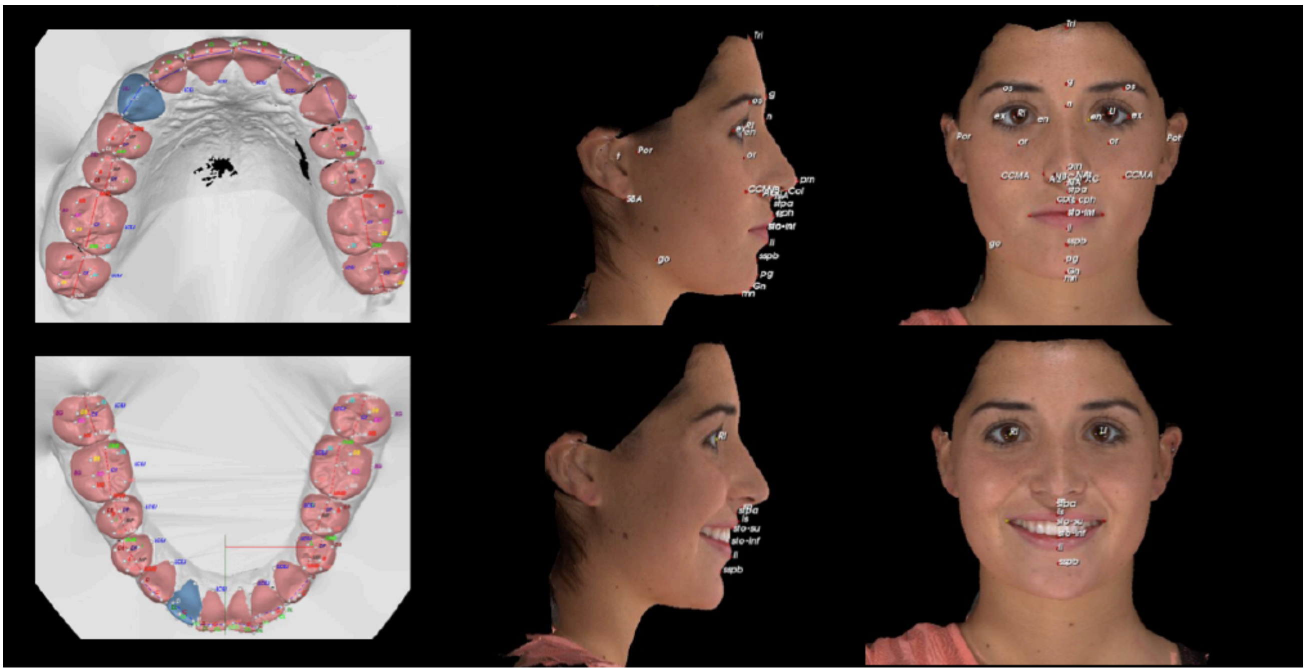


**Fig 11:** 3D denofacial image in NHP, 3 reference planes are present to facilitate analysis. **Red;** Mid-Axial, MA, **Blue**, Mid-Sagittal, MS, **Yellow**, Mid-Coronal, MC

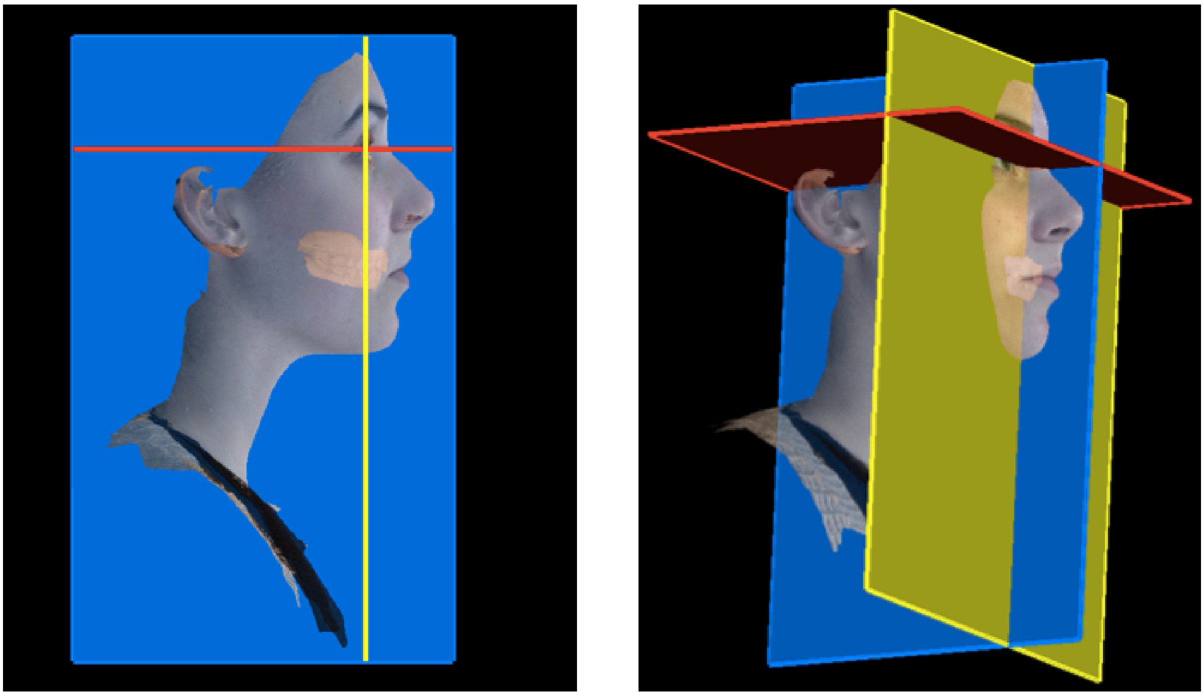


**Fig 12:** Using two different repose facial images of the same subject to assess the consistency of 3D facial image acquisition

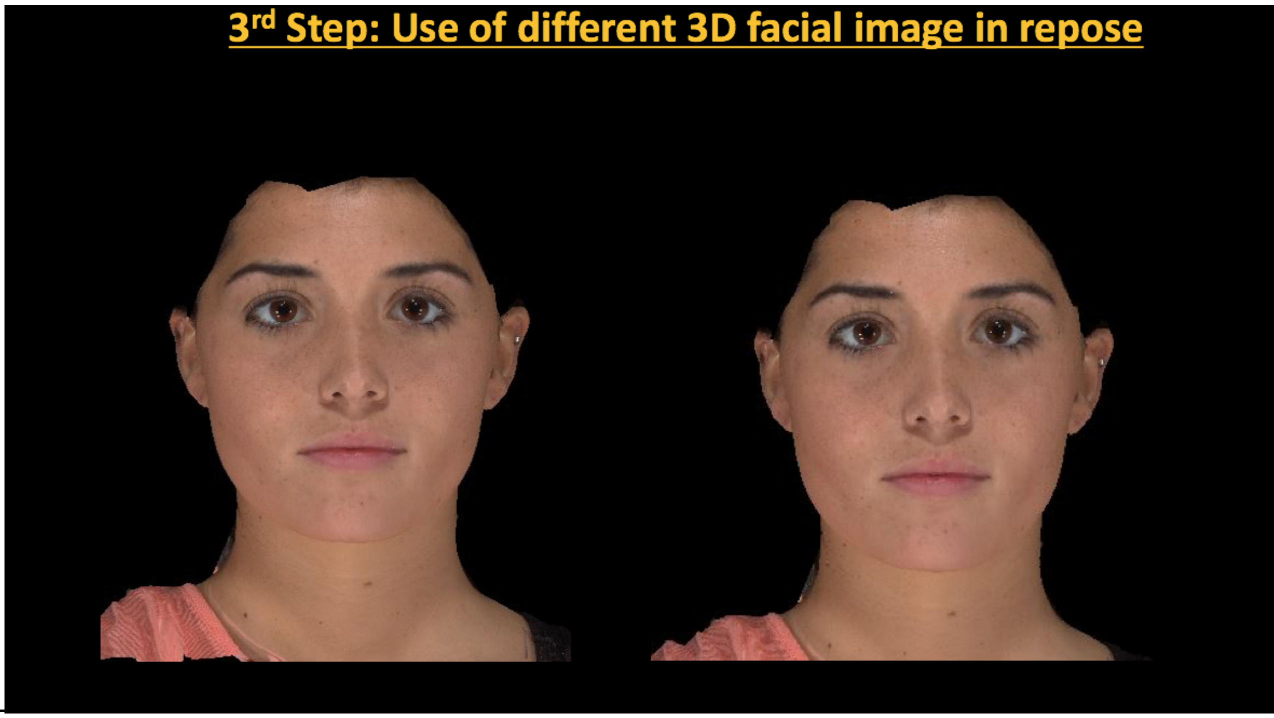


**Fig 13:** The mandibular plane angle (MPMA); the angle between the Mandibular plane (connecting Menton (mn) and Gonion (go); red, and the Mid-Axial plane (MA); yellow

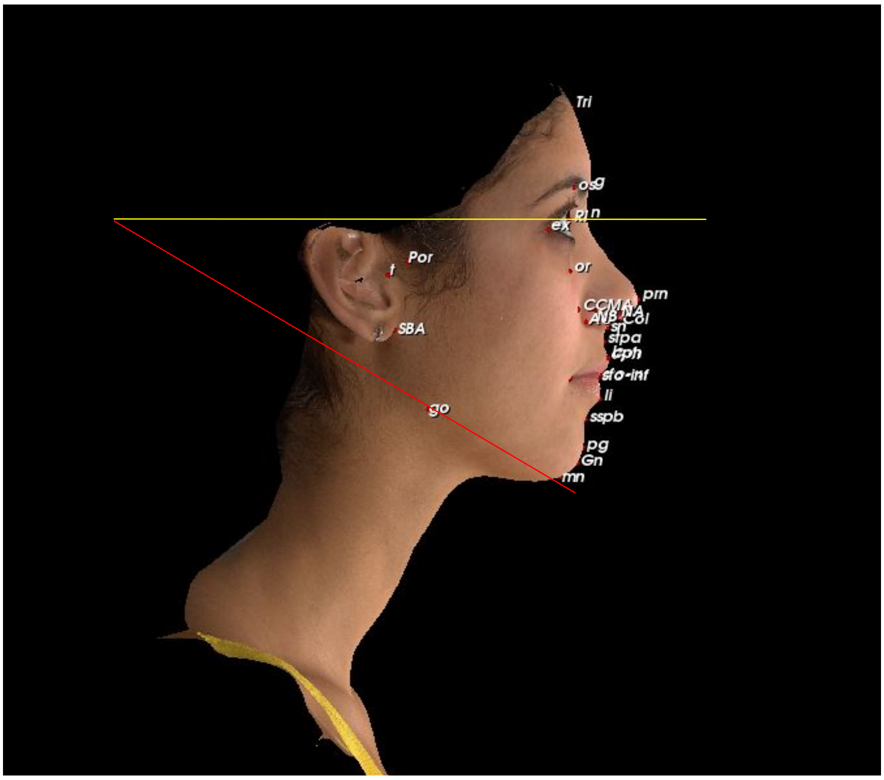



**Fig 14:** Sample selection process flow chart

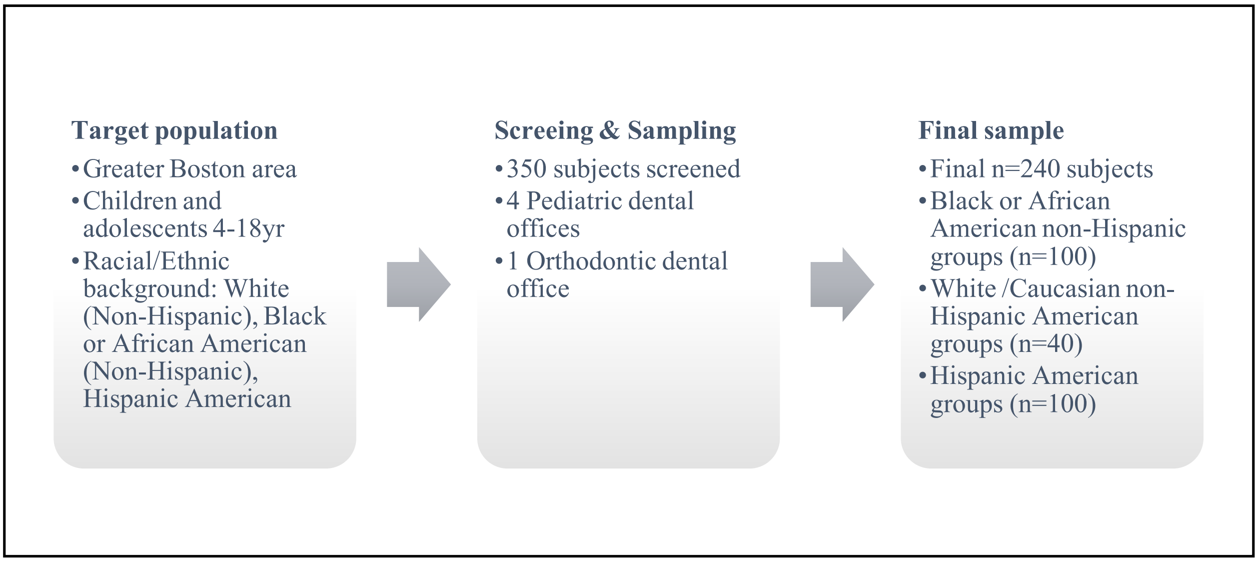


**Fig 15:** Black, African American Non-Hispanic 3D mesh diagram; Primary dentition stage.

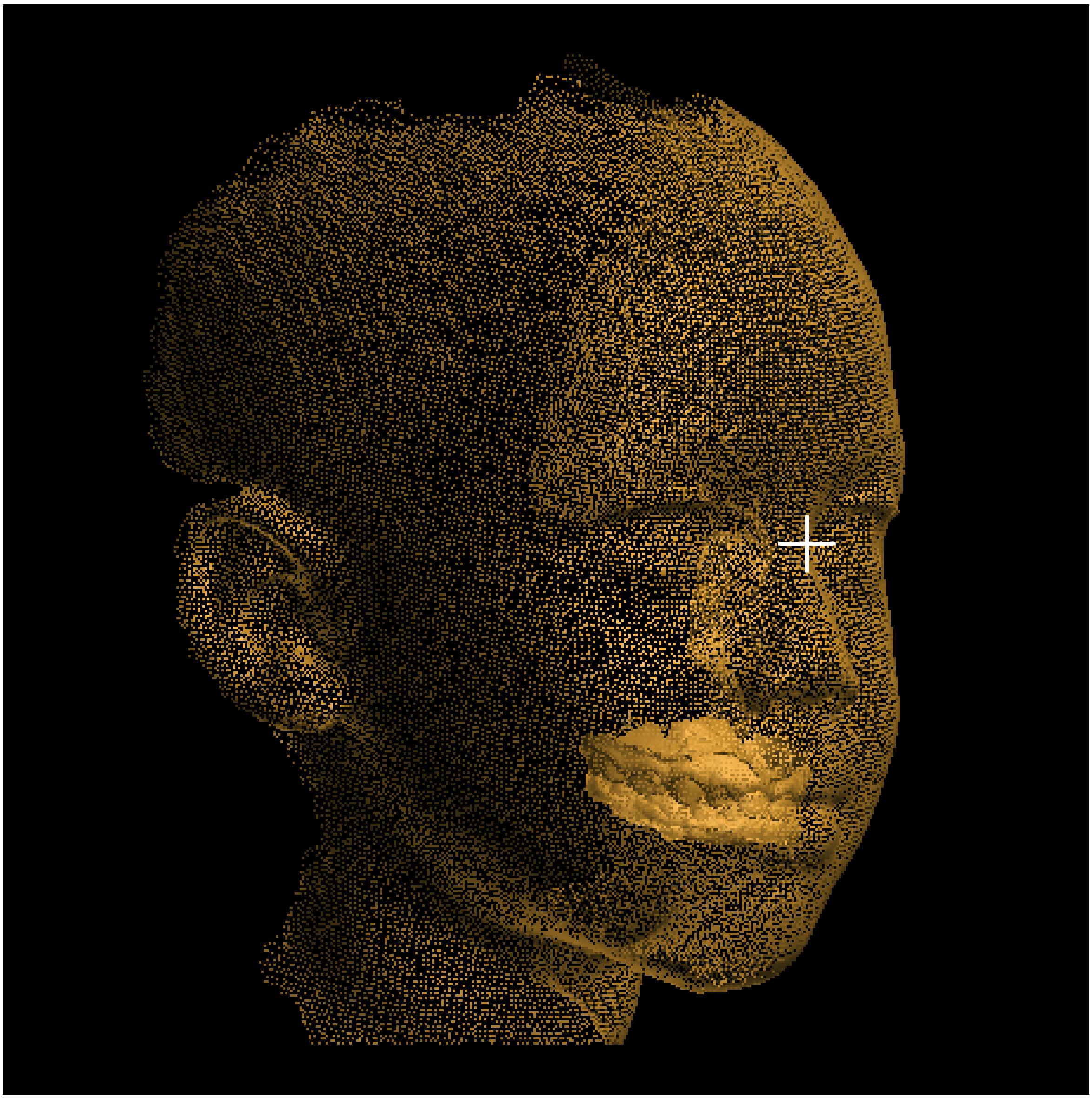
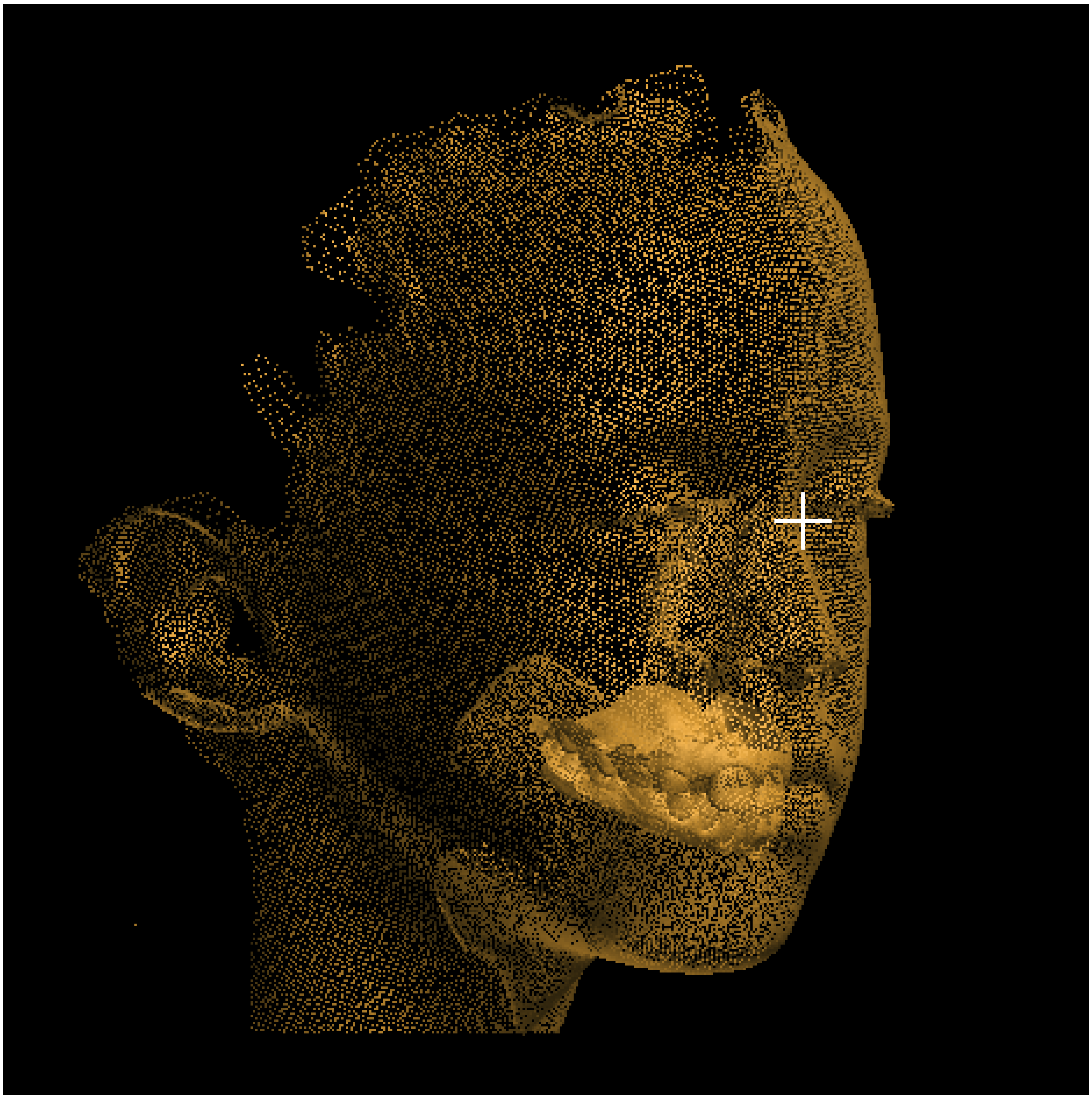


**Fig 16:** Black, African American Non-Hispanic 3D mesh diagram; Early mixed dentition stage



**<u>Fig 17:</u>** Black, African American Non-Hispanic 3D mesh diagram; Late mixed dentition stage

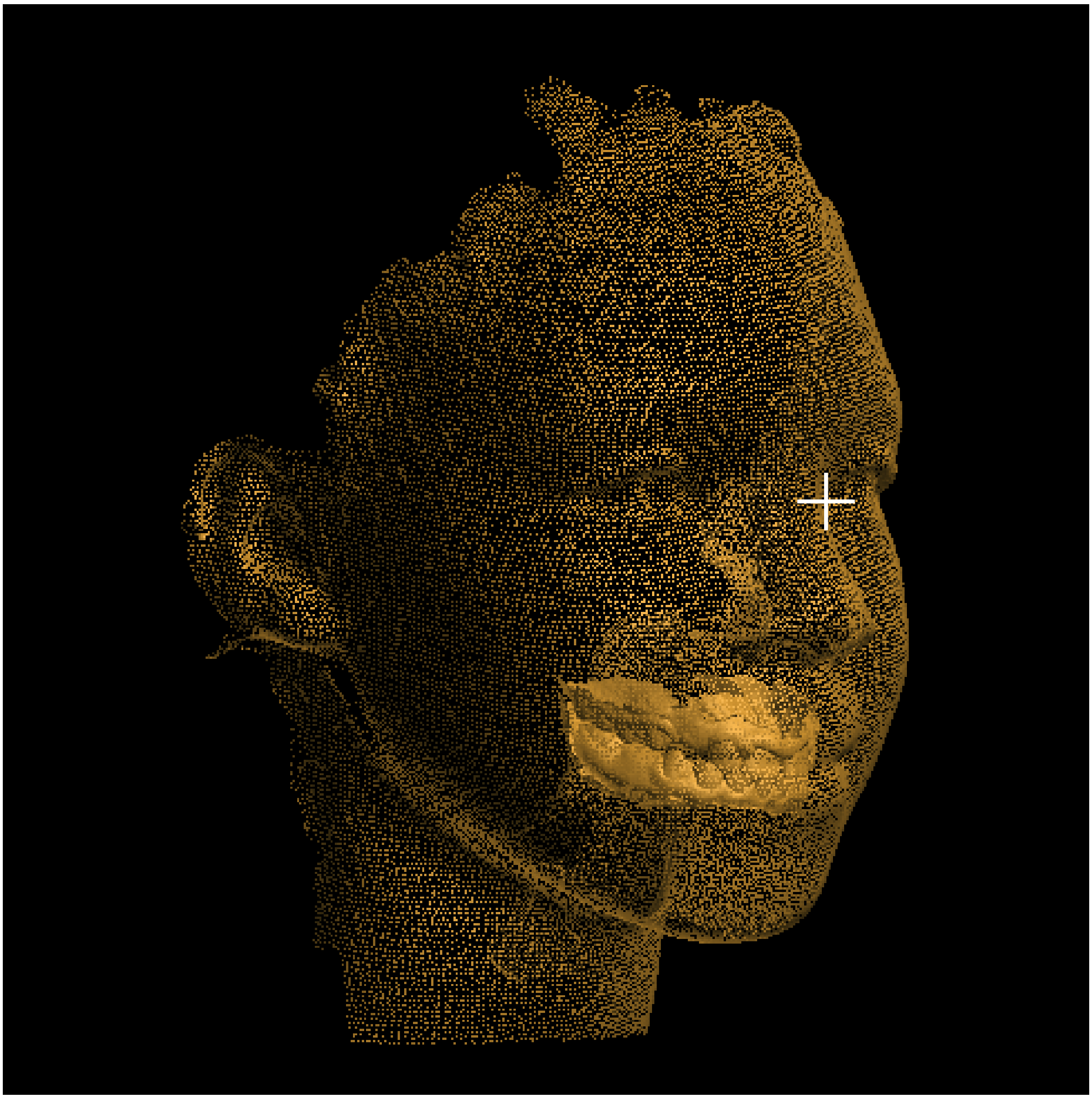
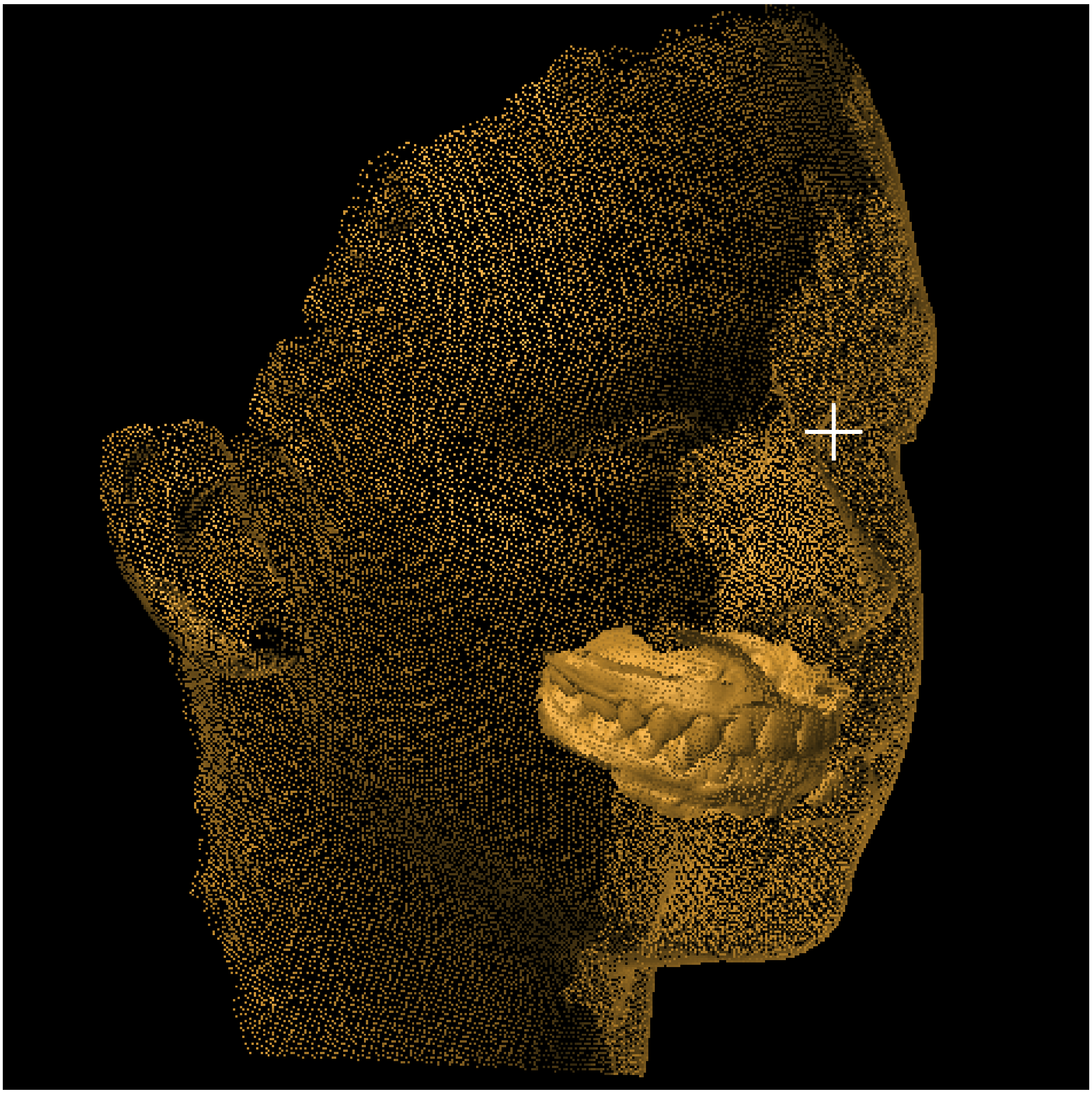
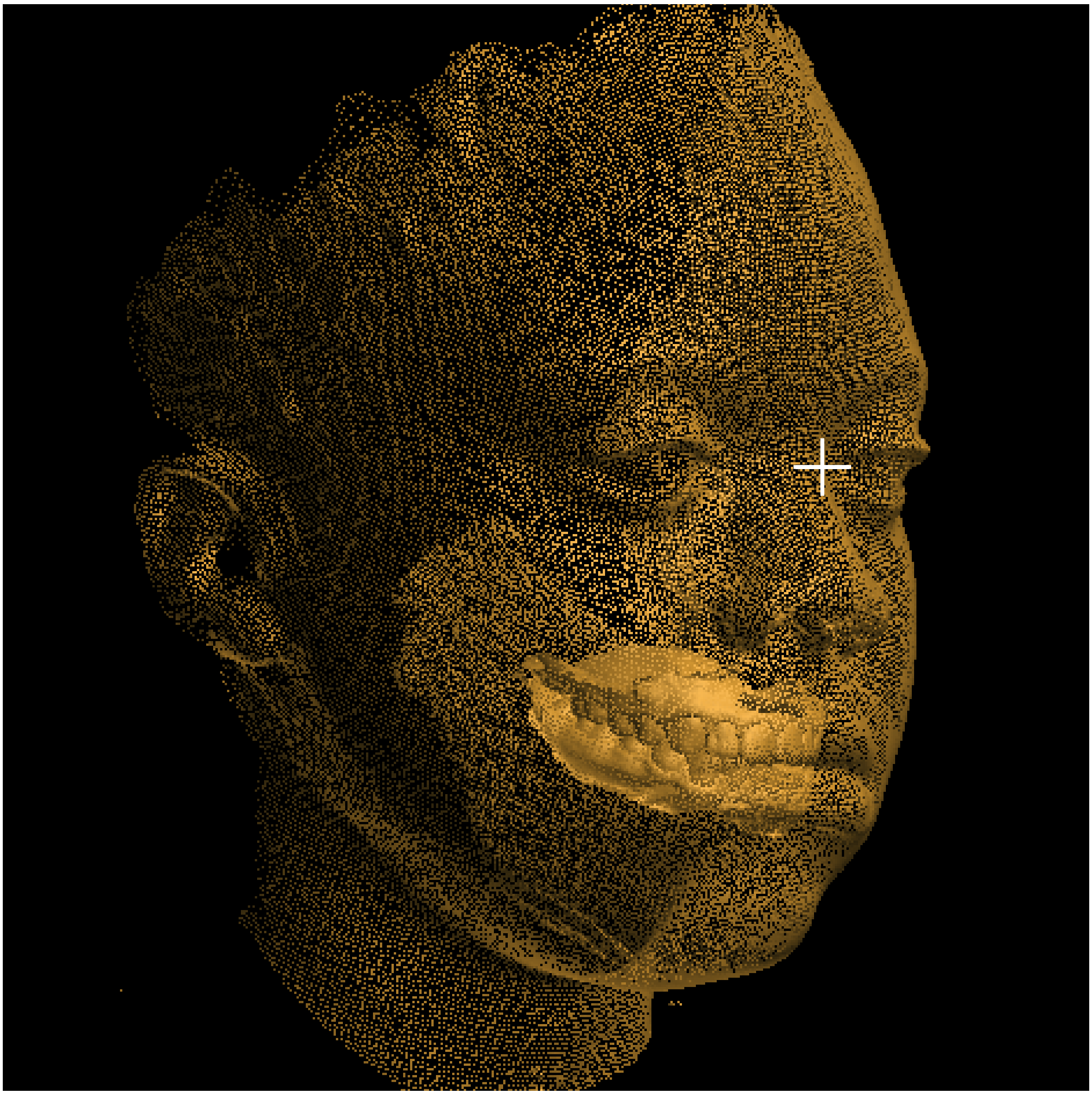


**Fig 18:** Black, African American Non-Hispanic 3D mesh diagram; Permanent dentition stage; Female specific 3D mesh composite



**<u>Fig 19:</u>** Black, African American Non-Hispanic 3D mesh diagram; Permanent dentition stage; Male specific 3D mesh composite



- **Fig 20:** White Non-Hispanic American 3D mesh diagram; Permanent dentition stage; Female specific 3D mesh composite

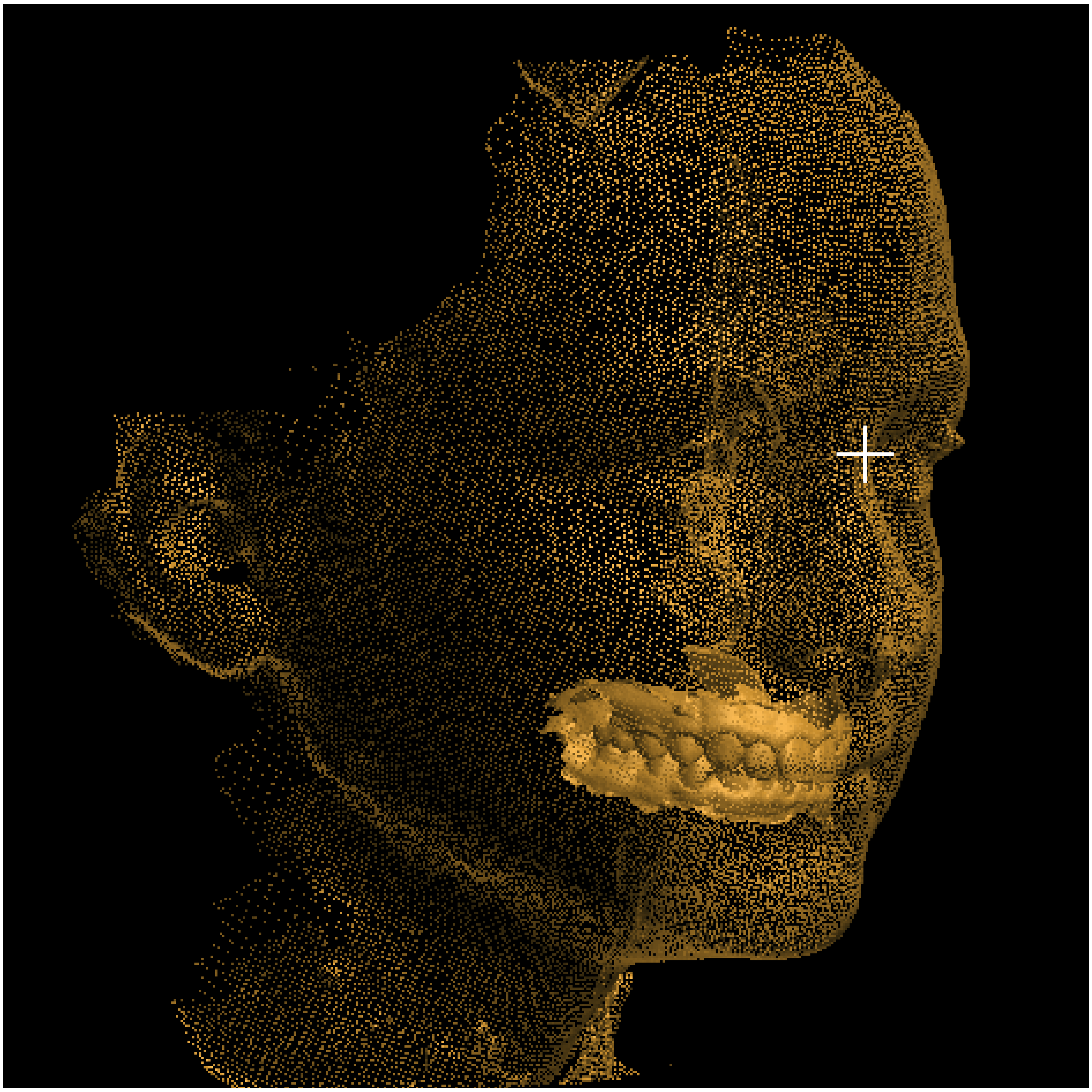


**Fig 21:** White Non-Hispanic American 3D mesh diagram; Permanent dentition stage; Male specific 3D mesh composite

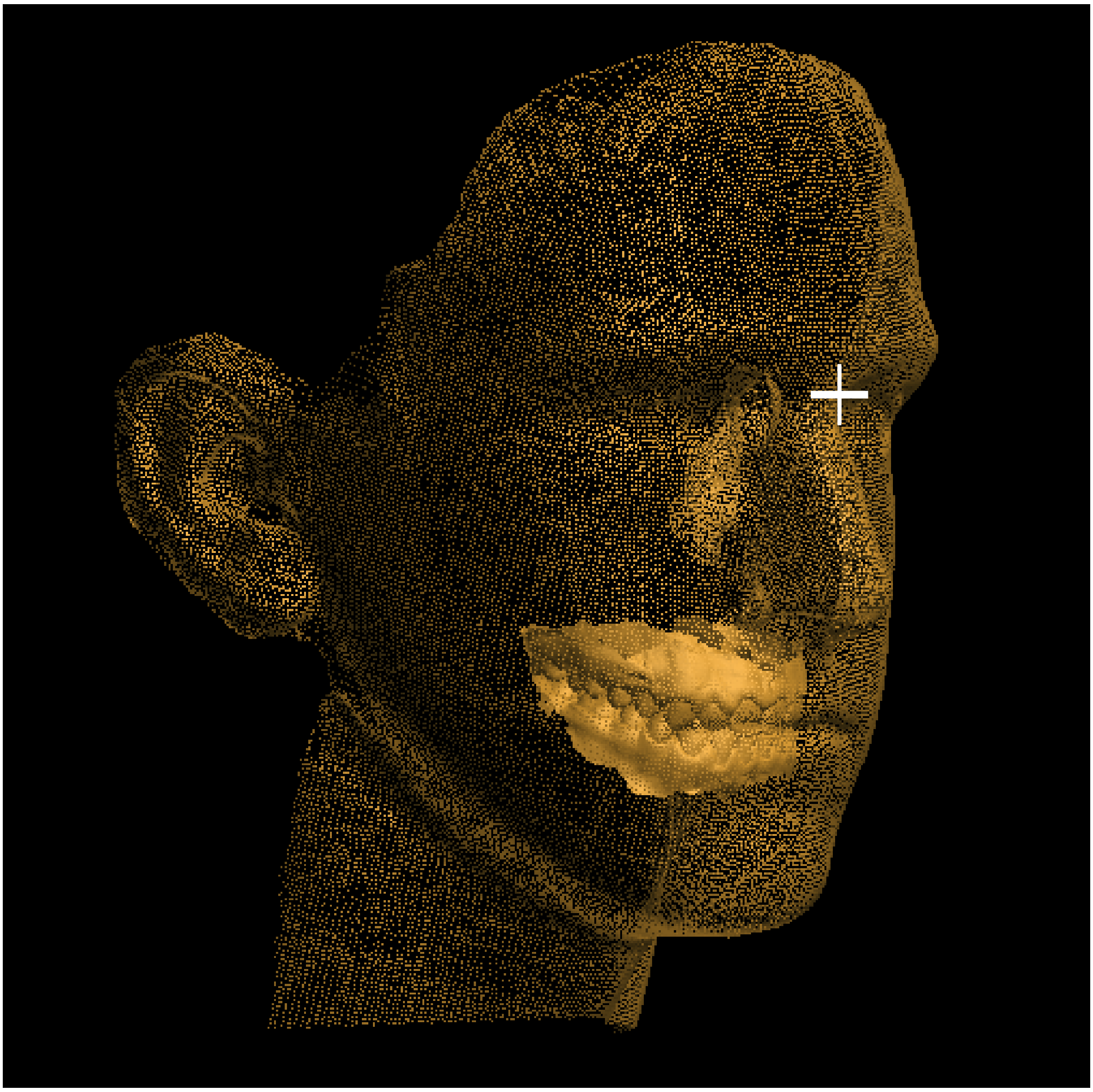


**Fig 22:** Hispanic American 3D mesh diagram; Primary dentition stage.

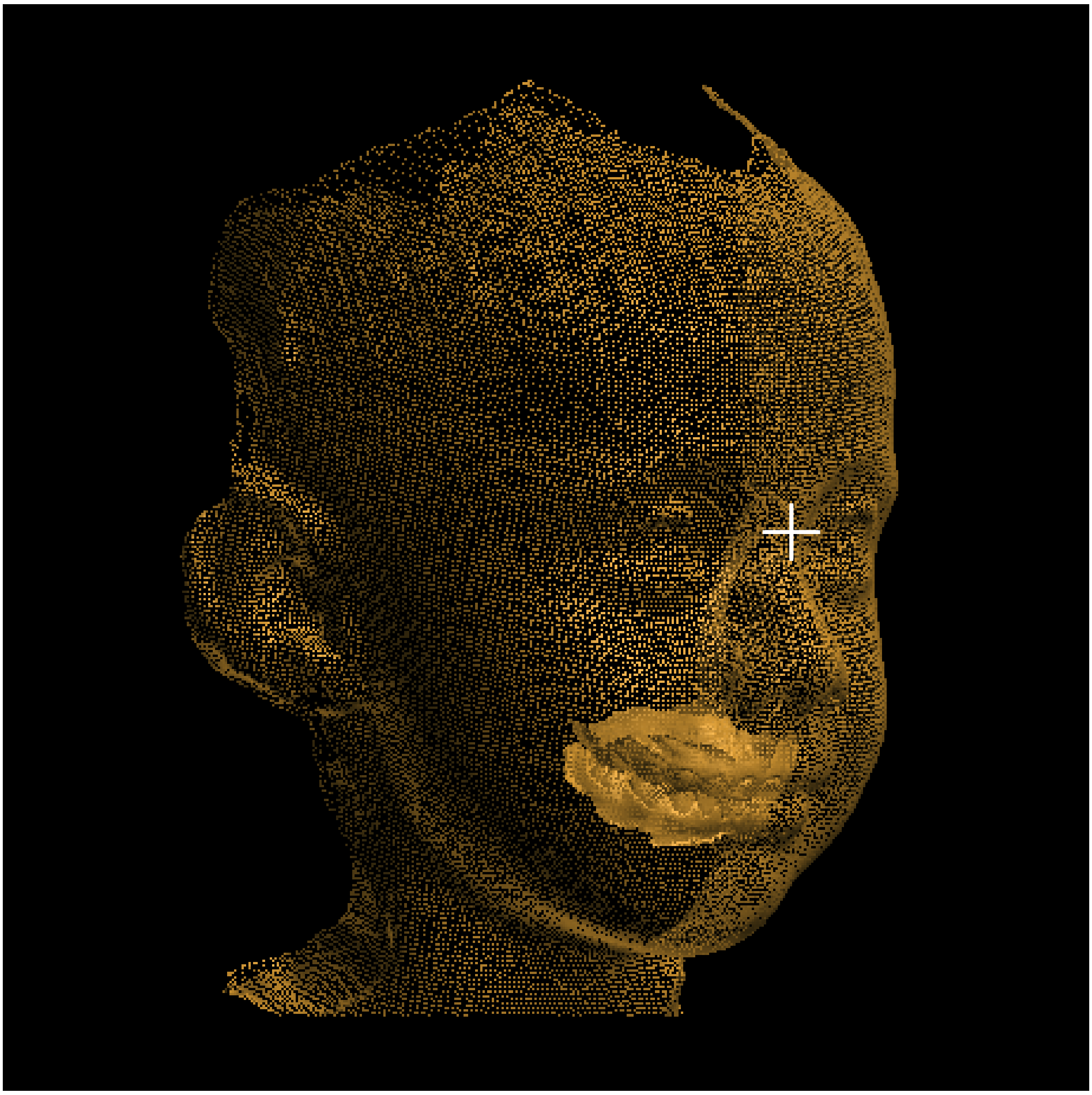


**Fig 23:** Hispanic American 3D mesh diagram; Early mixed dentition stage.

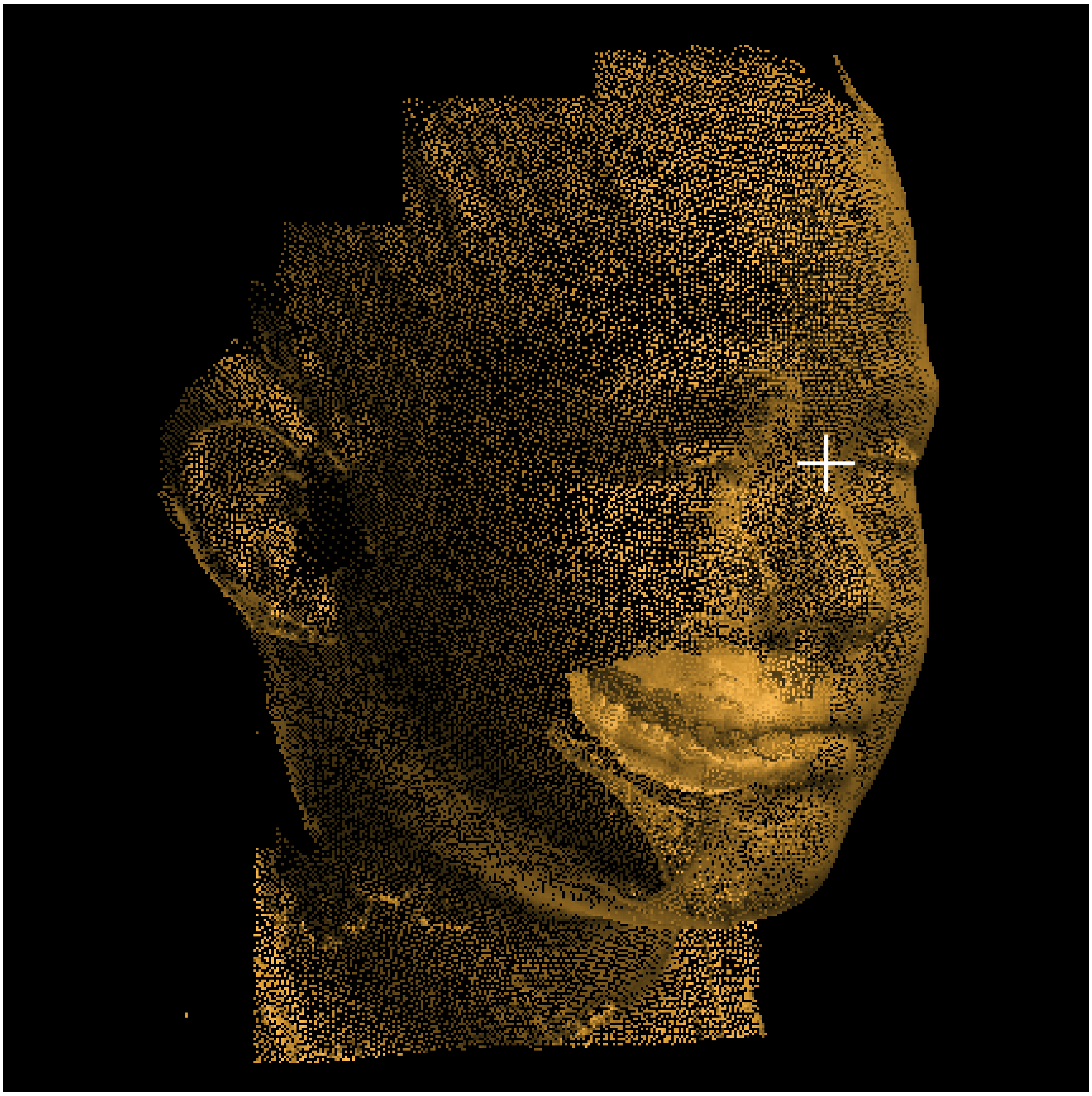
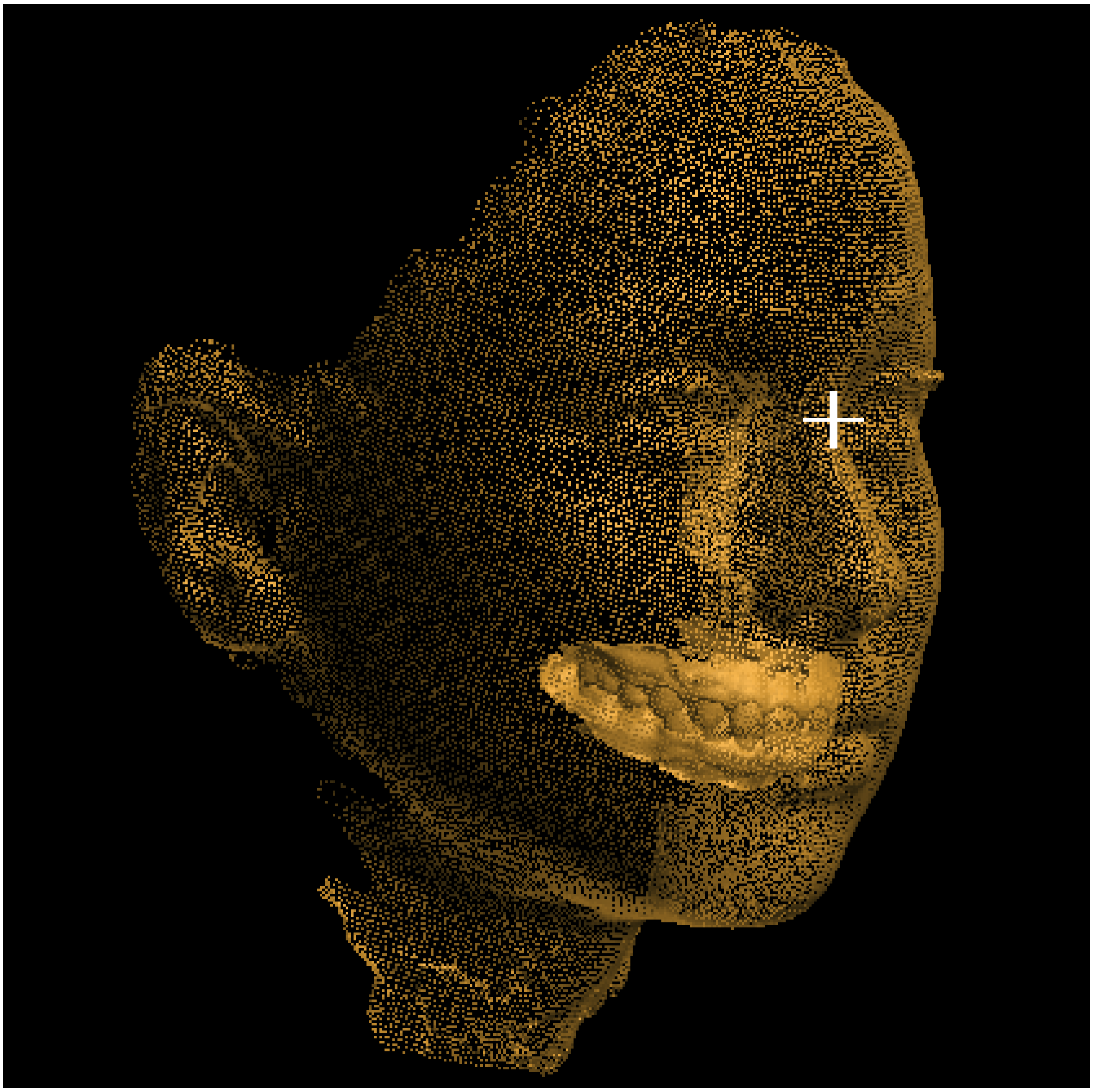


**Fig 24:** Hispanic American 3D mesh diagram; Late mixed dentition stage.



**<u>Fig 25:</u>** Hispanic American 3D mesh diagram; Permanent dentition stage; Female specific 3D mesh composite

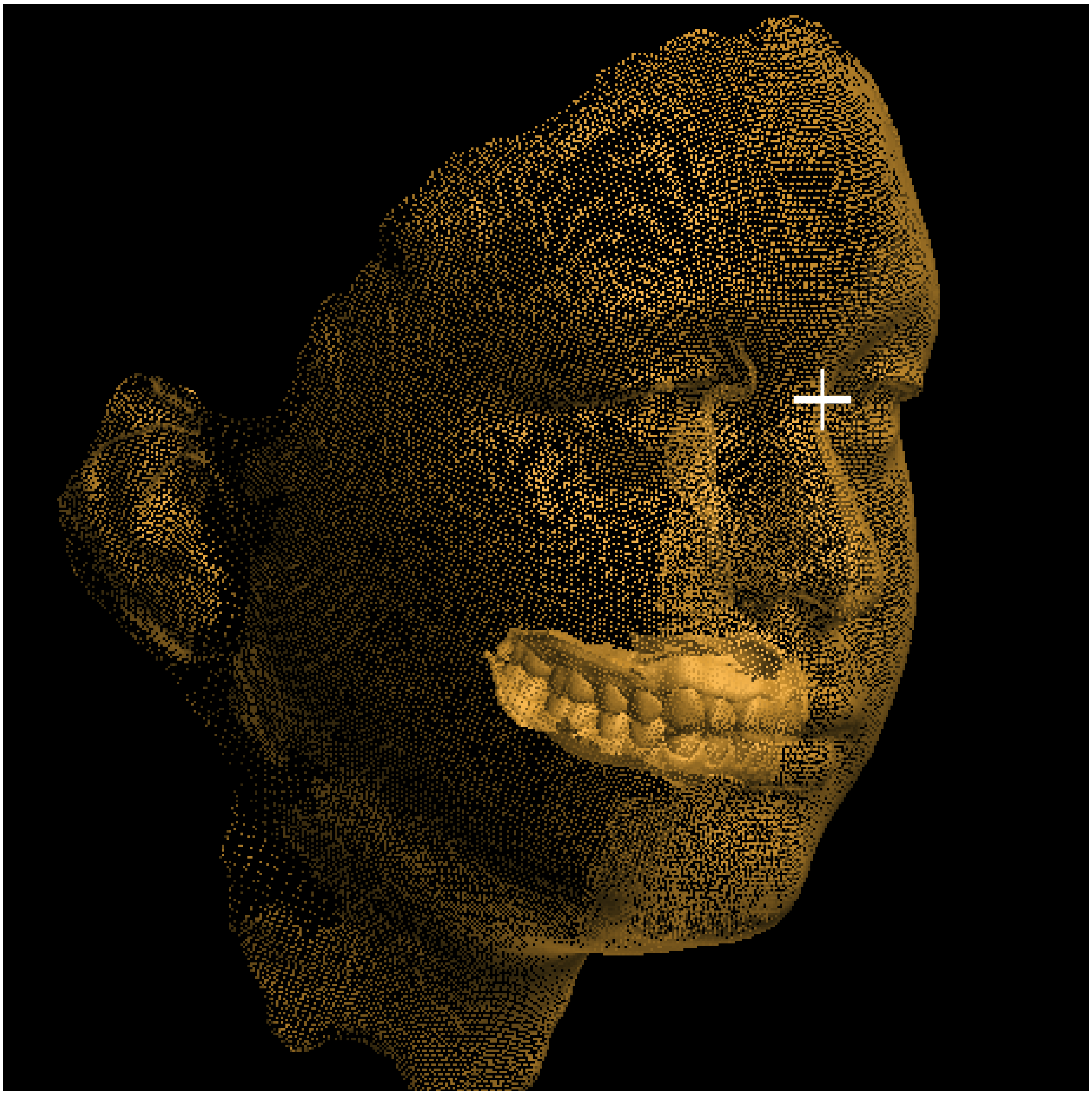
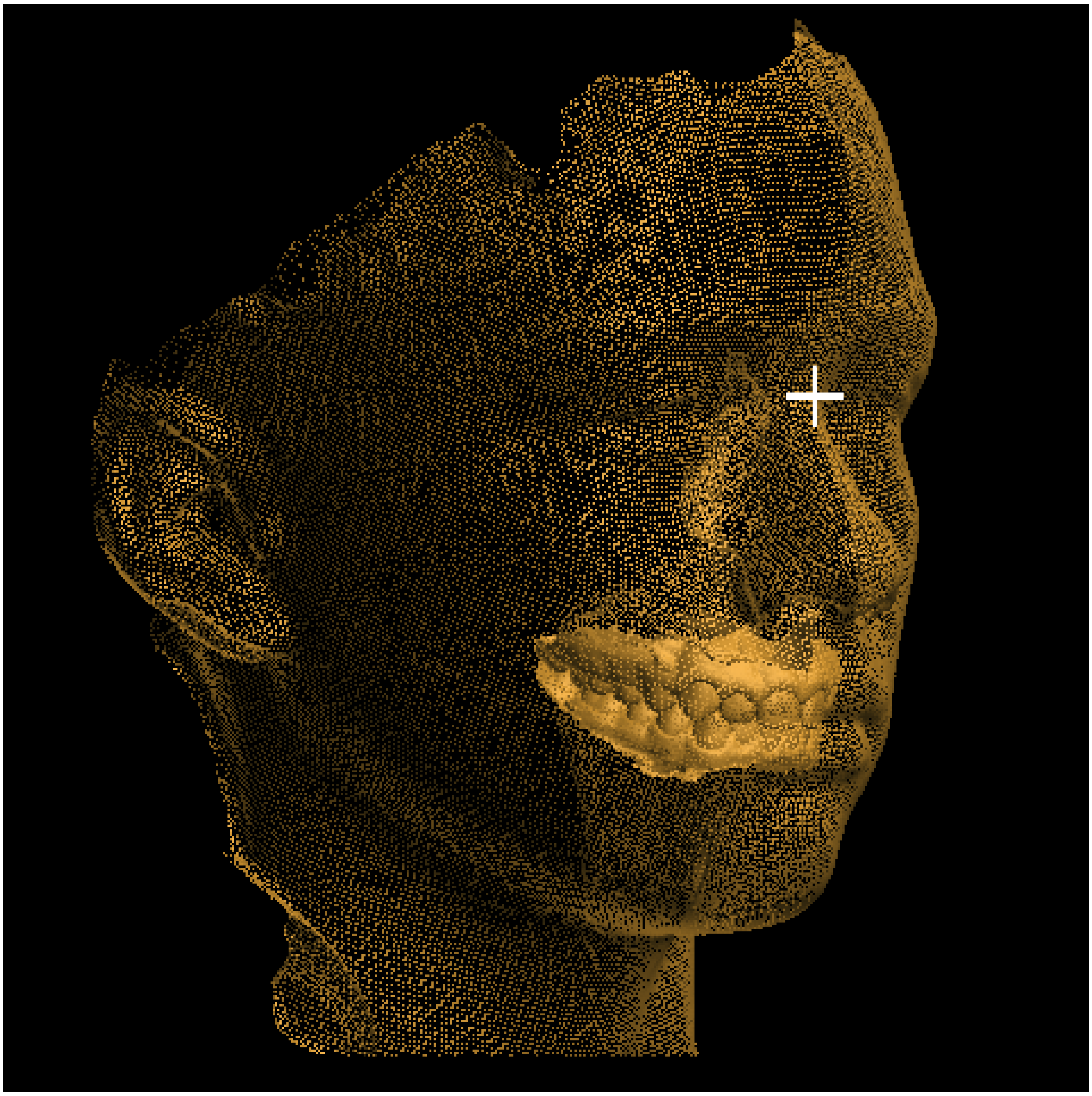
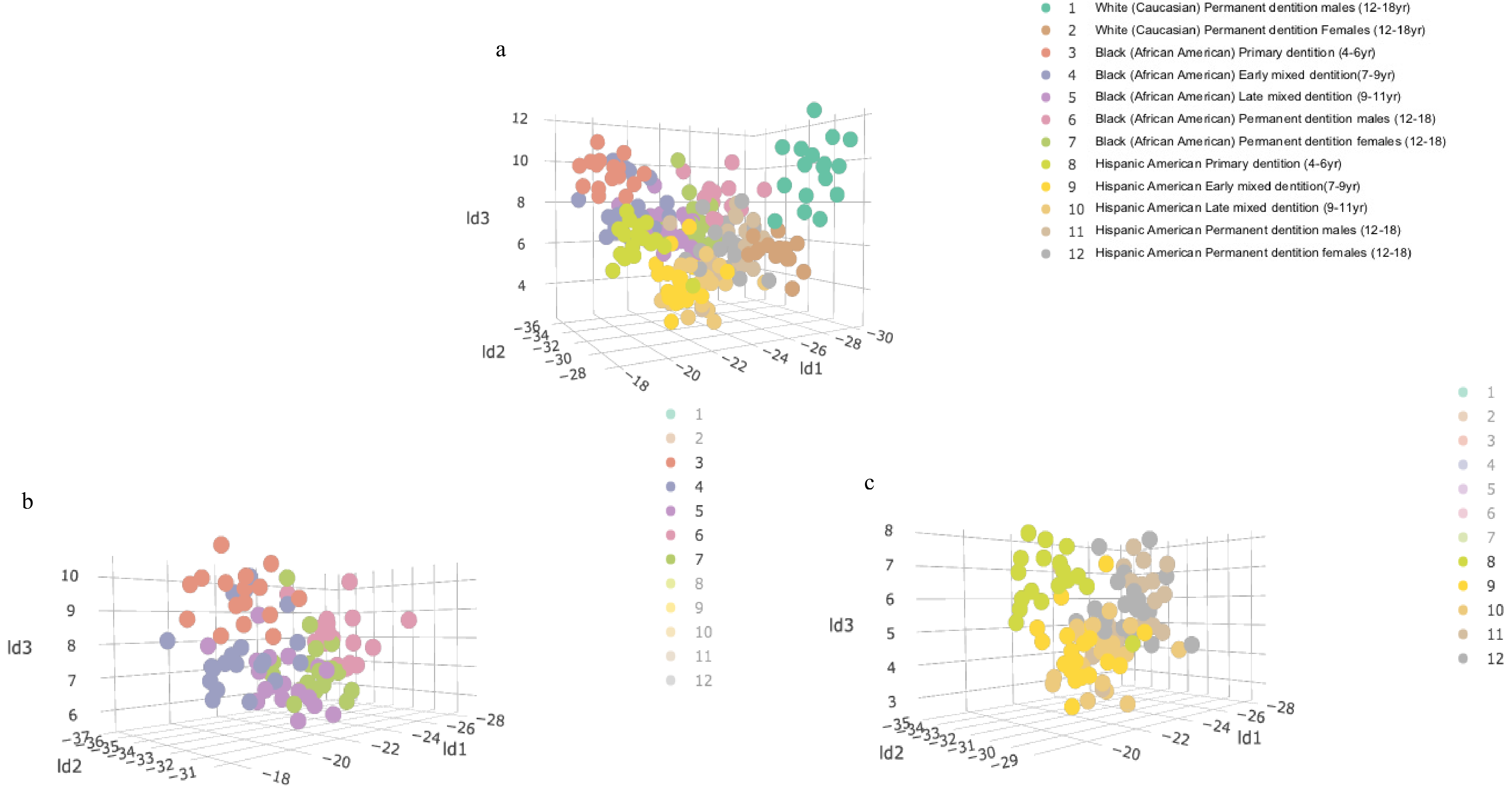


**Fig 26:** Hispanic American 3D mesh diagram; Permanent dentition stage; Male specific 3D mesh composite



**<u>Fig 27:</u>**2D views of a 3D diagram based on the linear discriminative analysis of the dentofacial measurements *a) across all groups b) across age groups in the African american sample c) across age groups in the Hispanic American sample*



**<u>Fig 28:</u>**2D views of a 3D diagram based on linear discriminative analysis on dentofacial measurements **<u>a</u>**.adolescent males across race/ethnicitys **<u>b</u>**. adolescent females across race/ethnicitys **<u>c</u>**.Hispanic males vs females **<u>d</u>**.African American males vs females **<u>e</u>**.White males vs females **<u>f.</u>** Primary dentition Hispanic vs African American **<u>h</u>**. Early mixed dentition Hispanic vs African American **<u>g</u>**. Late mixed dentition Hispanic vs African American

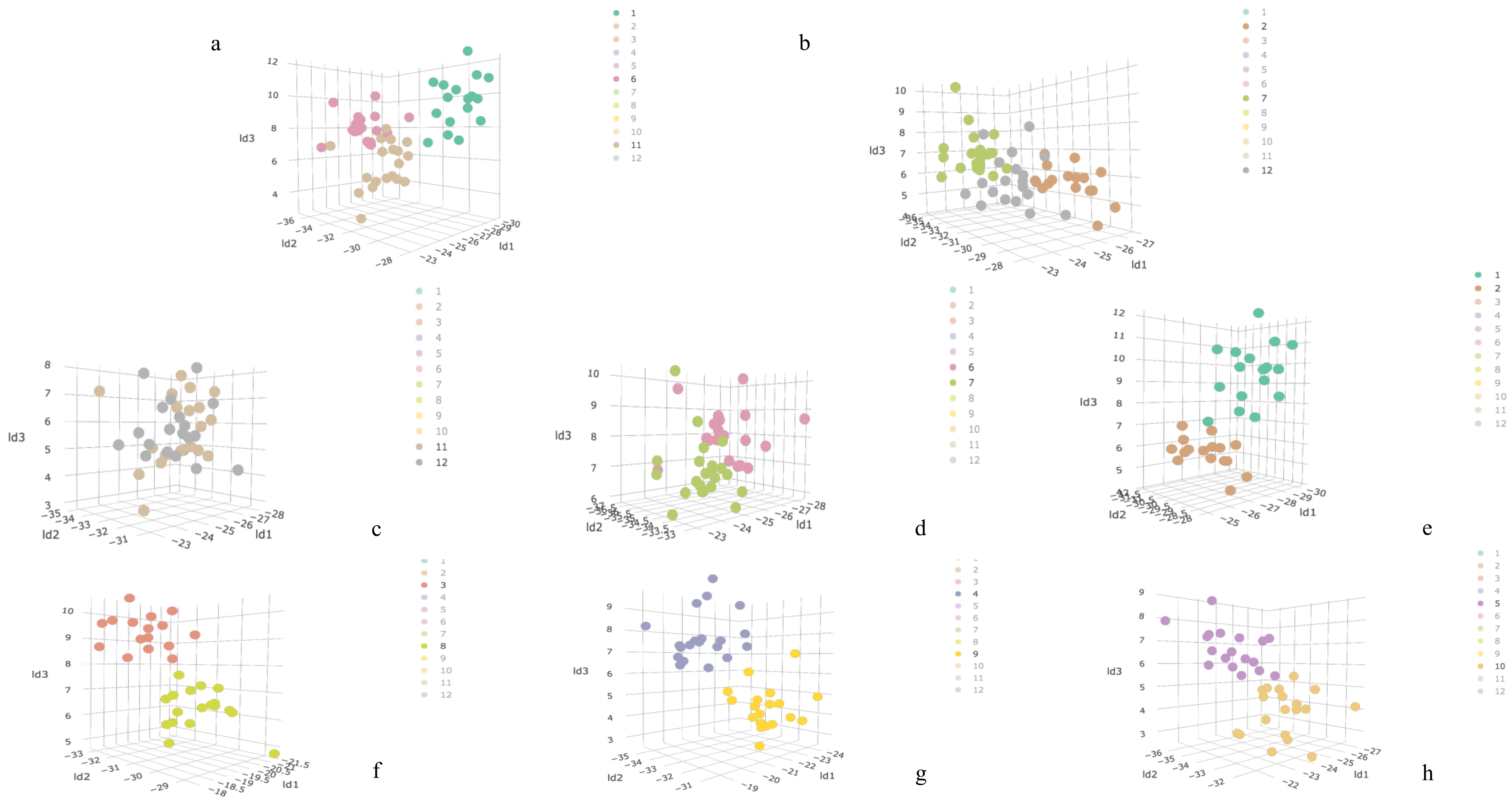
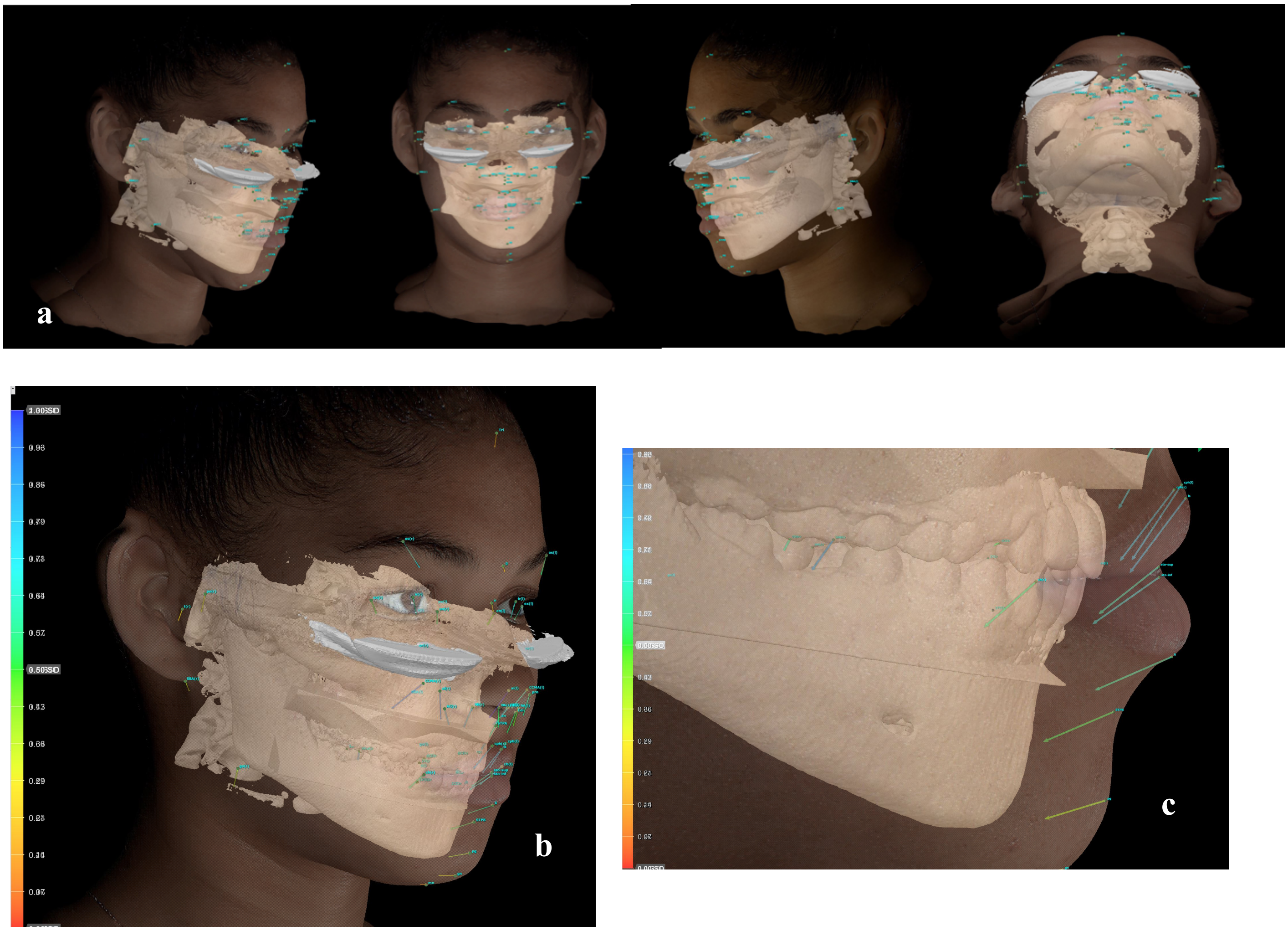


**Fig 29:** a)An example of a limited field CBCT, superimposed on 3D facial and dental images)using directional arrows that indicate the amount and direction of deviation of the current patient to their average value. c) a closer look at the directional arrows in the area below Subnasale indicating protrusive lips and dentition to the norm.



## XIV. Tables:

**Table 1:** Facial landmarks used in 3D orthodontic diagnosis.

| Landmark | Landmark name | Definition |
|---|---|---|
| **Tr** | Trichion | Superior part of the forehead at the start of the hairline |
| **G** | Glabella | Most protrusive midline area above the eyebrows |
| **N** | Nasion | Most concave area between the eyebrows and the nose |
| **Ir(r)** | Iris | Center of the pupil – right eye |
| **Ir(l)** | Iris | Center of the pupil – left eye |
| **Ex (r)** | Exocanthion | Lateral boarder of the right eye |
| **Ex (l)** | Exocanthion | Lateral boarder of the left eye |
| **En (r)** | Endocanthion | Medial boarder of the right eye |
| **En (l)** | Endocanthion | Medial boarder of the left eye |
| **Os (r)** | Orbitale superior(right) | Highest part of the eyebrow arch |
| **Os (l)** | Orbitale superior(left) | Highest part of the eyebrow arch |
| **Or(r)** | Orbitale right | Lower boarder of the inferior eyelid |
| **Or(l)** | Orbitale left | Lower boarder of the inferior eyelid |
| **CCma(r)** | Cheek contour right | Most convex part of the cheek (in line with ir and or) |
| **CCma(l)** | Cheek contour left | Most convex part of the cheek (in line with ir and or) |
| **Prn** | Pronasale | Most protrusive point on the tip of the nose |
| **Col** | Columella | Middle of the philtrum of the nose |
| **Al(r)** | Alare (right) | Outer part of the nostril (where it meets the cheek) |
| **Al(l)** | Alare (left) | Outer part of the nostril (where it meets the cheek) |
| **Ac(r)** | Alare curvature (right) | Most convex part of the nostril |
| **Ac(l)** | Alare curvature (left) | Most convex part of the nostril |
| **Nb(r)** | Nostril base (right) | The base of the nostril (inner) |
| **Nb(l)** | Nostril base (left) | The base of the nostril (inner) |
| **Na(r)** | Nostril apex (right) | The apex of the nostril (inner) |
| **Na(l)** | Nostril apex (left) | The apex of the nostril (inner) |
| **Sn** | Subnasale | Most inferior/posterior point where the lip and nose meet |
| **Stpa** | Soft tissue A point | Most concave point between the lip and nose |
| **Ls** | Labrale superius | Most superior point on the upper lip |
| **Cph (r)** | Crista philtra(right) | Most superior of the right cupids bow on the upper lip |
| **Cph (l)** | Crista philtra(left) | Most superior of the left cupids bow on the upper lip |
| **Ch(r)** | Chelion (right) | Right corner of the mouth |
| **Ch(l)** | Chelion (left) | Left corner of the mouth |
| **Sto-sup** | Stomion superior | Inner most inferior of the upper lip(vermillion) |
| **Sto-inf** | Stomion inferior | Inner most inferior of the upper lip(vermillion) |
| **Li** | Labrale inferius | Most inferior point on the upper lip |
| **Stpb** | Soft tissue B point | Most concave point between the lower lip and chin |
| **Gn** | Gnathion | Most inferior and anterior point on the chin |
| **Pg** | Pogonion | Most anterior point on soft tissue chin |
| **Mn** | Menton | Most inferior point on the soft tissue chin |
| **T(r)** | Tragion(right) | Superior part of the tragus |
| **T(l)** | Tragion(left) | Superior part of the tragus |
| **Po(r)** | Porion (right) | Anterior and superior to tragus |
| **Po(l)** | Porion (left) | Anterior and superior to tragus |
| **Sba(r)** | Subaurale (right) | Inferior part of the lobe of the ear |
| **Sba(l)** | Subaurale (left) | Inferior part of the lobe of the ear |
| **Go(r)** | Gonion (right) | Angle of the mandible |
| **Go(l)** | Gonion (left) | Angle of the mandible |

| | | |
|---|---|---|
| **Zyg(r)** | Lateral zygomatic right | The most prominent superior point on the cheek area just below Exocanthion and slightly medial to it |
| **Zyg(l)** | Lateral zygomatic left | The most prominent superior point on the cheek area just below Exocanthion and slightly medial to it |

**Table 2:** Dental landmarks used in 3D orthodontic diagnosis (Applies to Maxillary and Mandibular teeth bilaterally; right and left).

| Max & Mnd Teeth | Landmark name | Definition |
|---|---|---|
| **1ST premolars** | BC | Buccal cusp tip |
| | CEJ | CEJ buccal |
| | CEJL | CEJ lingual/Palatal |
| | DMR | Distal marginal ridge |
| | MMR | Mesial Marginal ridge |
| | DP | Distal pit /fossa |
| | MP | Mesial pit/fossa |
| | LC | Lingual/Palatal cusp tip |
| | | |
| **1st molars** | BGO | Buccal groove occlusal |
| | BGG=CEJ | Buccal groove gingival |
| | CEJL | CEJ lingual/Palatal |
| | CO | Central fossa |
| | DMR | Distal marginal ridge |
| | MMR | Mesial Marginal ridge |
| | DB cusp | Distal buccal cusp tip |
| | DL cusp | Distal lingual/Palatal cusp tip |
| | MB cusp | Mesial buccal cusp tip |
| | ML cusp | Mesial lingual/Palatal cusp tip |
| | | |
| **Cuspids** | CEJ | CEJ buccal |
| | CEJL | CEJ lingual/Palatal |
| | Cusp | Cusp tip |
| | | |
| **Central incisors** | CEJ | CEJ labial |
| | CEJ L | CEJ lingual/Palatal |
| | CI | Central incisal edge |
| | CL | Central labial edge |
| | DI | Distal incisal edge |
| | DL | Distal labial edge |
| | MI | Mesial incisal edge |
| | ML | Mesial labial edge |

**Table 3:** Definition of 3D Dentofacial Orthodontic measurements.

| Measurement | Definition: (MSP: MID SAGITTAL PLANE, MCP: MID CORONAL PLANE, MAP/MA: MID AXIAL PLANE) |
|---|---|
| **ALAREANG** | Maxillary Sagittal position to Alar base(°) |
| **SNPMCP** | Maxillary Sagittal position to Subnasale(°) |
| **SAPMCP** | Maxillary Apical Base Angle(°) |
| **ISMCP** | Maxillary Lip Position(mm) |
| **SNMA** | Maxillary Vertical Position(mm) |
| **STUSN** | Upper lip length(mm) |
| **OCCMA** | Occlusal Plane Angle(°) to MA |
| **MAX Cant** | Maxillary Cant Angle(°) |
| **UR3MS** | Maxillary right anterior width(mm) |
| **UL3MS** | Maxillary left anterior width(mm) |
| **SBPMC** | mandibular base angle(°) |
| **LIMC** | Mandibular Lip Position(mm) |
| **PGMC** | Chin Position(mm) |
| **STMEMA** | Anterior Face Height(mm) |
| **PFH** | Posterior Face Height(mm) |
| **MPMA** | Mandibular Plane Angle(°) |
| **STGORMS** | Right facial Width(mm) |
| **STGOLMS** | Left facial Width(mm) |
| **CHINMS** | Chin deviation(mm) |
| **LR3MS** | Mandibular right anterior width(mm) |
| **LL3MS** | Mandibular left anterior width(mm) |
| **SAPSBP** | intermaxillary angle(°) |
| **ARPOG** | intermaxillary apical base(°) |
| **SNSTME** | Lower Face Height(mm) |
| **SWITS** | Soft tissue Wits/ intermaxillary distance (mm) |
| **STZYSTGO** | Facial taper(mm) / Distance stzy - stgo |
| **UR1IMCP** | Maxillary Incisors (mm) |
| **UR1LAMCP** | Maxillary Incisors (°) |
| **LRLIMC** | Mandibular Incisors (mm) |
| **LR1LAMCP** | Mandibular Incisors (°) |
| **LR1LAMP** | Lower incisor to MP angle (°) |
| **UR1STSREST** | upper incisal display at rest (mm) |
| **ANTALV** | Max Anterior Alveolar Height (mm) |
| **POSTALV** | Max Posterior Alveolar Height (mm) |
| **LANTALV** | Mand Anterior Alveolar Height (mm) |
| **LPOSTALV** | Mand Posterior Alveolar Height (mm) |
| **UR3CUR3C** | Maxillary intercanine distance (mm) |
| **LL3CLR3C** | Mandibular intercanine distance (mm) |
| **UR6MPUL6MP** | Maxillary intermolar distance (mm) |
| **LL6CLR6C** | Mandibular intermolar width (mm) |
| **UR6LAMSP** | Upper Right molar angle (°) |
| **UL6LAMSP** | Upper Left molar angle (°) |
| **LR6LAMSP** | Lower Right molar angle (°) |
| **LL6LAMSP** | Lower left molar angle (°) |

**Table 4: Clinical significance and interpretation of ICC value according to Cicchetti.**

| Cronbach's alpha: ICC | INTERNAL CONSISTENCY |
|---|---|
| **Above 0.9** | Excellent |
| **0.8 - 0.9** | Good |
| **0.7 - 0.8** | Acceptable |
| **0.6 - 0.7** | Questionable |
| **0.5-0.6** | Poor |

**Table 5:** ICC values for each orthodontic measurement generated at each digitization step. Definition of each measurement can be found in table 3.

| Variable | 1)Superimposition | | 2)Landmarking | | 3)New face image | |
|---|---|---|---|---|---|---|
| | Intra-Examiner ICC | Inter-Examiner ICC | Intra-Examiner ICC | Inter-Examiner ICC | Intra-Examiner ICC | Inter-Examiner ICC |
| **ALAREANG** | 0.986 | 0.96 | 0.977 | 0.966 | 0.959 | 0.972 |
| **SNPMCP** | 0.936 | 0.819 | 0.934 | 0.822 | 0.794 | 0.91 |
| **SAPMCP** | 0.926 | 0.782 | 0.932 | 0.899 | 0.852 | 0.946 |
| **ISMCP** | 0.94 | 0.831 | 0.951 | 0.921 | 0.879 | 0.936 |
| **SNMA** | 0.969 | 0.923 | 0.933 | 0.935 | 0.931 | 0.978 |
| **STUSN** | 0.991 | 0.935 | 0.955 | 0.927 | 0.91 | 0.973 |
| **OCCMA** | 0.915 | 0.903 | 0.972 | 0.917 | 0.816 | 0.984 |
| **MAX Cant** | 0.987 | 0.949 | 0.974 | 0.992 | 0.807 | 0.884 |
| **UR3MS** | 0.915 | 0.892 | 0.947 | 0.981 | 0.753 | 0.74 |
| **UL3MS** | 0.926 | 0.904 | 0.94 | 0.983 | 0.807 | 0.813 |
| **SBPMC** | 0.952 | 0.935 | 0.905 | 0.807 | 0.678 | 0.923 |
| **LIMC** | 0.912 | 0.792 | 0.956 | 0.902 | 0.786 | 0.864 |
| **PGMC** | 0.979 | 0.974 | 0.888 | 0.803 | 0.88 | 0.871 |
| **STMEMA** | 0.999 | 0.998 | 0.995 | 0.997 | 0.997 | 0.995 |
| **PFH** | 0.944 | 0.901 | 0.875 | 0.801 | 0.893 | 0.801 |
| **MPMA** | 0.939 | 0.924 | 0.771 | 0.467 | 0.639 | 0.699 |
| **STGORMS** | 0.84 | 0.967 | 0.77 | 0.862 | 0.805 | 0.813 |
| **STGOLMS** | 0.811 | 0.806 | 0.734 | 0.74 | 0.829 | 0.823 |
| **CHINMS** | 0.93 | 0.866 | 0.745 | 0.916 | 0.851 | 0.961 |
| **LR3MS** | 0.911 | 0.879 | 0.935 | 0.987 | 0.682 | 0.697 |
| **LL3MS** | 0.91 | 0.895 | 0.927 | 0.978 | 0.705 | 0.732 |
| **SAPSBP** | 0.981 | 0.967 | 0.963 | 0.96 | 0.956 | 0.954 |
| **ARPOG** | 0.941 | 0.843 | 0.938 | 0.934 | 0.901 | 0.951 |
| **SNSTME** | 0.993 | 0.978 | 0.981 | 0.983 | 0.978 | 0.995 |
| **SWITS** | 0.932 | 0.952 | 0.686 | 0.727 | 0.82 | 0.805 |
| **STZYSTGO** | 0.926 | 0.905 | 0.944 | 0.949 | 0.966 | 0.923 |
| **UR1IMCP** | 0.951 | 0.81 | 0.975 | 0.893 | 0.902 | 0.973 |
| **UR1LAMCP** | 0.926 | 0.907 | 0.943 | 0.946 | 0.956 | 0.991 |
| **LRLIMC** | 0.957 | 0.831 | 0.971 | 0.955 | 0.912 | 0.961 |
| **LR1LAMCP** | 0.981 | 0.961 | 0.96 | 0.92 | 0.952 | 0.986 |
| **LR1LAMP** | 0.945 | 0.954 | 0.954 | 0.946 | 0.961 | 0.955 |
| **UR1STSREST** | 0.949 | 0.89 | 0.937 | 0.977 | 0.867 | 0.893 |
| **ANTALV** | 0.95 | 0.897 | 0.93 | 0.945 | 0.853 | 0.937 |
| **POSTALV** | 0.72 | 0.68 | 0.854 | 0.89 | 0.713 | 0.951 |
| **LANTALV** | 0.937 | 0.917 | 0.89 | 0.912 | 0.785 | 0.755 |
| **LPOSTALV** | 0.875 | 0.874 | 0.899 | 0.884 | 0.921 | 0.77 |
| **UR3CUR3C** | 0.999 | 0.988 | 0.987 | 0.976 | 0.947 | 0.965 |
| **LL3CLR3C** | 0.995 | 0.986 | 0.964 | 0.948 | 0.985 | 0.99 |
| **UR6MPUL6MP** | 0.993 | 0.988 | 0.987 | 0.984 | 0.913 | 0.923 |
| **LL6CLR6C** | 0.999 | 0.996 | 0.933 | 0.989 | 0.944 | 0.96 |
| **UR6LAMSP** | 0.926 | 0.926 | 0.89 | 0.852 | 0.91 | 0.999 |
| **UL6LAMSP** | 0.957 | 0.896 | 0.914 | 0.924 | 0.953 | 0.919 |
| **LR6LAMSP** | 0.984 | 0.964 | 0.853 | 0.84 | 0.964 | 0.979 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **LL6LAMSP** | 0.981 | 0.905 | 0.932 | 0.907 | 0.905 | 0.973 |

**Table 6: Demographics**

| | n (%) | Gender (males%) | Average age(Yr.M) |
|---|---|---|---|
| **Total sample** | **240** | **112 M:128 F** | |
| **Black African American** | 100 (41.7) | **48 M: 52 F** | |
| Primary dentition | 20 | 75% | 4.8 |
| Early mixed dentition | 20 | 65% | 7.0 |
| Late mixed dentition | 20 | 25% | 9.5 |
| Permanent dentition (Females) | 20 | 0% | 14.6 |
| Permanent dentition (Males) | 20 | 100% | 15.7 |
| | | | |
| **White Non-Hispanic American** | **40 (16.7)** | **20 M:20 F** | |
| Permanent dentition (Females) | 20 | 0% | 15.9 |
| Permanent dentition (Males) | 20 | 100% | 15.8 |
| | | | |
| **Hispanic American** | **100 (41.7)** | **48 M: 52 F** | |
| Primary dentition | 20 | 40% | 5.2 |
| Early mixed dentition | 20 | 45% | 7.4 |
| Late mixed dentition | 20 | 45% | 10 |
| Permanent dentition (Females) | 20 | 0% | 14.6 |
| Permanent dentition (Males) | 20 | 100% | 13.8 |

## Table 7: Maxillary, Mandibular, Inter-Maxillary measurements and their definitions

| Description of measurement: Maxillary | CODE | Unit |
|---|---|---|
| Maxillary sagittal position, average right & left alar curvature to MC plane | ACMC | mm |
| Maxillary sagittal position, alar curvature plane to pupil, to mc angle | ACPMCP | deg |
| Subnasale sagittal position to MC plane | SNMC | mm |
| Maxillary apical base, soft tissue a to MC plane | SAMC | mm |
| Maxillary apical base, soft tissue a plane to pupils, to MC plane angle | SAPMCP | deg |
| Maxillary lip sagittal position, labrale superius to MC plane | ISMCP | mm |
| Maxillary vertical position, subnasale to MA plane | SNMA | mm |
| Upper lip length, subnasale to stomion superior | STUSN | mm |
| Right upper facial width, right soft tissue zygion to MS plane | ZYR-MS | mm |
| Left upper facial width, left soft tissue zygion to MS plane | ZYL-MS | mm |
| Upper facial width, right to left soft tissue zygion | ZY-ZY | mm |
| Maxillary right incisal edge to MC plane | UR1I-MCP | mm |
| Maxillary right incisor long axis to MC plane | UR1LA-MCP | deg |
| Maxillary left incisal edge to MC plane | UL1I-MCP | mm |
| Maxillary left incisor long axis to MC plane | UL1LA-MCP | deg |
| Maxillary right incisor vertical position to MA plane | UR1-MA | mm |
| Maxillary left incisor vertical position to MA plane | UL1-MA | mm |
| Upper right incisal display at rest, incisal edge to stomion superior | UR1STSREST | mm |
| Upper left incisal display at rest, incisal edge to stomion superior | L1STSREST | mm |
| Maxillary right canine width, cusp tip to MS plane | UR3C-MS | mm |
| Maxillary left canine width, cusp tip to MS plane | UL3C-MS | mm |
| Maxillary inter-canine distance, UR canine tip to UL canine tip | UR3C-UR3C | mm |
| Maxillary right canine long axis to MS plane | UR3LA-MSP | deg |
| Maxillary left canine long axis to MS plane | UL3LA-MSP | deg |
| Maxillary right canine vertical position to MA plane | UR3MA | mm |
| Maxillary left canine vertical position to MA plane | UL3MA | mm |
| Maxillary right 1$^{st}$ molar width, mesio-palatal cusp to MS plane | UR6MP - MS | mm |
| Maxillary left 1$^{st}$ molar width, mesio-palatal cusp to MS plane | UL6MP - MS | mm |
| Maxillary inter-molar distance | UR6MP - UL6MP | mm |

| | | |
|---|---|---|
| Maxillary right 1st molar vertical position (mesio-buccal cusp) to MA plane | UR6MB-MA | mm |
| Maxillary left 1st molar vertical position (mesio-buccal cusp) to MA plane | UL6MB-MA | mm |
| Maxillary right 1st molar long axis to MS plane | UR6LA-MSP | deg |
| Maxillary left 1st molar long axis to MS plane | UL6LA-MSP | deg |
| **Mandibular facial and dental measurements** | **CODE** | **unit** |
| Mandibular apical base position, soft tissue b to MC plane | SBMC | mm |
| Mandibular apical base angle (°), soft tissue b to MC plane | SBP-MC | deg |
| Labiale inferius sagittal position to MC plane | LI - MC | mm |
| Chin sagittal position, soft tissue pg to MC plane | PG - MC | mm |
| Chin sagittal position, soft tissue pg to MC plane angle | SPGP - MCP | deg |
| Anterior face height, soft tissue menton to MA plane | STME - MA | mm |
| Lower face height, subnasale to menton | SN - STME | mm |
| Distance from stomion inferius to soft tissue menton | STME - STI | mm |
| Right posterior face height, right soft tissue gonion to MA plane | STGOR - MA | mm |
| Left posterior face height, left soft tissue gonion to MA plane | STGOL - MA | mm |
| Mandibular plane angle(°), R&L go(mp)to soft tissue menton | MP - MA | deg |
| Chin deviation, soft tissue pogonion to MS plane | CHIN-MS | mm |
| Lower right facial width, right soft tissue gonion to MA plane | STGOR - MA | mm |
| Lower left facial width, left soft tissue gonion to MA plane | STGOL - MA | mm |
| Lower face width, right to left soft tissue gonion | STGOL – STGOR | mm |
| Mandibular right lower incisal edge to MC plane | LR1I - MC | mm |
| Mandibular left lower incisal edge to MC plane | LL1I - MC | mm |
| Mandibular right lower incisor long axis to MC plane angle | LR1LA - MCP | deg |
| Mandibular left lower incisor long axis to MC plane angle | LL1LA-MCP | deg |
| Mandibular right lower incisor long axis to mandibular plane angle | LR1LA-MP | deg |
| Mandibular left lower incisor long axis to mandibular plane angle | LL1LA-MP | deg |
| Mandibular right lower incisal edge vertical position to MP | LR1I - MP | mm |
| Mandibular left lower incisal edge vertical position to MP | LL1I - MP | mm |
| Mandibular right canine width, cusp tip to MS plane | LR3C - MS | mm |
| Mandibular left canine width, cusp tip to MS plane | LL3C - MS | mm |
| Mandibular inter-canine distance, right canine cusp to right canine cusp | LL3C - LR3C | mm |

| | | |
|---|---|---|
| Mandibular right canine long axis to MS plane | LR3LA - MSP | deg |
| Mandibular left canine long axis to MS plane | LL3LA - MSP | deg |
| Mandibular right canine vertical position to MP | LR3C - MP | mm |
| Mandibular right canine vertical position to MP | LL3C - MP | mm |
| Mandibular right 1st molar width, central fossa to MS plane | LR6CF- MS | mm |
| Mandibular right 1st molar width, central fossa to MA plane | LL6CF - MS | mm |
| Mandibular inter-molar width, from central fossa to central fossa | LL6CF - LR6CF | mm |
| Lower right 1st molar long axis to MS plane | LR6LA - MSP | deg |
| Lower left 1st molar long axis to MS plane | LL6LA - MSP | deg |
| **Inter-Maxillary facial and dental measurements** | **CODE** | **unit** |
| Sagittal distance from soft tissue a point to soft tissue b point | SA-MCP - SB-MCP | mm |
| Apical base angle, from eyes to soft tissue a and b points | SAP - SBP | deg |
| Sagittal distance from alar curvature to soft tissue pogonion | PG - ALR | mm |
| Inter-maxillary angle, from alar curvature to pupils to pogonion | ACP-STPGP | deg |
| Sagittal distance from subnasale to pogonion | SN-STPG | mm |
| Facial taper(mm) / upper face width minus lower face width | STZY - STGO | mm |
| Lower face height/total anterior face height | RATIO STU/STME | mm |
| Right overjet | UR1I - LR1I | mm |
| Left overjet | UL1I - LL1I | mm |
| Difference between upper and lower inter-canine width | DIFF U-L3C | mm |
| Difference between upper and lower inter-molar width | DIFF U-L6CF | mm |

**Table 8: Standard average values, standard deviations, and differences among Black African American groups; Age differences**

| MAXILLARY | Unit | Primary stage | | Early mixed stage | | Late mixed stage | | Permanent stage | | *p-value* | *Sig* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** | | |
| ACMC | mm | 10.24 | 2.31 | 11.47 | 2.13 | 10.64 | 1.94 | 11.68 | 3.15 | **0.233** | NS |
| ACPMCP | deg | 15.78 | 3.65 | 16.60 | 3.25 | 14.43 | 2.60 | 14.88 | 3.60 | **0.163** | NS |
| SNMC | mm | 15.87 | 2.63 | 16.52 | 2.46 | 17.14 | 2.03 | 19.75 | 3.57 | **<0.01** | S |
| SAMC | mm | 16.31 | 2.28 | 17.72 | 2.54 | 18.04 | 2.41 | 20.19 | 3.41 | **<0.01** | S |
| SAPMCP | deg | 21.47 | 2.95 | 22.05 | 3.11 | 21.10 | 2.29 | 22.02 | 3.33 | **0.747** | NS |
| ISMCP | mm | 19.64 | 2.19 | 21.38 | 3.15 | 22.00 | 2.69 | 24.86 | 3.67 | **<0.01** | S |
| SNMA | mm | 36.73 | 2.22 | 38.44 | 3.11 | 41.65 | 2.65 | 44.30 | 3.68 | **<0.01** | S |
| STUSN | mm | 17.89 | 2.17 | 19.49 | 1.59 | 20.50 | 2.04 | 21.91 | 2.97 | **<0.01** | S |
| ZYR-MS | mm | 52.40 | 3.13 | 55.85 | 2.14 | 58.22 | 4.74 | 62.04 | 3.46 | **<0.01** | S |
| ZYL-MS | mm | 54.62 | 2.48 | 57.19 | 2.84 | 60.20 | 4.79 | 62.57 | 3.68 | **<0.01** | S |
| ZY-ZY | mm | 107.02 | 5.09 | 113.04 | 4.66 | 118.43 | 9.10 | 124.61 | 5.99 | **<0.01** | S |
| UR1I-MCP | mm | 4.47 | 2.45 | 5.91 | 3.17 | 7.30 | 4.04 | 8.83 | 3.98 | **<0.01** | S |
| UR1LA-MCP | deg | 14.55 | 7.01 | 12.19 | 8.48 | 16.39 | 8.05 | 19.08 | 8.09 | **0.023** | S |
| UL1I-MCP | mm | 4.49 | 2.54 | 6.01 | 3.26 | 7.45 | 3.88 | 9.14 | 3.78 | <0.01 | S |
| UL1LA-MCP | deg | 12.92 | 6.71 | 12.61 | 9.41 | 16.68 | 6.85 | 18.63 | 8.06 | **0.029** | S |
| UR1-MA | mm | 57.23 | 2.86 | 59.87 | 3.77 | 65.61 | 3.74 | 68.89 | 5.18 | **<0.01** | S |
| UL1-MA | mm | 57.59 | 2.69 | 60.08 | 3.49 | 65.53 | 3.87 | 69.01 | 5.17 | **<0.01** | S |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UR1STSREST | mm | 2.62 | 1.71 | 1.94 | 2.43 | 3.46 | 2.20 | 2.66 | 2.32 | **0.243** | NS |
| L1STSREST | mm | 2.97 | 1.78 | 2.14 | 2.45 | 3.38 | 2.21 | 2.79 | 2.34 | **0.414** | NS |
| UR3C-MS | mm | 16.60 | 1.93 | 17.81 | 1.78 | 18.27 | 1.16 | 19.29 | 1.60 | **<0.01** | S |
| UL3C-MS | mm | 15.48 | 1.17 | 15.70 | 1.79 | 16.05 | 1.81 | 17.69 | 2.75 | **<0.01** | S |
| UR3C-UR3C | mm | 32.13 | 2.17 | 33.54 | 2.59 | 34.42 | 1.83 | 37.05 | 2.32 | **<0.01** | S |
| UR3LA-MSP | deg | 11.48 | 5.35 | 12.86 | 8.29 | 16.66 | 11.12 | 18.53 | 6.97 | **<0.01** | S |
| UL3LA-MSP | deg | 7.99 | 6.61 | 12.87 | 7.82 | 18.70 | 19.54 | 17.62 | 5.98 | **<0.01** | S |
| UR3MA | mm | 54.83 | 2.64 | 57.94 | 2.88 | 60.99 | 2.93 | 66.59 | 4.92 | **<0.01** | S |
| UL3MA | mm | 55.56 | 2.57 | 58.00 | 3.15 | 61.55 | 3.31 | 67.19 | 4.56 | **<0.01** | S |
| UR6MP - MS | mm | 18.27 | 2.44 | 21.03 | 1.93 | 21.66 | 1.45 | 21.68 | 2.47 | **<0.01** | S |
| UL6MP - MS | mm | 18.06 | 1.25 | 18.67 | 2.30 | 19.94 | 2.17 | 21.53 | 2.61 | **<0.01** | S |
| UR6MP - UL6MP | mm | 36.39 | 2.40 | 39.75 | 2.81 | 41.68 | 2.66 | 43.28 | 3.17 | **<0.01** | S |
| UR6MB-MA | mm | 49.97 | 3.23 | 51.49 | 4.03 | 55.61 | 3.40 | 61.11 | 4.75 | **<0.01** | S |
| UL6MB-MA | mm | 50.95 | 3.39 | 51.44 | 4.15 | 56.01 | 3.94 | 61.59 | 4.30 | **<0.01** | S |
| UR6LA-MSP | deg | 7.04 | 6.24 | 19.94 | 28.00 | 16.40 | 12.47 | 9.24 | 7.77 | **<0.01** | S |
| UL6LA-MSP | deg | 12.31 | 5.19 | 20.14 | 7.92 | 21.67 | 9.82 | 13.65 | 6.97 | **<0.01** | S |
| **MANDIBULAR** | **unit** | | | | | | | | | | |
| SBMC | mm | 8.74 | 2.54 | 9.35 | 2.20 | 9.18 | 3.40 | 12.61 | 3.80 | **<0.01** | S |
| SBP-MC | deg | 7.25 | 2.28 | 7.23 | 1.84 | 6.61 | 2.43 | 8.45 | 2.55 | **<0.01** | S |
| LI - MC | mm | 15.01 | 2.39 | 16.48 | 2.54 | 17.69 | 2.69 | 20.88 | 3.82 | **<0.01** | S |
| PG - MC | mm | 6.77 | 2.79 | 7.45 | 2.97 | 7.76 | 3.77 | 12.45 | 4.12 | **<0.01** | S |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SPGP - MCP | deg | 4.97 | 2.06 | 5.14 | 2.11 | 4.97 | 2.44 | 7.40 | 2.49 | **<0.01** | S |
| STME - MA | mm | 90.65 | 4.46 | 96.20 | 4.56 | 103.01 | 6.59 | 112.65 | 7.49 | **<0.01** | S |
| SN - STME | mm | 53.92 | 3.12 | 57.76 | 2.66 | 61.36 | 4.84 | 68.35 | 5.55 | **<0.01** | S |
| STME - STI | mm | 33.45 | 2.04 | 35.87 | 2.75 | 38.35 | 4.31 | 43.67 | 4.66 | **<0.01** | S |
| STGOR - MA | mm | 61.93 | 3.72 | 66.74 | 5.13 | 72.23 | 5.28 | 78.78 | 5.94 | **<0.01** | S |
| STGOL - MA | mm | 60.26 | 3.92 | 65.17 | 5.09 | 70.25 | 5.21 | 76.12 | 6.12 | **<0.01** | S |
| MP - MA | deg | 30.28 | 3.61 | 27.70 | 6.87 | 27.15 | 7.21 | 26.63 | 9.60 | **0.299** | NS |
| CHIN-MS | mm | 1.24 | 0.67 | 1.01 | 0.66 | 1.24 | 0.95 | 1.13 | 6.30 | **0.760** | NS |
| STGOR - MS | mm | 46.01 | 4.06 | 47.48 | 4.69 | 51.43 | 7.99 | 56.16 | 0.77 | **<0.01** | S |
| STGOL - MS | mm | 47.14 | 3.12 | 47.80 | 4.27 | 51.51 | 5.89 | 57.10 | 4.79 | **<0.01** | S |
| STGOL – STGOR | mm | 93.28 | 6.53 | 95.49 | 8.58 | 103.22 | 13.40 | 113.5 | 9.60 | **<0.01** | S |
| LR1I - MC | mm | 2.38 | 1.76 | 3.87 | 3.00 | 5.12 | 3.11 | 6.26 | 4.11 | **<0.01** | S |
| LL1I - MC | mm | 2.24 | 1.92 | 3.85 | 2.97 | 5.25 | 3.29 | 6.52 | 4.08 | **<0.01** | S |
| LR1LA - MCP | deg | 27.06 | 10.70 | 33.95 | 9.56 | 36.68 | 7.21 | 37.46 | 9.37 | **<0.01** | S |
| LL1LA-MCP | deg | 25.09 | 12.56 | 33.19 | 13.73 | 37.63 | 7.65 | 37.94 | 9.82 | **<0.01** | S |
| LR1LA-MP | deg | 79.07 | 6.36 | 76.33 | 12.96 | 78.64 | 6.97 | 76.22 | 7.36 | **0.601** | NS |
| LL1LA-MP | deg | 76.88 | 6.34 | 75.74 | 6.02 | 77.59 | 7.75 | 75.85 | 6.39 | **0.807** | NS |
| LR1I - MP | mm | 34.42 | 1.67 | 37.07 | 3.48 | 40.24 | 3.72 | 43.89 | 3.64 | **<0.01** | S |
| LL1I - MP | mm | 34.28 | 1.58 | 37.03 | 3.44 | 40.22 | 3.62 | 43.95 | 3.69 | **<0.01** | S |
| LR3C - MS | mm | 14.10 | 1.47 | 14.92 | 1.87 | 15.88 | 1.95 | 15.63 | 1.92 | **0.017** | S |
| LL3C - MS | mm | 13.11 | 1.06 | 13.45 | 1.96 | 14.00 | 1.50 | 14.12 | 2.51 | **0.432** | NS |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LL3C - LR3C | mm | 25.13 | 2.24 | 26.90 | 2.27 | 28.25 | 1.68 | 29.57 | 2.06 | **<0.01** | S |
| LR3LA - MSP | deg | 8.76 | 6.83 | 14.03 | 9.43 | 12.85 | 6.91 | 17.68 | 6.51 | **<0.01** | S |
| LL3LA - MSP | deg | 15.22 | 6.88 | 17.78 | 8.21 | 16.13 | 9.01 | 18.61 | 7.22 | **0.413** | NS |
| LR3C - MP | mm | 33.72 | 1.97 | 36.11 | 3.50 | 36.79 | 3.91 | 42.35 | 3.53 | **<0.01** | S |
| LL3C - MP | mm | 32.96 | 1.96 | 35.50 | 3.80 | 36.36 | 3.93 | 42.20 | 4.02 | **<0.01** | S |
| LR6CF- MS | mm | 22.72 | 2.25 | 26.74 | 2.90 | 27.48 | 1.63 | 27.82 | 2.11 | **<0.01** | S |
| LL6CF - MS | mm | 23.08 | 1.59 | 25.30 | 2.79 | 26.61 | 2.61 | 27.82 | 2.91 | **<0.01** | S |
| LL6CF - LR6CF | mm | 36.31 | 2.00 | 40.71 | 3.14 | 42.36 | 2.64 | 43.71 | 2.59 | **<0.01** | S |
| LR6LA - MSP | deg | 18.21 | 6.33 | 18.63 | 10.79 | 20.54 | 7.65 | 18.25 | 7.87 | **0.815** | NS |
| LL6LA - MSP | deg | 10.04 | 7.06 | 18.56 | 15.35 | 22.49 | 14.72 | 14.27 | 6.19 | <0.01 | S |
| **Inter-maxillary** | | | | | | | | | | | |
| SA-MCP - SB-MCP | mm | 7.57 | 2.56 | 8.38 | 2.34 | 8.86 | 3.52 | 7.74 | 2.89 | **0.486** | NS |
| SAP - SBP | deg | 14.21 | 2.62 | 14.81 | 2.36 | 14.48 | 2.96 | 13.57 | 2.68 | **0.361** | NS |
| PG - ALR | mm | 2.15 | 2.20 | 2.37 | 1.75 | 2.46 | 2.29 | 5.29 | 3.36 | **<0.01** | S |
| ACP-STPGP | deg | 10.81 | 2.99 | 11.46 | 2.80 | 9.45 | 2.86 | 7.48 | 3.25 | **<0.01** | S |
| SN-STPG | mm | 9.16 | 3.10 | 9.07 | 3.15 | 9.38 | 3.76 | 7.55 | 3.49 | **0.162** | NS |
| STZY - STGO | mm | 13.75 | 6.47 | 17.55 | 6.27 | 15.21 | 8.29 | 10.99 | 8.30 | **0.014** | S |
| RATIO STU/STME | mm | 0.33 | 0.03 | 0.34 | 0.03 | 0.33 | 0.03 | 0.32 | 0.04 | **0.252** | NS |
| UR1I - LR1I | mm | 2.64 | 0.86 | 2.67 | 1.55 | 2.72 | 1.21 | 2.61 | 1.48 | **0.994** | NS |
| UL1I - LL1I | mm | 2.77 | 1.04 | 2.69 | 1.30 | 2.65 | 0.99 | 2.65 | 1.47 | **0.989** | NS |
| DIFF U-L3C | mm | 7.00 | 1.19 | 6.65 | 2.35 | 6.17 | 2.48 | 7.48 | 1.70 | **0.118** | NS |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DIFF U-L6CF | mm | 0.07 | 0.97 | -0.97 | 1.33 | -0.69 | 1.76 | -0.44 | 1.74 | **0.252** | NS |

- *P-values were calculated using MANOVA: Multi-variate analysis of variance*
- *NS: non-significant >0.05, S: significant <0.05*

**Table 9: Standard average values, standard deviations, and differences among Hispanic American groups; age differences**

| MAXILLARY | Unit | Primary stage | | Early mixed stage | | Late mixed stage | | Permanent stage | | *p-value* | *Sig* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD | Mean | SD | *Anova-P* | |
| ACMC | mm | 11.31 | 2.02 | 11.93 | 2.67 | 11.21 | 1.87 | 11.90 | 2.32 | **0.653** | NS |
| ACPMCP | deg | 17.33 | 3.29 | 16.79 | 3.25 | 15.34 | 2.46 | 15.10 | 2.70 | **0.030** | S |
| SNMC | mm | 16.82 | 2.15 | 18.23 | 2.88 | 18.23 | 2.18 | 20.52 | 2.58 | **<0.01** | S |
| SAMC | mm | 15.74 | 2.06 | 17.24 | 2.72 | 17.36 | 2.12 | 19.27 | 2.36 | **<0.01** | S |
| SAPMCP | deg | 20.60 | 2.85 | 20.70 | 2.92 | 20.03 | 2.24 | 20.86 | 2.46 | **0.773** | NS |
| ISMCP | mm | 17.61 | 2.32 | 19.07 | 2.96 | 19.70 | 2.60 | 22.15 | 3.06 | **<0.01** | S |
| SNMA | mm | 36.02 | 2.39 | 39.09 | 2.30 | 41.29 | 2.44 | 44.23 | 3.75 | **<0.01** | S |
| STUSN | mm | 17.88 | 2.16 | 19.44 | 1.95 | 19.47 | 2.27 | 20.50 | 2.51 | **<0.01** | S |
| ZYR-MS | mm | 53.39 | 2.77 | 56.87 | 2.86 | 57.12 | 4.27 | 61.32 | 3.90 | **<0.01** | S |
| ZYL-MS | mm | 52.07 | 2.16 | 56.34 | 2.62 | 58.38 | 5.18 | 61.90 | 4.07 | **<0.01** | S |
| ZY-ZY | mm | 105.46 | 4.28 | 113.21 | 3.83 | 115.50 | 8.82 | 123.22 | 7.30 | **<0.01** | S |
| UR1I-MCP | mm | 4.25 | 2.70 | 10.77 | 17.93 | 5.21 | 2.64 | 6.59 | 2.70 | **0.093** | NS |
| UR1LA-MCP | deg | 9.23 | 6.75 | 13.92 | 8.70 | 11.10 | 6.79 | 12.40 | 8.82 | **0.321** | NS |
| UR1I-MCP | mm | 4.41 | 2.68 | 11.12 | 17.80 | 5.59 | 2.87 | 6.70 | 2.86 | **0.083** | NS |
| UR1I-MCP | deg | 9.80 | 5.84 | 14.14 | 8.80 | 11.37 | 6.43 | 12.73 | 9.40 | **0.395** | NS |
| UR1-MA | mm | 55.79 | 3.04 | 55.05 | 13.70 | 63.17 | 2.88 | 67.06 | 3.61 | **<0.01** | S |
| UL1-MA | mm | 55.88 | 3.05 | 55.31 | 13.69 | 63.40 | 2.79 | 67.14 | 3.64 | **<0.01** | S |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UR1STSREST | mm | 1.89 | 2.12 | -3.48 | 13.78 | 2.42 | 1.71 | 2.33 | 1.65 | **<0.01** | S |
| L1STSREST | mm | 1.97 | 1.99 | -3.23 | 13.70 | 2.65 | 1.57 | 2.41 | 1.68 | **0.010** | S |
| UR3C-MS | mm | 15.96 | 1.96 | 17.41 | 2.73 | 17.20 | 1.87 | 18.80 | 1.57 | **<0.01** | S |
| UL3C-MS | mm | 13.86 | 1.65 | 15.35 | 2.44 | 17.13 | 1.66 | 17.39 | 1.78 | **<0.01** | S |
| UR3C-UR3C | mm | 29.86 | 1.93 | 32.85 | 2.70 | 34.49 | 2.55 | 36.27 | 2.07 | **<0.01** | S |
| UR3LA-MSP | deg | 8.27 | 5.13 | 14.07 | 8.17 | 13.57 | 8.34 | 16.58 | 5.14 | **<0.01** | S |
| UL3LA-MSP | deg | 6.53 | 4.89 | 13.40 | 8.62 | 13.77 | 8.80 | 14.95 | 6.10 | **<0.01** | S |
| UR3MA | mm | 53.97 | 2.75 | 53.23 | 13.18 | 59.10 | 2.99 | 64.53 | 3.48 | **<0.01** | S |
| UL3MA | mm | 54.24 | 2.66 | 53.97 | 13.23 | 60.00 | 3.11 | 64.97 | 3.32 | **<0.01** | S |
| UR6MP - MS | mm | 18.38 | 2.02 | 20.33 | 2.61 | 20.81 | 2.38 | 21.25 | 2.51 | **<0.01** | S |
| UL6MP - MS | mm | 16.72 | 2.20 | 19.76 | 2.59 | 20.91 | 2.14 | 20.55 | 2.45 | **<0.01** | S |
| UR6MP - UL6MP | mm | 35.15 | 2.30 | 40.22 | 3.21 | 41.77 | 3.43 | 41.89 | 2.85 | **<0.01** | S |
| UR6MB-MA | mm | 50.56 | 2.46 | 47.35 | 11.97 | 54.20 | 3.18 | 58.66 | 3.53 | **<0.01** | S |
| UL6MB-MA | mm | 50.76 | 2.64 | 47.92 | 12.47 | 54.88 | 3.47 | 59.19 | 3.84 | **<0.01** | S |
| UR6LA-MSP | deg | 7.38 | 4.35 | 20.02 | 7.23 | 12.94 | 8.99 | 8.63 | 5.59 | **<0.01** | S |
| UL6LA-MSP | deg | 9.38 | 6.56 | 22.11 | 15.33 | 18.76 | 10.02 | 12.53 | 5.21 | **<0.01** | S |
| **MANDIBULAR** | **unit** | | | | | | | | | | |
| SBMC | mm | 6.79 | 2.68 | 7.97 | 3.20 | 8.06 | 1.85 | 10.03 | 2.94 | <0.01 | S |
| SBP-MC | deg | 5.85 | 2.56 | 6.25 | 2.57 | 6.08 | 1.49 | 7.09 | 2.16 | **0.198** | NS |
| LI - MC | mm | 12.32 | 1.95 | 14.06 | 3.16 | 14.82 | 2.06 | 16.92 | 2.95 | **<0.01** | S |
| PG - MC | mm | 5.80 | 2.97 | 6.85 | 3.58 | 7.57 | 3.61 | 10.72 | 4.38 | **<0.01** | S |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SPGP - MCP | deg | 4.47 | 2.30 | 4.74 | 2.36 | 4.92 | 2.23 | 6.61 | 2.72 | **<0.01** | S |
| STME - MA | mm | 88.76 | 4.07 | 96.58 | 3.35 | 100.83 | 5.31 | 108.37 | 5.80 | **<0.01** | S |
| SN - STME | mm | 52.74 | 3.01 | 57.49 | 3.08 | 59.54 | 4.76 | 64.14 | 4.80 | **<0.01** | S |
| STME - STI | mm | 32.61 | 1.90 | 35.93 | 2.27 | 37.88 | 4.05 | 41.66 | 3.64 | **<0.01** | S |
| STGOR - MA | mm | 62.88 | 4.64 | 69.20 | 4.59 | 70.57 | 5.13 | 75.54 | 5.60 | **<0.01** | S |
| STGOL - MA | mm | 60.95 | 4.12 | 73.45 | 21.37 | 69.84 | 5.27 | 74.72 | 5.54 | **<0.01** | S |
| MP - MA | deg | 28.96 | 3.72 | 26.60 | 7.06 | 28.22 | 7.77 | 26.51 | 4.96 | **0.420** | NS |
| CHIN-MS | mm | 1.28 | 0.68 | 1.50 | 0.79 | 0.60 | 0.48 | 1.32 | 0.87 | **<0.01** | S |
| STGOR - MS | mm | 48.10 | 3.71 | 50.54 | 4.91 | 52.03 | 6.74 | 58.00 | 5.63 | **<0.01** | S |
| STGOL - MS | mm | 48.72 | 2.89 | 50.70 | 5.51 | 52.37 | 7.04 | 57.63 | 5.51 | **<0.01** | S |
| STGOL – STGOR | mm | 97.02 | 5.93 | 103.51 | 9.52 | 104.63 | 13.44 | 115.89 | 10.31 | **<0.01** | S |
| LR1I - MC | mm | 3.01 | 2.19 | 5.93 | 8.19 | 3.05 | 2.12 | 4.62 | 2.80 | **0.119** | NS |
| LL1I - MC | mm | 3.12 | 2.09 | 5.97 | 8.19 | 3.32 | 2.41 | 4.76 | 2.84 | **0.156** | NS |
| LR1LA - MCP | deg | 25.09 | 10.32 | 27.68 | 11.04 | 33.61 | 8.88 | 36.89 | 9.94 | **<0.01** | S |
| LL1LA-MCP | deg | 24.56 | 9.98 | 28.29 | 12.22 | 35.03 | 9.64 | 36.99 | 9.49 | **<0.01** | S |
| LR1LA-MP | deg | 79.00 | 8.37 | 74.14 | 15.66 | 78.86 | 3.89 | 76.88 | 7.51 | **0.353** | NS |
| LL1LA-MP | deg | 79.69 | 8.25 | 76.38 | 13.52 | 78.87 | 7.12 | 77.01 | 7.48 | **0.613** | NS |
| LR1I - MP | mm | 34.30 | 2.67 | 36.79 | 5.46 | 39.28 | 3.65 | 42.30 | 3.26 | **<0.01** | S |
| LL1I - MP | mm | 34.36 | 2.60 | 37.14 | 4.84 | 39.33 | 3.75 | 42.36 | 3.27 | **<0.01** | S |
| LR3C - MS | mm | 14.57 | 1.72 | 16.13 | 2.34 | 15.69 | 1.73 | 16.01 | 1.77 | **0.041** | S |
| LL3C - MS | mm | 11.70 | 1.73 | 13.11 | 2.65 | 13.97 | 2.13 | 13.45 | 1.77 | **<0.01** | S |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LL3C - LR3C | mm | 24.05 | 1.64 | 27.19 | 2.07 | 27.79 | 2.12 | 28.77 | 1.95 | **<0.01** | S |
| LR3LA - MSP | deg | 9.30 | 6.53 | 13.04 | 11.36 | 10.87 | 5.96 | 13.29 | 6.70 | **0.256** | NS |
| LL3LA - MSP | deg | 13.39 | 5.59 | 17.16 | 8.22 | 12.81 | 8.72 | 17.59 | 6.53 | **0.048** | S |
| LR3C - MP | mm | 33.33 | 2.89 | 34.65 | 6.17 | 36.61 | 2.85 | 40.91 | 3.46 | **<0.01** | S |
| LL3C - MP | mm | 33.20 | 2.72 | 36.03 | 3.64 | 36.73 | 3.60 | 40.87 | 3.77 | **<0.01** | S |
| LR6CF- MS | mm | 23.65 | 1.65 | 27.44 | 2.66 | 27.36 | 2.15 | 27.73 | 2.38 | **<0.01** | S |
| LL6CF - MS | mm | 21.57 | 2.12 | 26.55 | 2.76 | 27.14 | 2.65 | 26.64 | 2.26 | **<0.01** | S |
| LL6CF - LR6CF | mm | 35.62 | 2.02 | 41.77 | 2.54 | 42.48 | 3.09 | 42.25 | 2.62 | **<0.01** | S |
| LR6LA - MSP | deg | 19.63 | 8.25 | 29.51 | 13.64 | 27.70 | 12.82 | 20.34 | 7.26 | **<0.01** | S |
| LL6LA - MSP | deg | 12.13 | 7.96 | 25.81 | 11.30 | 19.42 | 7.62 | 15.86 | 5.88 | **<0.01** | S |
| **Inter-maxillary** | | | | | | | | | | | |
| SA-MCP - SB-MCP | mm | 8.96 | 2.67 | 9.27 | 2.66 | 9.30 | 2.35 | 9.23 | 2.85 | **0.979** | NS |
| SAP - SBP | deg | 14.74 | 2.22 | 14.45 | 2.35 | 13.95 | 2.06 | 13.77 | 2.20 | **0.400** | NS |
| PG - ALR | mm | 3.22 | 2.67 | 2.99 | 2.69 | 3.39 | 3.07 | 3.84 | 3.01 | **0.749** | NS |
| ACP-STPGP | deg | 12.86 | 2.91 | 12.05 | 3.01 | 10.42 | 3.83 | 8.50 | 2.69 | <0.01 | S |
| SN-STPG | mm | 11.08 | 3.14 | 11.39 | 3.56 | 10.66 | 3.68 | 9.80 | 3.82 | **0.387** | NS |
| STZY - STGO | mm | 8.44 | 5.24 | 9.70 | 10.55 | 10.87 | 7.54 | 7.33 | 7.30 | **0.453** | NS |
| RATIO STU/STME | mm | 0.34 | 0.03 | 0.34 | 0.02 | 0.33 | 0.04 | 0.32 | 0.03 | **0.063** | NS |
| UR1I - LR1I | mm | 2.27 | 0.90 | 2.46 | 1.09 | 2.49 | 1.26 | 2.21 | 0.98 | **0.735** | NS |
| UL1I - LL1I | mm | 2.33 | 0.87 | 2.63 | 1.00 | 2.49 | 1.34 | 2.20 | 1.10 | **0.511** | NS |
| DIFF U-L3C | mm | 5.81 | 1.49 | 5.66 | 1.81 | 6.39 | 1.68 | 7.50 | 1.56 | **<0.01** | S |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DIFF U-L6CF | mm | -0.47 | 1.21 | -1.56 | 2.12 | -0.72 | 0.96 | -0.36 | 1.93 | **0.113** | NS |

- *P-values were calculated using MANOVA: Multi-variate analysis of variance*
- *NS: non-significant >0.05, S: significant <0.05*

**Table 10: Standard average values, standard deviations, and differences across race/ethnicitys in the permanent dentition stage: gender differences**

| **Maxillary** | **UNIT** | White non-Hispanic | | | | ***p-value*** | African American | | | | ***p-value*** | Hispanic American | | | | ***p-value*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M/Mean | SD | F/Mean | SD | | M/Mean | SD | F/Mean | SD | | M/Mean | SD | F/Mean | SD | |
| **ACMC** | mm | 13.40 | 4.42 | 10.38 | 4.35 | **0.05** | 12.58 | 3.46 | 10.78 | 2.83 | **0.081** | 13.18 | 2.64 | 10.61 | 2.00 | **<0.01*** |
| **ACPMCP** | deg | 16.44 | 5.16 | 13.59 | 5.72 | **0.14** | 15.77 | 4.19 | 13.99 | 3.02 | **0.133** | 16.47 | 2.95 | 13.74 | 2.45 | **<0.01*** |
| **SNMC** | mm | 24.05 | 4.86 | 19.49 | 5.24 | **0.015*** | 20.89 | 4.05 | 18.61 | 3.09 | **0.054** | 21.77 | 2.94 | 19.27 | 2.22 | **<0.01*** |
| **SAMC** | mm | 21.52 | 4.64 | 16.08 | 4.72 | **<0.01*** | 21.57 | 3.59 | 18.81 | 3.24 | **0.015*** | 21.01 | 2.70 | 17.52 | 2.01 | **<0.01*** |
| **SAPMCP** | deg | 22.31 | 4.76 | 17.43 | 5.38 | **<0.01*** | 23.13 | 4.19 | 20.92 | 2.48 | **0.054** | 22.32 | 2.44 | 19.41 | 2.49 | **<0.01*** |
| **ISMCP** | mm | 23.37 | 5.52 | 17.61 | 5.48 | **<0.01*** | 26.50 | 3.78 | 23.22 | 3.56 | **<0.01*** | 23.91 | 3.30 | 20.39 | 2.83 | **<0.01*** |
| **SNMA** | mm | 45.69 | 4.02 | 44.82 | 3.04 | **0.487** | 45.33 | 4.65 | 43.28 | 2.71 | **0.101** | 44.77 | 4.47 | 43.68 | 3.02 | **0.381** |
| **STUSN** | mm | 21.67 | 2.70 | 18.59 | 2.12 | **<0.01*** | 21.90 | 3.18 | 21.93 | 2.76 | **0.978** | 20.84 | 2.56 | 20.16 | 2.45 | **0.398** |
| **ZYR-MS** | mm | 64.29 | 4.39 | 61.82 | 3.30 | **0.076** | 62.74 | 3.62 | 61.35 | 3.31 | **0.210** | 61.09 | 3.32 | 61.55 | 4.48 | **0.717** |
| **ZYL-MS** | mm | 65.94 | 3.91 | 63.73 | 2.21 | **0.055** | 63.52 | 4.23 | 61.61 | 3.13 | **0.114** | 60.82 | 3.31 | 62.98 | 4.83 | **0.111** |
| **ZY-ZY** | mm | 130.23 | 7.09 | 125.55 | 5.09 | **0.037*** | 126.26 | 6.78 | 122.96 | 5.21 | **0.093** | 121.91 | 6.03 | 124.53 | 8.57 | **0.276** |
| **UR1I-MCP** | mm | 11.90 | 9.75 | 9.89 | 15.97 | **0.669** | 9.82 | 4.64 | 7.84 | 3.31 | **0.129** | 8.11 | 2.32 | 5.06 | 3.09 | **<0.01*** |
| **UR1LA-MCP** | deg | 16.59 | 10.80 | 13.27 | 8.25 | **0.327** | 21.70 | 8.42 | 16.45 | 7.76 | **0.046*** | 12.38 | 8.89 | 12.41 | 8.75 | **0.990** |
| **UR1I-MCP** | mm | 11.92 | 9.68 | 7.14 | 5.55 | **0.092** | 10.22 | 4.40 | 8.07 | 3.15 | **0.085** | 8.31 | 2.41 | 5.08 | 3.31 | **<0.01*** |
| **UL1LA-MCP** | deg | 16.65 | 10.64 | 12.51 | 8.39 | **0.224** | 21.65 | 8.62 | 15.61 | 7.50 | **0.023*** | 12.47 | 8.66 | 12.98 | 10.14 | **0.867** |
| **UR1-MA** | mm | 69.57 | 4.39 | 66.09 | 3.16 | **0.014*** | 69.53 | 6.47 | 68.24 | 3.90 | **0.451** | 67.51 | 4.95 | 66.61 | 2.26 | **0.476** |
| **UL1-MA** | mm | 69.58 | 4.44 | 66.13 | 3.12 | **0.015*** | 69.60 | 6.57 | 68.42 | 3.76 | **0.495** | 67.66 | 5.14 | 66.61 | 2.13 | **0.418** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UR1STSREST | mm | 2.22 | 2.20 | 2.69 | 1.72 | 0.496 | 2.30 | 1.83 | 3.03 | 2.80 | 0.326 | 1.89 | 1.64 | 2.77 | 1.65 | 0.106 |
| L1STSREST | mm | 2.22 | 2.26 | 2.73 | 1.79 | 0.478 | 2.36 | 1.86 | 3.21 | 2.82 | 0.495 | 2.04 | 1.79 | 2.77 | 1.57 | 0.188 |
| UR3C-MS | mm | 18.12 | 1.42 | 17.68 | 1.70 | 0.427 | 19.65 | 1.50 | 18.93 | 1.70 | 0.160 | 18.81 | 1.43 | 18.78 | 1.71 | 0.957 |
| UL3C-MS | mm | 17.58 | 1.43 | 16.41 | 1.38 | 0.023* | 18.65 | 2.79 | 16.73 | 2.72 | 0.032* | 17.93 | 1.87 | 16.86 | 1.70 | 0.069 |
| UR3C-UR3C | mm | 35.75 | 1.63 | 34.15 | 1.86 | 0.014* | 38.37 | 2.40 | 35.73 | 2.24 | <0.01* | 36.80 | 2.20 | 35.73 | 1.93 | 0.115 |
| UR3LA-MSP | deg | 14.30 | 4.52 | 16.61 | 5.50 | 0.199 | 18.49 | 6.76 | 18.57 | 7.18 | 0.968 | 15.11 | 5.55 | 18.05 | 4.74 | 0.084 |
| UL3LA-MSP | deg | 14.15 | 7.75 | 12.73 | 5.05 | 0.536 | 18.10 | 5.01 | 17.13 | 6.96 | 0.606 | 13.08 | 8.14 | 16.81 | 4.06 | 0.084 |
| UR3MA | mm | 68.00 | 4.25 | 63.63 | 3.50 | <0.01* | 67.55 | 6.24 | 65.62 | 3.60 | 0.245 | 65.07 | 4.63 | 64.00 | 2.34 | 0.378 |
| UL3MA | mm | 68.24 | 4.31 | 63.83 | 3.28 | <0.01* | 67.93 | 6.20 | 66.45 | 2.91 | 0.348 | 65.67 | 4.70 | 64.28 | 1.93 | 0.242 |
| UR6MP - MS | mm | 21.25 | 1.61 | 19.67 | 2.08 | 0.021* | 22.24 | 2.39 | 21.12 | 2.55 | 0.154 | 21.15 | 2.17 | 21.34 | 2.85 | 0.818 |
| UL6MP - MS | mm | 21.03 | 1.99 | 19.67 | 1.40 | 0.031* | 22.99 | 2.29 | 20.06 | 2.92 | <0.01* | 21.65 | 2.32 | 19.45 | 2.57 | <0.01* |
| UR6MP - | mm | 42.32 | 2.37 | 39.40 | 1.84 | <0.01* | 45.33 | 2.81 | 41.23 | 3.54 | | 42.88 | 2.61 | 40.90 | 3.09 | |
| UL6MP | | | | | | | | | | | <0.01* | | | | | 0.037* |
| UR6MB-MA | mm | 63.54 | 4.95 | 57.70 | 4.94 | <0.01* | 62.58 | 6.02 | 59.65 | 3.47 | 0.072 | 59.06 | 3.45 | 58.25 | 3.61 | 0.477 |
| UL6MB-MA | mm | 63.91 | 5.40 | 57.71 | 4.85 | <0.01* | 63.03 | 5.46 | 60.16 | 3.13 | 0.053 | 59.68 | 3.58 | 58.71 | 4.10 | 0.434 |
| UR6LA-MSP | deg | 8.18 | 7.12 | 8.59 | 6.22 | 0.864 | 7.69 | 7.48 | 10.80 | 8.06 | 0.208 | 10.28 | 5.62 | 6.98 | 5.56 | 0.073 |
| UL6LA-MSP | deg | 11.83 | 6.59 | 14.62 | 8.10 | 0.288 | 13.02 | 5.45 | 14.28 | 8.50 | 0.570 | 14.18 | 4.07 | 10.88 | 6.34 | 0.061 |
| **Mandibular** | **unit** | | | | | | | | | | | | | | | |
| SBMC | mm | 13.08 | 7.50 | 8.95 | 5.71 | 0.084 | 14.75 | 4.83 | 10.47 | 2.77 | <0.01* | 11.35 | 2.78 | 8.72 | 3.09 | <0.01* |
| SBP-MC | deg | 8.79 | 5.07 | 6.52 | 4.19 | 0.171 | 9.80 | 3.33 | 7.09 | 1.77 | <0.01* | 7.99 | 2.07 | 6.20 | 2.25 | 0.014* |
| LI - MC | mm | 19.54 | 6.55 | 13.96 | 6.05 | 0.016* | 23.37 | 4.26 | 18.38 | 3.38 | <0.01* | 18.21 | 2.71 | 15.62 | 3.18 | <0.01* |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PG - MC** | mm | 15.35 | 10.20 | 11.35 | 6.61 | **0.190** | 14.37 | 5.40 | 10.53 | 2.83 | **<0.01*** | 12.17 | 4.54 | 9.26 | 4.22 | **0.046*** |
| **SPGP - MCP** | deg | 8.66 | 5.63 | 7.13 | 4.20 | **0.380** | 8.45 | 3.32 | 6.34 | 1.66 | **0.019*** | 7.44 | 2.82 | 5.78 | 2.61 | **0.064** |
| **STME - MA** | mm | 115.75 | 6.36 | 106.30 | 5.52 | **<0.01*** | 114.41 | 9.54 | 110.89 | 5.43 | **0.166** | 109.45 | 7.35 | 107.29 | 4.26 | **0.274** |
| **SN - STME** | mm | 70.06 | 6.81 | 61.48 | 5.10 | **<0.01*** | 69.08 | 6.42 | 67.62 | 4.67 | **0.416** | 64.67 | 5.23 | 63.60 | 4.38 | **0.494** |
| **STME - STI** | mm | 46.09 | 4.88 | 40.93 | 4.25 | **<0.01*** | 44.56 | 4.70 | 42.79 | 4.61 | **0.232** | 41.91 | 4.01 | 41.40 | 3.28 | **0.664** |
| **STGOR - MA** | mm | 80.30 | 7.50 | 72.47 | 6.06 | **<0.01*** | 82.59 | 5.95 | 74.97 | 5.92 | **<0.01*** | 76.10 | 6.94 | 74.98 | 4.26 | **0.552** |
| **STGOL - MA** | mm | 77.87 | 7.97 | 69.81 | 7.28 | **<0.01*** | 79.33 | 6.50 | 72.92 | 5.74 | **<0.01*** | 74.62 | 7.38 | 74.83 | 3.70 | **0.910** |
| **MP - MA** | deg | 27.38 | 8.01 | 29.60 | 6.07 | **0.375** | 25.09 | 6.09 | 28.17 | 6.50 | **0.126** | 26.20 | 5.92 | 26.81 | 4.00 | **0.712** |
| **CHIN-MS** | mm | 1.91 | 1.40 | 1.71 | 1.27 | **0.673** | 1.20 | 0.80 | 1.07 | 0.74 | **0.589** | 1.37 | 1.11 | 1.26 | 0.63 | **0.723** |
| **STGOR - MS** | mm | 60.04 | 6.98 | 55.57 | 3.85 | **0.030*** | 56.25 | 4.72 | 56.06 | 4.86 | **0.896** | 58.52 | 5.59 | 57.47 | 5.66 | **0.562** |
| **STGOL - MS** | mm | 61.51 | 5.26 | 56.07 | 2.31 | **<0.01*** | 58.35 | 5.87 | 55.84 | 5.34 | **0.162** | 59.22 | 6.26 | 56.03 | 4.76 | **0.083** |
| **STGOL – STGOR** | mm | 121.85 | 11.71 | 111.89 | 5.54 | **<0.01*** | 114.97 | 9.59 | 112.25 | 9.60 | **0.371** | 117.95 | 11.00 | 113.83 | 9.62 | **0.222** |
| **LR1I - MC** | mm | 10.78 | 8.89 | 5.71 | 5.51 | **0.057** | 7.34 | 4.65 | 5.17 | 3.57 | **0.108** | 5.87 | 2.78 | 3.38 | 2.82 | **<0.01*** |
| **LL1I - MC** | mm | 10.70 | 8.84 | 5.70 | 5.53 | **0.060** | 7.61 | 4.60 | 5.42 | 3.56 | **0.101** | 6.06 | 2.80 | 3.46 | 2.88 | **<0.01*** |
| **LR1LA - MCP** | deg | 30.16 | 16.04 | 35.59 | 9.12 | **0.239** | 36.23 | 11.55 | 38.68 | 7.20 | **0.432** | 34.85 | 9.48 | 38.92 | 10.40 | **0.209** |
| **LL1LA-MCP** | deg | 30.03 | 15.81 | 36.34 | 9.40 | **0.172** | 36.58 | 11.83 | 39.29 | 7.80 | **0.401** | 34.78 | 9.39 | 39.19 | 9.59 | **0.155** |
| **LR1LA-MP** | deg | 80.40 | 10.88 | 80.19 | 9.24 | **0.952** | 74.81 | 8.16 | 77.62 | 6.56 | **0.238** | 78.48 | 7.71 | 75.28 | 7.31 | **0.192** |
| **LL1LA-MP** | deg | 76.53 | 5.10 | 79.67 | 9.96 | **0.271** | 73.63 | 6.78 | 78.08 | 6.01 | **0.034*** | 78.72 | 7.13 | 75.31 | 7.83 | **0.164** |
| **LR1I - MP** | mm | 31.65 | 18.55 | 37.14 | 9.44 | **0.291** | 45.48 | 3.78 | 42.31 | 3.51 | **<0.01*** | 43.07 | 3.68 | 41.53 | 2.83 | **0.156** |
| **LL1I - MP** | mm | 31.59 | 18.47 | 37.20 | 9.49 | **0.279** | 45.50 | 3.80 | 42.39 | 3.59 | **0.011*** | 43.17 | 3.70 | 41.56 | 2.84 | **0.137** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LR3C - MS** | mm | 15.24 | 1.22 | 14.86 | 1.77 | **0.481** | 15.55 | 1.81 | 15.71 | 2.04 | **0.791** | 16.15 | 1.57 | 15.88 | 1.97 | **0.634** |
| **LL3C - MS** | mm | 15.13 | 1.02 | 14.05 | 1.75 | **0.043*** | 15.18 | 2.20 | 13.07 | 2.81 | **0.011*** | 14.00 | 1.98 | 12.90 | 1.56 | **0.062** |
| **LL3C - LR3C** | mm | 27.82 | 1.41 | 26.58 | 1.45 | **0.019*** | 30.55 | 2.19 | 28.60 | 1.94 | <0.01* | 28.83 | 1.74 | 28.71 | 2.16 | **0.851** |
| **LR3LA - MSP** | deg | 9.09 | 3.91 | 10.31 | 6.59 | **0.525** | 18.22 | 8.79 | 17.14 | 4.23 | **0.631** | 12.80 | 6.98 | 13.79 | 6.42 | **0.647** |
| **LL3LA - MSP** | deg | 9.16 | 8.36 | 7.93 | 4.79 | **0.606** | 17.73 | 9.00 | 19.50 | 5.44 | **0.462** | 15.16 | 6.53 | 20.02 | 6.54 | **0.026*** |
| **LR3C - MP** | mm | 30.74 | 18.15 | 35.99 | 9.18 | **0.301** | 44.09 | 3.60 | 40.61 | 3.46 | <0.01* | 41.63 | 4.02 | 40.20 | 2.90 | **0.213** |
| **LL3C - MP** | mm | 30.71 | 17.77 | 36.02 | 9.28 | **0.289** | 43.60 | 4.21 | 40.81 | 3.84 | **0.034*** | 41.53 | 4.52 | 40.21 | 3.01 | **0.293** |
| **LR6CF- MS** | mm | 27.67 | 1.59 | 26.66 | 2.15 | **0.137** | 28.04 | 2.13 | 27.61 | 2.09 | **0.519** | 27.67 | 2.02 | 27.79 | 2.75 | **0.871** |
| **LL6CF - MS** | mm | 27.44 | 1.73 | 26.19 | 1.66 | **0.043*** | 29.22 | 2.70 | 26.42 | 3.11 | <0.01* | 27.48 | 2.03 | 25.80 | 2.48 | **0.026*** |
| **LL6CF - LR6CF** | mm | 43.11 | 2.38 | 40.66 | 1.79 | <0.01* | 45.36 | 2.67 | 42.06 | 2.51 | <0.01* | 42.87 | 2.50 | 41.64 | 2.74 | **0.152** |
| **LR6LA - MSP** | deg | 15.66 | 6.89 | 23.18 | 7.19 | <0.01* | 16.09 | 7.04 | 20.40 | 8.71 | **0.088** | 20.36 | 9.14 | 20.32 | 5.38 | **0.987** |
| **LL6LA - MSP** | deg | 18.53 | 8.41 | 21.99 | 7.58 | **0.224** | 10.84 | 5.30 | 17.71 | 7.07 | <0.01* | 17.62 | 5.55 | 14.10 | 6.21 | **0.070** |
| **INTER-MAXILLARY** | | | | | | | | | | | | | | | | |
| **SA-MCP - SB-MCP** | mm | 8.44 | 3.79 | 7.98 | 3.23 | **0.713** | 7.13 | 3.66 | 8.34 | 2.11 | **0.215** | 9.66 | 3.41 | 8.80 | 2.28 | **0.362** |
| **SAP - SBP** | deg | 13.52 | 1.75 | 11.49 | 2.34 | <0.01* | 13.32 | 3.60 | 13.82 | 1.75 | **0.582** | 14.33 | 2.67 | 13.20 | 1.72 | **0.131** |
| **PG - ALR** | mm | 7.11 | 5.59 | 5.02 | 3.09 | **0.193** | 6.95 | 4.74 | 3.63 | 1.99 | <0.01* | 4.53 | 3.40 | 3.15 | 2.62 | **0.166** |
| **ACP-STPGP** | deg | 7.78 | 2.86 | 6.47 | 2.89 | **0.201** | 7.32 | 3.67 | 7.65 | 2.83 | **0.754** | 9.03 | 3.34 | 7.96 | 2.05 | **0.240** |
| **SN-STPG** | mm | 9.61 | 5.23 | 9.81 | 5.31 | **0.917** | 7.03 | 3.96 | 8.08 | 3.01 | **0.354** | 9.60 | 4.40 | 10.00 | 3.24 | **0.746** |
| **STZY - STGO** | mm | 8.38 | 7.90 | 13.66 | 3.22 | **0.019*** | 11.28 | 9.25 | 10.71 | 7.36 | **0.828** | 3.96 | 8.64 | 10.70 | 5.96 | <0.01* |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **RATIO** | mm | 0.31 | 0.02 | 0.30 | 0.03 | **0.493** | 0.32 | 0.03 | 0.33 | 0.04 | | 0.32 | 0.03 | 0.32 | 0.03 | |
| **STU/STME** | | | | | | | | | | | **0.450** | | | | | **0.543** |
| **UR1I - LR1I** | mm | 1.95 | 0.61 | 2.01 | 1.04 | **0.831** | 2.53 | 1.39 | 2.70 | 1.57 | **0.704** | 2.24 | 1.00 | 2.19 | 0.96 | **0.862** |
| **UL1I - LL1I** | mm | 2.05 | 0.65 | 1.97 | 1.03 | **0.781** | 2.61 | 1.41 | 2.68 | 1.52 | **0.877** | 2.26 | 1.11 | 2.14 | 1.10 | **0.743** |
| **DIFF U-L3C** | mm | 7.93 | 0.93 | 7.57 | 1.07 | **0.306** | 7.82 | 2.09 | 7.13 | 1.31 | **0.224** | 7.98 | 2.11 | 7.02 | 1.00 | **0.085** |
| **DIFF U-L6CF** | mm | -0.80 | 1.48 | -1.27 | 1.55 | **0.377** | -0.03 | 1.86 | -0.84 | 1.62 | **0.153** | 0.01 | 1.25 | -0.74 | 2.62 | **0.258** |

*- M: Male, F: Female*
*- P-values were calculated using the Hotelling’s t-squared statistic; a generalization of Student’s t-statistic that is used in multivariate hypothesis testing*
*- * and ** indicate Sig p-values (*<0.05) (*<0.01)*

**Table 11: Standard average values, standard deviations, and differences between females in the permanent dentition stage: comparing racial backgrounds**

| Maxillary | UNIT | White non-Hispanic | | African American | | Hispanic American | | *p-value* | SIG |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD | | S / NS |
| **ACMC** | mm | 10.38 | 4.35 | 10.78 | 2.83 | 10.61 | 2.00 | **0.878** | **NS** |
| **ACPMCP** | deg | 13.59 | 5.72 | 13.99 | 3.02 | 13.74 | 2.45 | **0.948** | **NS** |
| **SNMC** | mm | 19.49 | 5.24 | 18.61 | 3.09 | 19.27 | 2.22 | **0.729** | **NS** |
| **SAMC** | mm | 16.08 | 4.72 | 18.81 | 3.24 | 17.52 | 2.01 | **0.056** | **NS** |
| **SAPMCP** | deg | 17.43 | 5.38 | 20.92 | 2.48 | 19.41 | 2.49 | **0.015** | **S** |
| **ISMCP** | mm | 17.61 | 5.48 | 23.22 | 3.56 | 20.39 | 2.83 | **<0.011** | **S** |
| **SNMA** | mm | 44.82 | 3.04 | 43.28 | 2.71 | 43.68 | 3.02 | **0.270** | **NS** |
| **STUSN** | mm | 18.59 | 2.12 | 21.93 | 2.76 | 20.16 | 2.45 | **0.001** | **S** |
| **ZYR-MS** | mm | 61.82 | 3.30 | 61.35 | 3.31 | 61.55 | 4.48 | **0.931** | **NS** |
| **ZYL-MS** | mm | 63.73 | 2.21 | 61.61 | 3.13 | 62.98 | 4.83 | **0.192** | **NS** |
| **ZY-ZY** | mm | 125.55 | 5.09 | 122.96 | 5.21 | 124.53 | 8.57 | **0.472** | **NS** |
| **UR1I-MCP** | mm | 9.89 | 15.97 | 7.84 | 3.31 | 5.06 | 3.09 | **0.260** | **NS** |
| **UR1LA-MCP** | deg | 13.27 | 8.25 | 16.45 | 7.76 | 12.41 | 8.75 | **0.257** | **NS** |
| **UR1I-MCP** | mm | 7.14 | 5.55 | 8.07 | 3.15 | 5.08 | 3.31 | **0.058** | **NS** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **UL1LA-MCP** | deg | 12.51 | 8.39 | 15.61 | 7.50 | 12.98 | 10.14 | **0.484** | **NS** |
| **UR1-MA** | mm | 66.09 | 3.16 | 68.24 | 3.90 | 66.61 | 2.26 | **0.100** | **NS** |
| **UL1-MA** | mm | 66.13 | 3.12 | 68.42 | 3.76 | 66.61 | 2.13 | **0.058** | **NS** |
| **UR1STSREST** | mm | 2.69 | 1.72 | 3.03 | 2.80 | 2.77 | 1.65 | **0.877** | **NS** |
| **L1STSREST** | mm | 2.73 | 1.79 | 3.21 | 2.82 | 2.77 | 1.57 | **0.736** | **NS** |
| **UR3C-MS** | mm | 17.68 | 1.70 | 18.93 | 1.70 | 18.78 | 1.71 | **0.068** | **NS** |
| **UL3C-MS** | mm | 16.41 | 1.38 | 16.73 | 2.72 | 16.86 | 1.70 | **0.812** | **NS** |
| **UR3C-UR3C** | mm | 34.15 | 1.86 | 35.73 | 2.24 | 35.73 | 1.93 | **0.037** | **S** |
| **UR3LA-MSP** | deg | 16.61 | 5.50 | 18.57 | 7.18 | 18.05 | 4.74 | **0.600** | **NS** |
| **UL3LA-MSP** | deg | 12.73 | 5.05 | 17.13 | 6.96 | 16.81 | 4.06 | **0.041** | **S** |
| **UR3MA** | mm | 63.63 | 3.50 | 65.62 | 3.60 | 64.00 | 2.34 | **0.120** | **NS** |
| **UL3MA** | mm | 63.83 | 3.28 | 66.45 | 2.91 | 64.28 | 1.93 | **<0.01** | **S** |
| **UR6MP - MS** | mm | 19.67 | 2.08 | 21.12 | 2.55 | 21.34 | 2.85 | **0.121** | **NS** |
| **UL6MP - MS** | mm | 19.67 | 1.40 | 20.06 | 2.92 | 19.45 | 2.57 | **0.719** | **NS** |
| **UR6MP - UL6MP** | mm | 39.40 | 1.84 | 41.23 | 3.54 | 40.90 | 3.09 | **0.165** | **NS** |
| **UR6MB-MA** | mm | 57.70 | 4.94 | 59.65 | 3.47 | 58.25 | 3.61 | **0.293** | **NS** |
| **UL6MB-MA** | mm | 57.71 | 4.85 | 60.16 | 3.13 | 58.71 | 4.10 | **0.175** | **NS** |
| **UR6LA-MSP** | deg | 8.59 | 6.22 | 10.80 | 8.06 | 6.98 | 5.56 | **0.196** | **NS** |
| **UL6LA-MSP** | deg | 14.62 | 8.10 | 14.28 | 8.50 | 10.88 | 6.34 | **0.256** | **NS** |
| **Mandibular** | **unit** | | | | | | | | |
| **SBMC** | mm | 8.95 | 5.71 | 10.47 | 2.77 | 8.72 | 3.09 | **0.294** | **NS** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **SBP-MC** | deg | 6.52 | 4.19 | 7.09 | 1.77 | 6.20 | 2.25 | **0.579** | **NS** |
| **LI - MC** | mm | 13.96 | 6.05 | 18.38 | 3.38 | 15.62 | 3.18 | **<0.01** | **S** |
| **PG - MC** | mm | 11.35 | 6.61 | 10.53 | 2.83 | 9.26 | 4.22 | **0.392** | **NS** |
| **SPGP - MCP** | deg | 7.13 | 4.20 | 6.34 | 1.66 | 5.78 | 2.61 | **0.379** | **NS** |
| **STME - MA** | mm | 106.30 | 5.52 | 110.89 | 5.43 | 107.29 | 4.26 | **0.016** | **S** |
| **SN - STME** | mm | 61.48 | 5.10 | 67.62 | 4.67 | 63.60 | 4.38 | **<0.01** | **S** |
| **STME - STI** | mm | 40.93 | 4.25 | 42.79 | 4.61 | 41.40 | 3.28 | **0.340** | **NS** |
| **STGOR - MA** | mm | 72.47 | 6.06 | 74.97 | 5.92 | 74.98 | 4.26 | **0.301** | **NS** |
| **STGOL - MA** | mm | 69.81 | 7.28 | 72.92 | 5.74 | 74.83 | 3.70 | **0.035** | **S** |
| **MP - MA** | deg | 29.60 | 6.07 | 28.17 | 6.50 | 26.81 | 4.00 | **0.341** | **NS** |
| **CHIN-MS** | mm | 1.71 | 1.27 | 1.07 | 0.74 | 1.26 | 0.63 | **0.096** | **NS** |
| **STGOR - MS** | mm | 55.57 | 3.85 | 56.06 | 4.86 | 57.47 | 5.66 | **0.476** | **NS** |
| **STGOL - MS** | mm | 56.07 | 2.31 | 55.84 | 5.34 | 56.03 | 4.76 | **0.984** | **NS** |
| **STGOL – STGOR** | mm | 111.89 | 5.54 | 112.25 | 9.60 | 113.83 | 9.62 | **0.766** | **NS** |
| **LR1I - MC** | mm | 5.71 | 5.51 | 5.17 | 3.57 | 3.38 | 2.82 | **0.181** | **NS** |
| **LL1I - MC** | mm | 5.70 | 5.53 | 5.42 | 3.56 | 3.46 | 2.88 | **0.178** | **NS** |
| **LR1LA - MCP** | deg | 35.59 | 9.12 | 38.68 | 7.20 | 38.92 | 10.40 | **0.478** | **NS** |
| **LL1LA-MCP** | deg | 36.34 | 9.40 | 39.29 | 7.80 | 39.19 | 9.59 | **0.543** | **NS** |
| **LR1LA-MP** | deg | 80.19 | 9.24 | 77.62 | 6.56 | 75.28 | 7.31 | **0.167** | **NS** |
| **LL1LA-MP** | deg | 79.67 | 9.96 | 78.08 | 6.01 | 75.31 | 7.83 | **0.246** | **NS** |
| **LR1I - MP** | mm | 37.14 | 9.44 | 42.31 | 3.51 | 41.53 | 2.83 | **0.019** | **S** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **LL1I - MP** | mm | 37.20 | 9.49 | 42.39 | 3.59 | 41.56 | 2.84 | **0.019** | **S** |
| **LR3C - MS** | mm | 14.86 | 1.77 | 15.71 | 2.04 | 15.88 | 1.97 | **0.264** | **NS** |
| **LL3C - MS** | mm | 14.05 | 1.75 | 13.07 | 2.81 | 12.90 | 1.56 | **0.248** | **NS** |
| **LL3C - LR3C** | mm | 26.58 | 1.45 | 28.60 | 1.94 | 28.71 | 2.16 | **<0.01** | **S** |
| **LR3LA - MSP** | deg | 10.31 | 6.59 | 17.14 | 4.23 | 13.79 | 6.42 | **<0.01** | **S** |
| **LL3LA - MSP** | deg | 7.93 | 4.79 | 19.50 | 5.44 | 20.02 | 6.54 | **<0.01** | **S** |
| **LR3C - MP** | mm | 35.99 | 9.18 | 40.61 | 3.46 | 40.20 | 2.90 | **0.030** | **S** |
| **LL3C - MP** | mm | 36.02 | 9.28 | 40.81 | 3.84 | 40.21 | 3.01 | **0.031** | **S** |
| **LR6CF- MS** | mm | 26.66 | 2.15 | 27.61 | 2.09 | 27.79 | 2.75 | **0.321** | **NS** |
| **LL6CF - MS** | mm | 26.19 | 1.66 | 26.42 | 3.11 | 25.80 | 2.48 | **0.731** | **NS** |
| **LL6CF - LR6CF** | mm | 40.66 | 1.79 | 42.06 | 2.51 | 41.64 | 2.74 | **0.216** | **NS** |
| **LR6LA - MSP** | deg | 23.18 | 7.19 | 20.40 | 8.71 | 20.32 | 5.38 | **0.425** | **NS** |
| **LL6LA - MSP** | deg | 21.99 | 7.58 | 17.71 | 7.07 | 14.10 | 6.21 | **<0.01** | **S** |
| **INTER-MAXILLARY** | | | | | | | | | |
| **SA-MCP - SB-MCP** | mm | 7.98 | 3.23 | 8.34 | 2.11 | 8.80 | 2.28 | **0.623** | **NS** |
| **SAP - SBP** | deg | 11.49 | 2.34 | 13.82 | 1.75 | 13.20 | 1.72 | **<0.01** | **S** |
| **PG - ALR** | mm | 5.02 | 3.09 | 3.63 | 1.99 | 3.15 | 2.62 | **0.089** | **NS** |
| **ACP-STPGP** | deg | 6.47 | 2.89 | 7.65 | 2.83 | 7.96 | 2.05 | **0.214** | **NS** |
| **SN-STPG** | mm | 9.81 | 5.31 | 8.08 | 3.01 | 10.00 | 3.24 | **0.217** | **NS** |
| **STZY - STGO** | mm | 13.66 | 3.22 | 10.71 | 7.36 | 10.70 | 5.96 | **0.253** | **NS** |
| **RATIO STU/STME** | mm | 0.30 | 0.03 | 0.33 | 0.04 | 0.32 | 0.03 | **0.147** | **NS** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **UR1I - LR1I** | mm | 2.01 | 1.04 | 2.70 | 1.57 | 2.19 | 0.96 | **0.206** | **NS** |
| **UL1I - LL1I** | mm | 1.97 | 1.03 | 2.68 | 1.52 | 2.14 | 1.10 | **0.185** | **NS** |
| **DIFF U-L3C** | mm | 7.57 | 1.07 | 7.13 | 1.31 | 7.02 | 1.00 | **0.339** | **NS** |
| **DIFF U-L6CF** | mm | -1.27 | 1.55 | -0.84 | 1.62 | -0.74 | 2.62 | **0.713** | **NS** |

- *P-values were calculated using MANOVA: Multi-variate analysis of variance*
- *NS: non-significant >0.05, S: significant <0.05*

**Table 12:** Standard average values, standard deviation, and differences between Males in the permanent dentition stage: Comparing racial backgrounds

| **Maxillary** | **UNIT** | White non-Hispanic | | African American | | Hispanic American | | ***p-value*** | **Sig** |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD | | **S / NS** |
| **ACMC** | mm | 13.40 | 4.42 | 12.58 | 3.46 | 13.18 | 2.64 | **0.732** | **NS** |
| **ACPMCP** | deg | 16.44 | 5.16 | 15.77 | 4.19 | 16.47 | 2.95 | **0.845** | **NS** |
| **SNMC** | mm | 24.05 | 4.86 | 20.89 | 4.05 | 21.77 | 2.94 | **0.060** | **NS** |
| **SAMC** | mm | 21.52 | 4.64 | 21.57 | 3.59 | 21.01 | 2.70 | **0.879** | **NS** |
| **SAPMCP** | deg | 22.31 | 4.76 | 23.13 | 4.19 | 22.32 | 2.44 | **0.764** | **NS** |
| **ISMCP** | mm | 23.37 | 5.52 | 26.50 | 3.78 | 23.91 | 3.30 | **0.066** | **NS** |
| **SNMA** | mm | 45.69 | 4.02 | 45.33 | 4.65 | 44.77 | 4.47 | **0.820** | **NS** |
| **STUSN** | mm | 21.67 | 2.70 | 21.90 | 3.18 | 20.84 | 2.56 | **0.487** | **NS** |
| **ZYR-MS** | mm | 64.29 | 4.39 | 62.74 | 3.62 | 61.09 | 3.32 | **0.931** | **NS** |
| **ZYL-MS** | mm | 65.94 | 3.91 | 63.52 | 4.23 | 60.82 | 3.31 | **0.047** | **S** |
| **ZY-ZY** | mm | 130.23 | 7.09 | 126.26 | 6.78 | 121.91 | 6.03 | **0.001** | **S** |
| **UR1I-MCP** | mm | 11.90 | 9.75 | 9.82 | 4.64 | 8.11 | 2.32 | **0.197** | **NS** |
| **UR1LA-MCP** | deg | 16.59 | 10.80 | 21.70 | 8.42 | 12.38 | 8.89 | **0.013** | **S** |
| **UR1I-MCP** | mm | 11.92 | 9.68 | 10.22 | 4.40 | 8.31 | 2.41 | **0.220** | **NS** |
| **UL1LA-MCP** | deg | 16.65 | 10.64 | 21.65 | 8.62 | 12.47 | 8.66 | **0.014** | **S** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **UR1-MA** | mm | 69.57 | 4.39 | 69.53 | 6.47 | 67.51 | 4.95 | **0.412** | **NS** |
| **UL1-MA** | mm | 69.58 | 4.44 | 69.60 | 6.57 | 67.66 | 5.14 | **0.470** | **NS** |
| **UR1STSREST** | mm | 2.22 | 2.20 | 2.30 | 1.83 | 1.89 | 1.64 | **0.782** | **NS** |
| **L1STSREST** | mm | 2.22 | 2.26 | 2.36 | 1.86 | 2.04 | 1.79 | **0.882** | **NS** |
| **UR3C-MS** | mm | 18.12 | 1.42 | 19.65 | 1.50 | 18.81 | 1.43 | **0.010** | **S** |
| **UL3C-MS** | mm | 17.58 | 1.43 | 18.65 | 2.79 | 17.93 | 1.87 | **0.310** | **NS** |
| **UR3C-UR3C** | mm | 35.75 | 1.63 | 38.37 | 2.40 | 36.80 | 2.20 | **0.002** | **S** |
| **UR3LA-MSP** | deg | 14.30 | 4.52 | 18.49 | 6.76 | 15.11 | 5.55 | **0.072** | **NS** |
| **UL3LA-MSP** | deg | 14.15 | 7.75 | 18.10 | 5.01 | 13.08 | 8.14 | **0.080** | **NS** |
| **UR3MA** | mm | 68.00 | 4.25 | 67.55 | 6.24 | 65.07 | 4.63 | **0.183** | **NS** |
| **UL3MA** | mm | 68.24 | 4.31 | 67.93 | 6.20 | 65.67 | 4.70 | **0.263** | **NS** |
| **UR6MP - MS** | mm | 21.25 | 1.61 | 22.24 | 2.39 | 21.15 | 2.17 | **0.225** | **NS** |
| **UL6MP - MS** | mm | 21.03 | 1.99 | 22.99 | 2.29 | 21.65 | 2.32 | **0.029** | **S** |
| **UR6MP - UL6MP** | mm | 42.32 | 2.37 | 45.33 | 2.81 | 42.88 | 2.61 | **0.002** | **S** |
| **UR6MB-MA** | mm | 63.54 | 4.95 | 62.58 | 6.02 | 59.06 | 3.45 | **0.019** | **S** |
| **UL6MB-MA** | mm | 63.91 | 5.40 | 63.03 | 5.46 | 59.68 | 3.58 | **0.027** | **S** |
| **UR6LA-MSP** | deg | 8.18 | 7.12 | 7.69 | 7.48 | 10.28 | 5.62 | **0.463** | **NS** |
| **UL6LA-MSP** | deg | 11.83 | 6.59 | 13.02 | 5.45 | 14.18 | 4.07 | **0.438** | **NS** |
| **Mandibular** | **unit** | | | | | | | | |
| **SBMC** | mm | 13.08 | 7.50 | 14.75 | 4.83 | 11.35 | 2.78 | **0.151** | **NS** |
| **SBP-MC** | deg | 8.79 | 5.07 | 9.80 | 3.33 | 7.99 | 2.07 | **0.314** | **NS** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **LI - MC** | mm | 19.54 | 6.55 | 23.37 | 4.26 | 18.21 | 2.71 | **<0.01** | **S** |
| **PG - MC** | mm | 15.35 | 10.20 | 14.37 | 5.40 | 12.17 | 4.54 | **0.380** | **NS** |
| **SPGP - MCP** | deg | 8.66 | 5.63 | 8.45 | 3.32 | 7.44 | 2.82 | **0.620** | **NS** |
| **STME - MA** | mm | 115.75 | 6.36 | 114.41 | 9.54 | 109.45 | 7.35 | **0.047** | **S** |
| **SN - STME** | mm | 70.06 | 6.81 | 69.08 | 6.42 | 64.67 | 5.23 | **0.024** | **S** |
| **STME - STI** | mm | 46.09 | 4.88 | 44.56 | 4.70 | 41.91 | 4.01 | **0.025** | **S** |
| **STGOR - MA** | mm | 80.30 | 7.50 | 82.59 | 5.95 | 76.10 | 6.94 | **0.016** | **S** |
| **STGOL - MA** | mm | 77.87 | 7.97 | 79.33 | 6.50 | 74.62 | 7.38 | **0.135** | **NS** |
| **MP - MA** | deg | 27.38 | 8.01 | 25.09 | 6.09 | 26.20 | 5.92 | **0.593** | **NS** |
| **CHIN-MS** | mm | 1.91 | 1.40 | 1.20 | 0.80 | 1.37 | 1.11 | **0.155** | **NS** |
| **STGOR - MS** | mm | 60.04 | 6.98 | 56.25 | 4.72 | 58.52 | 5.59 | **0.151** | **NS** |
| **STGOL - MS** | mm | 61.51 | 5.26 | 58.35 | 5.87 | 59.22 | 6.26 | **0.259** | **NS** |
| **STGOL – STGOR** | mm | 121.85 | 11.71 | 114.97 | 9.59 | 117.95 | 11.00 | **0.170** | **NS** |
| **LR1I - MC** | mm | 10.78 | 8.89 | 7.34 | 4.65 | 5.87 | 2.78 | **0.045** | **S** |
| **LL1I - MC** | mm | 10.70 | 8.84 | 7.61 | 4.60 | 6.06 | 2.80 | **0.063** | **NS** |
| **LR1LA - MCP** | deg | 30.16 | 16.04 | 36.23 | 11.55 | 34.85 | 9.48 | **0.325** | **NS** |
| **LL1LA-MCP** | deg | 30.03 | 15.81 | 36.58 | 11.83 | 34.78 | 9.39 | **0.280** | **NS** |
| **LR1LA-MP** | deg | 80.40 | 10.88 | 74.81 | 8.16 | 78.48 | 7.71 | **0.170** | **NS** |
| **LL1LA-MP** | deg | 76.53 | 5.10 | 73.63 | 6.78 | 78.72 | 7.13 | **0.059** | **NS** |
| **LR1I - MP** | mm | 31.65 | 18.55 | 45.48 | 3.78 | 43.07 | 3.68 | **<0.01** | **S** |
| **LL1I - MP** | mm | 31.59 | 18.47 | 45.50 | 3.80 | 43.17 | 3.70 | **<0.01** | **S** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **LR3C - MS** | mm | 15.24 | 1.22 | 15.55 | 1.81 | 16.15 | 1.57 | **0.264** | **NS** |
| **LL3C - MS** | mm | 15.13 | 1.02 | 15.18 | 2.20 | 14.00 | 1.98 | **0.248** | **NS** |
| **LL3C - LR3C** | mm | 27.82 | 1.41 | 30.55 | 2.19 | 28.83 | 1.74 | **<0.01** | **S** |
| **LR3LA - MSP** | deg | 9.09 | 3.91 | 18.22 | 8.79 | 12.80 | 6.98 | **<0.01** | **S** |
| **LL3LA - MSP** | deg | 9.16 | 8.36 | 17.73 | 9.00 | 15.16 | 6.53 | **<0.01** | **S** |
| **LR3C - MP** | mm | 30.74 | 18.15 | 44.09 | 3.60 | 41.63 | 4.02 | **0.211** | **NS** |
| **LL3C - MP** | mm | 30.71 | 17.77 | 43.60 | 4.21 | 41.53 | 4.52 | **0.094** | **NS** |
| **LR6CF- MS** | mm | 27.67 | 1.59 | 28.04 | 2.13 | 27.67 | 2.02 | **0.80** | **NS** |
| **LL6CF - MS** | mm | 27.44 | 1.73 | 29.22 | 2.70 | 27.48 | 2.03 | **0.026** | **S** |
| **LL6CF - LR6CF** | mm | 43.11 | 2.38 | 45.36 | 2.67 | 42.87 | 2.50 | **<0.01** | **S** |
| **LR6LA - MSP** | deg | 15.66 | 6.89 | 16.09 | 7.04 | 20.36 | 9.14 | **0.137** | **NS** |
| **LL6LA - MSP** | deg | 18.53 | 8.41 | 10.84 | 5.30 | 17.62 | 5.55 | **<0.01** | **S** |
| **INTER-MAXILLARY** | | | | | | | | | |
| **SA-MCP - SB-MCP** | mm | 8.44 | 3.79 | 7.13 | 3.66 | 9.66 | 3.41 | **0.107** | **NS** |
| **SAP - SBP** | deg | 13.52 | 1.75 | 13.32 | 3.60 | 14.33 | 2.67 | **0.51** | **NS** |
| **PG - ALR** | mm | 7.11 | 5.59 | 6.95 | 4.74 | 4.53 | 3.40 | **0.171** | **NS** |
| **ACP-STPGP** | deg | 7.78 | 2.86 | 7.32 | 3.67 | 9.03 | 3.34 | **0.270** | **NS** |
| **SN-STPG** | mm | 9.61 | 5.23 | 7.03 | 3.96 | 9.60 | 4.40 | **0.144** | **NS** |
| **STZY - STGO** | mm | 8.38 | 7.90 | 11.28 | 9.25 | 3.96 | 8.64 | **0.038** | **S** |
| **RATIO STU/STME** | mm | 0.31 | 0.02 | 0.32 | 0.03 | 0.32 | 0.03 | **0.392** | **NS** |
| **UR1I - LR1I** | mm | 1.95 | 0.61 | 2.53 | 1.39 | 2.24 | 1.00 | **0.274** | **NS** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **UL1I - LL1I** | mm | 2.05 | 0.65 | 2.61 | 1.41 | 2.26 | 1.11 | **0.316** | **NS** |
| **DIFF U-L3C** | mm | 7.93 | 0.93 | 7.82 | 2.09 | 7.98 | 2.11 | **0.96** | **NS** |
| **DIFF U-L6CF** | mm | -0.80 | 1.48 | -0.03 | 1.86 | 0.01 | 1.25 | **0.231** | **NS** |

- *P-values were calculated using MANOVA: Multi-variate analysis of variance*
- *NS: non-significant >0.05, S: significant <0.05*

**Table 13: Standard average values, standard deviations, and differences between African American and Hispanic American measurements across age groups**

| Maxillary | UNIT | Primary dentition | | | | *p-* | Early mixed dentition | | | | *p-* | Late mixed dentition | | | | *p-* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AA/Mean | SD | H/Mean | SD | ***value*** | AA/Mean | SD | H/Mean | SD | ***value*** | AA/Mean | SD | H/Mean | SD | ***value*** |
| **ACMC** | mm | 10.24 | 2.31 | 11.31 | 2.02 | **0.176** | 11.47 | 2.13 | 11.93 | 2.67 | **0.565** | 10.64 | 1.94 | 11.21 | 1.87 | **0.38** |
| **ACPMCP** | deg | 15.78 | 3.65 | 17.33 | 3.29 | **0.207** | 16.60 | 3.25 | 16.79 | 3.25 | **0.856** | 14.43 | 2.60 | 15.34 | 2.46 | **0.284** |
| **SNMC** | mm | 15.87 | 2.63 | 16.82 | 2.15 | **0.262** | 16.52 | 2.46 | 18.23 | 2.88 | **0.053** | 17.14 | 2.03 | 18.23 | 2.18 | **0.123** |
| **SAMC** | mm | 16.31 | 2.28 | 15.74 | 2.06 | **0.450** | 17.72 | 2.54 | 17.24 | 2.72 | **0.570** | 18.04 | 2.41 | 17.36 | 2.12 | **0.36** |
| **SAPMCP** | deg | 21.47 | 2.95 | 20.60 | 2.85 | **0.391** | 22.05 | 3.11 | 20.70 | 2.92 | **0.172** | 21.10 | 2.29 | 20.03 | 2.24 | **0.159** |
| **ISMCP** | mm | 19.64 | 2.19 | 17.61 | 2.32 | **0.013*** | 21.38 | 3.15 | 19.07 | 2.96 | **0.023*** | 22.00 | 2.69 | 19.70 | 2.60 | **0.012*** |
| **SNMA** | mm | 36.73 | 2.22 | 36.02 | 2.39 | **0.381** | 38.44 | 3.11 | 39.09 | 2.30 | **0.462** | 41.65 | 2.65 | 41.29 | 2.44 | **0.67** |
| **STUSN** | mm | 17.89 | 2.17 | 17.88 | 2.16 | **0.991** | 19.49 | 1.59 | 19.44 | 1.95 | **0.926** | 20.50 | 2.04 | 19.47 | 2.27 | **0.153** |
| **ZYR-MS** | mm | 52.40 | 3.13 | 53.39 | 2.77 | **0.340** | 55.85 | 2.14 | 56.87 | 2.86 | **0.216** | 58.22 | 4.74 | 57.12 | 4.27 | **0.460** |
| **ZYL-MS** | mm | 54.62 | 2.48 | 52.07 | 2.16 | **0.003*** | 57.19 | 2.84 | 56.34 | 2.62 | **0.334** | 60.20 | 4.79 | 58.38 | 5.18 | **0.274** |
| **ZY-ZY** | mm | 107.02 | 5.09 | 105.46 | 4.28 | **0.343** | 113.04 | 4.66 | 113.21 | 3.83 | **0.903** | 118.43 | 9.10 | 115.50 | 8.82 | **0.327** |
| **UR1I-MCP** | mm | 4.47 | 2.45 | 4.25 | 2.70 | **0.809** | 5.91 | 3.17 | 10.77 | 17.93 | **0.258** | 7.30 | 4.04 | 5.21 | 2.64 | **0.07** |
| **UR1LA-MCP** | deg | 14.55 | 7.01 | 9.23 | 6.75 | **0.032*** | 12.19 | 8.48 | 13.92 | 8.70 | **0.534** | 16.39 | 8.05 | 11.10 | 6.79 | **0.038*** |
| **UR1I-MCP** | mm | 4.49 | 2.54 | 4.41 | 2.68 | **0.935** | 6.01 | 3.26 | 11.12 | 17.80 | **0.233** | 7.45 | 3.88 | 5.59 | 2.87 | **0.108** |
| **UL1LA-MCP** | deg | 12.92 | 6.71 | 9.80 | 5.84 | **0.160** | 12.61 | 9.41 | 14.14 | 8.80 | **0.600** | 16.68 | 6.85 | 11.37 | 6.43 | **0.02*** |
| **UR1-MA** | mm | 57.23 | 2.86 | 55.79 | 3.04 | **0.165** | 59.87 | 3.77 | 55.05 | 13.70 | **0.154** | 65.61 | 3.74 | 63.17 | 2.88 | **0.034*** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **UL1-MA** | mm | 57.59 | 2.69 | 55.88 | 3.05 | **0.092** | 60.08 | 3.49 | 55.31 | 13.69 | **0.155** | 65.53 | 3.87 | 63.40 | 2.79 | **0.065** |
| **UR1STSREST** | mm | 2.62 | 1.71 | 1.89 | 2.12 | **0.275** | 1.94 | 2.43 | -3.48 | 13.78 | **0.107** | 3.46 | 2.20 | 2.42 | 1.71 | **0.119** |
| **L1STSREST** | mm | 2.97 | 1.78 | 1.97 | 1.99 | **0.133** | 2.14 | 2.45 | -3.23 | 13.70 | **0.108** | 3.38 | 2.21 | 2.65 | 1.57 | **0.253** |
| **UR3C-MS** | mm | 16.60 | 1.93 | 15.96 | 1.96 | **0.349** | 17.81 | 1.78 | 17.41 | 2.73 | **0.601** | 18.27 | 1.16 | 17.20 | 1.87 | **0.043*** |
| **UL3C-MS** | mm | 15.48 | 1.17 | 13.86 | 1.65 | **0.002*** | 15.70 | 1.79 | 15.35 | 2.44 | **0.616** | 16.05 | 1.81 | 17.13 | 1.66 | **0.069** |
| **UR3C-UR3C** | mm | 32.13 | 2.17 | 29.86 | 1.93 | **0.003*** | 33.54 | 2.59 | 32.85 | 2.70 | **0.417** | 34.42 | 1.83 | 34.49 | 2.55 | **0.93** |
| **UR3LA-MSP** | deg | 11.48 | 5.35 | 8.27 | 5.13 | **0.085** | 12.86 | 8.29 | 14.07 | 8.17 | **0.649** | 16.66 | 11.12 | 13.57 | 8.34 | **0.349** |
| **UL3LA-MSP** | deg | 7.99 | 6.61 | 6.53 | 4.89 | **0.475** | 12.87 | 7.82 | 13.40 | 8.62 | **0.839** | 18.70 | 19.54 | 13.77 | 8.80 | **0.337** |
| **UR3MA** | mm | 54.83 | 2.64 | 53.97 | 2.75 | **0.362** | 57.94 | 2.88 | 53.23 | 13.18 | **0.143** | 60.99 | 2.93 | 59.10 | 2.99 | **0.06** |
| **UL3MA** | mm | 55.56 | 2.57 | 54.24 | 2.66 | **0.152** | 58.00 | 3.15 | 53.97 | 13.23 | **0.210** | 61.55 | 3.31 | 60.00 | 3.11 | **0.152** |
| **UR6MP - MS** | mm | 18.27 | 2.44 | 18.38 | 2.02 | **0.889** | 21.03 | 1.93 | 20.33 | 2.61 | **0.345** | 21.66 | 1.45 | 20.81 | 2.38 | **0.194** |
| **UL6MP - MS** | mm | 18.06 | 1.25 | 16.72 | 2.20 | **0.035*** | 18.67 | 2.30 | 19.76 | 2.59 | **0.174** | 19.94 | 2.17 | 20.91 | 2.14 | **0.181** |
| **UR6MP - UL6MP** | mm | 36.39 | 2.40 | 35.15 | 2.30 | **0.136** | 39.75 | 2.81 | 40.22 | 3.21 | **0.629** | 41.68 | 2.66 | 41.77 | 3.43 | **0.925** |
| **UR6MB-MA** | mm | 49.97 | 3.23 | 50.56 | 2.46 | **0.560** | 51.49 | 4.03 | 47.35 | 11.97 | **0.166** | 55.61 | 3.40 | 54.20 | 3.18 | **0.203** |
| **UL6MB-MA** | mm | 50.95 | 3.39 | 50.76 | 2.64 | **0.854** | 51.44 | 4.15 | 47.92 | 12.47 | **0.254** | 56.01 | 3.94 | 54.88 | 3.47 | **0.363** |
| **UR6LA-MSP** | deg | 7.04 | 6.24 | 7.38 | 4.35 | **0.859** | 19.94 | 28.00 | 20.02 | 7.23 | **0.99** | 16.40 | 12.47 | 12.94 | 8.99 | **0.343** |
| **UL6LA-MSP** | deg | 12.31 | 5.19 | 9.38 | 6.56 | **0.157** | 20.14 | 7.92 | 22.11 | 15.33 | **0.619** | 21.67 | 9.82 | 18.76 | 10.02 | **0.379** |
| **Mandibular** | **unit** | | | | | | | | | | | | | | | |
| **SBMC** | mm | 8.74 | 2.54 | 6.79 | 2.68 | **0.037*** | 9.35 | 2.20 | 7.97 | 3.20 | **0.128** | 9.18 | 3.40 | 8.06 | 1.85 | **0.23** |
| **SBP-MC** | deg | 7.25 | 2.28 | 5.85 | 2.56 | **0.101** | 7.23 | 1.84 | 6.25 | 2.57 | **0.180** | 6.61 | 2.43 | 6.08 | 1.49 | **0.431** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LI - MC** | mm | 15.01 | 2.39 | 12.32 | 1.95 | **0.001*** | 16.48 | 2.54 | 14.06 | 3.16 | **0.012*** | 17.69 | 2.69 | 14.82 | 2.06 | **<0.01*** |
| **PG - MC** | mm | 6.77 | 2.79 | 5.80 | 2.97 | **0.333** | 7.45 | 2.97 | 6.85 | 3.58 | **0.57** | 7.76 | 3.77 | 7.57 | 3.61 | **0.874** |
| **SPGP - MCP** | deg | 4.97 | 2.06 | 4.47 | 2.30 | **0.507** | 5.14 | 2.11 | 4.74 | 2.36 | **0.58** | 4.97 | 2.44 | 4.92 | 2.23 | **0.944** |
| **STME - MA** | mm | 90.65 | 4.46 | 88.76 | 4.07 | **0.228** | 96.20 | 4.56 | 96.58 | 3.35 | **0.768** | 103.01 | 6.59 | 100.83 | 5.31 | **0.277** |
| **SN - STME** | mm | 53.92 | 3.12 | 52.74 | 3.01 | **0.271** | 57.76 | 2.66 | 57.49 | 3.08 | **0.772** | 61.36 | 4.84 | 59.54 | 4.76 | **0.256** |
| **STME - STI** | mm | 33.45 | 2.04 | 32.61 | 1.90 | **0.228** | 35.87 | 2.75 | 35.93 | 2.27 | **0.94** | 38.35 | 4.31 | 37.88 | 4.05 | **0.734** |
| **STGOR - MA** | mm | 61.93 | 3.72 | 62.88 | 4.64 | **0.510** | 66.74 | 5.13 | 69.20 | 4.59 | **0.122** | 72.23 | 5.28 | 70.57 | 5.13 | **0.337** |
| **STGOL - MA** | mm | 60.26 | 3.92 | 60.95 | 4.12 | **0.619** | 65.17 | 5.09 | 73.45 | 21.37 | **0.115** | 70.25 | 5.21 | 69.84 | 5.27 | **0.811** |
| **MP - MA** | deg | 30.28 | 3.61 | 28.96 | 3.72 | **0.302** | 27.70 | 6.87 | 26.60 | 7.06 | **0.624** | 27.15 | 7.21 | 28.22 | 7.77 | **0.668** |
| **CHIN-MS** | mm | 1.24 | 0.67 | 1.28 | 0.68 | **0.875** | 1.01 | 0.66 | 1.50 | 0.79 | **0.04*** | 1.24 | 0.95 | 0.60 | 0.48 | **0.016*** |
| **STGOR - MS** | mm | 46.01 | 4.06 | 48.10 | 3.71 | **0.130** | 47.48 | 4.69 | 50.54 | 4.91 | **0.054** | 51.43 | 7.99 | 52.03 | 6.74 | **0.806** |
| **STGOL - MS** | mm | 47.14 | 3.12 | 48.72 | 2.89 | **0.140** | 47.80 | 4.27 | 50.70 | 5.51 | **0.075** | 51.51 | 5.89 | 52.37 | 7.04 | **0.688** |
| **STGOL – STGOR** | mm | 93.28 | 6.53 | 97.02 | 5.93 | **0.092** | 95.49 | 8.58 | 103.51 | 9.52 | **<0.01*** | 103.22 | 13.40 | 104.63 | 13.44 | **0.752** |
| **LR1I - MC** | mm | 2.38 | 1.76 | 3.01 | 2.19 | **0.365** | 3.87 | 3.00 | 5.93 | 8.19 | **0.311** | 5.12 | 3.11 | 3.05 | 2.12 | **0.026*** |
| **LL1I - MC** | mm | 2.24 | 1.92 | 3.12 | 2.09 | **0.214** | 3.85 | 2.97 | 5.97 | 8.19 | **0.299** | 5.25 | 3.29 | 3.32 | 2.41 | **0.05*** |
| **LR1LA - MCP** | deg | 27.06 | 10.70 | 25.09 | 10.32 | **0.589** | 33.95 | 9.56 | 27.68 | 11.04 | **0.066** | 36.68 | 7.21 | 33.61 | 8.88 | **0.255** |
| **LL1LA-MCP** | deg | 25.09 | 12.56 | 24.56 | 9.98 | **0.894** | 33.19 | 13.73 | 28.29 | 12.22 | **0.246** | 37.63 | 7.65 | 35.03 | 9.64 | **0.369** |
| **LR1LA-MP** | deg | 79.07 | 6.36 | 79.00 | 8.37 | **0.976** | 76.33 | 12.96 | 74.14 | 15.66 | **0.639** | 78.64 | 6.97 | 78.86 | 3.89 | **0.903** |
| **LL1LA-MP** | deg | 76.88 | 6.34 | 79.69 | 8.25 | **0.272** | 75.74 | 6.02 | 76.38 | 13.52 | **0.852** | 77.59 | 7.75 | 78.87 | 7.12 | **0.604** |
| **LR1I - MP** | mm | 34.42 | 1.67 | 34.30 | 2.67 | **0.878** | 37.07 | 3.48 | 36.79 | 5.46 | **0.848** | 40.24 | 3.72 | 39.28 | 3.65 | **0.430** |
| **LL1I - MP** | mm | 34.28 | 1.58 | 34.36 | 2.60 | **0.907** | 37.03 | 3.44 | 37.14 | 4.84 | **0.932** | 40.22 | 3.62 | 39.33 | 3.75 | **0.465** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LR3C - MS** | mm | 14.10 | 1.47 | 14.57 | 1.72 | **0.406** | 14.92 | 1.87 | 16.13 | 2.34 | **0.083** | 15.88 | 1.95 | 15.69 | 1.73 | **0.748** |
| **LL3C - MS** | mm | 13.11 | 1.06 | 11.70 | 1.73 | **<0.01*** | 13.45 | 1.96 | 13.11 | 2.65 | **0.652** | 14.00 | 1.50 | 13.97 | 2.13 | **0.956** |
| **LL3C - LR3C** | mm | 25.13 | 2.24 | 24.05 | 1.64 | **0.124** | 26.90 | 2.27 | 27.19 | 2.07 | **0.67** | 28.25 | 1.68 | 27.79 | 2.12 | **0.467** |
| **LR3LA - MSP** | deg | 8.76 | 6.83 | 9.30 | 6.53 | **0.814** | 14.03 | 9.43 | 13.04 | 11.36 | **0.77** | 12.85 | 6.91 | 10.87 | 5.96 | **0.358** |
| **LL3LA - MSP** | deg | 15.22 | 6.88 | 13.39 | 5.59 | **0.405** | 17.78 | 8.21 | 17.16 | 8.22 | **0.815** | 16.13 | 9.01 | 12.81 | 8.72 | **0.262** |
| **LR3C - MP** | mm | 33.72 | 1.97 | 33.33 | 2.89 | **0.643** | 36.11 | 3.50 | 34.65 | 6.17 | **0.376** | 36.79 | 3.91 | 36.61 | 2.85 | **0.875** |
| **LL3C - MP** | mm | 32.96 | 1.96 | 33.20 | 2.72 | **0.770** | 35.50 | 3.80 | 36.03 | 3.64 | **0.66** | 36.36 | 3.93 | 36.73 | 3.60 | **0.766** |
| **LR6CF- MS** | mm | 22.72 | 2.25 | 23.65 | 1.65 | **0.187** | 26.74 | 2.90 | 27.44 | 2.66 | **0.442** | 27.48 | 1.63 | 27.36 | 2.15 | **0.846** |
| **LL6CF - MS** | mm | 23.08 | 1.59 | 21.57 | 2.12 | **0.025*** | 25.30 | 2.79 | 26.55 | 2.76 | **0.167** | 26.61 | 2.61 | 27.14 | 2.65 | **0.543** |
| **LL6CF - LR6CF** | mm | 36.31 | 2.00 | 35.62 | 2.02 | **0.321** | 40.71 | 3.14 | 41.77 | 2.54 | **0.251** | 42.36 | 2.64 | 42.48 | 3.09 | **0.901** |
| **LR6LA - MSP** | deg | 18.21 | 6.33 | 19.63 | 8.25 | **0.573** | 18.63 | 10.79 | 29.51 | 13.64 | **<0.01*** | 20.54 | 7.65 | 27.70 | 12.82 | **0.05*** |
| **LL6LA - MSP** | deg | 10.04 | 7.06 | 12.13 | 7.96 | **0.423** | 18.56 | 15.35 | 25.81 | 11.30 | **0.1** | 22.49 | 14.72 | 19.42 | 7.62 | **0.43** |
| **INTER-MAXILLARY** | | | | | | | | | | | | | | | | |
| **SAMCP - SBMCP** | mm | 7.57 | 2.56 | 8.96 | 2.67 | **0.134** | 8.38 | 2.34 | 9.27 | 2.66 | **0.273** | 8.86 | 3.52 | 9.30 | 2.35 | **0.66** |
| **SAP - SBP** | deg | 14.21 | 2.62 | 14.74 | 2.22 | **0.528** | 14.81 | 2.36 | 14.45 | 2.35 | **0.64** | 14.48 | 2.96 | 13.95 | 2.06 | **0.527** |
| **PG - ALR** | mm | 2.15 | 2.20 | 3.22 | 2.67 | **0.211** | 2.37 | 1.75 | 2.99 | 2.69 | **0.404** | 2.46 | 2.29 | 3.39 | 3.07 | **0.302** |
| **ACP-STPGP** | deg | 10.81 | 2.99 | 12.86 | 2.91 | **0.052** | 11.46 | 2.80 | 12.05 | 3.01 | **0.527** | 9.45 | 2.86 | 10.42 | 3.83 | **0.39** |
| **SN-STPG** | mm | 9.16 | 3.10 | 11.08 | 3.14 | **0.083** | 9.07 | 3.15 | 11.39 | 3.56 | **0.038*** | 9.38 | 3.76 | 10.66 | 3.68 | **0.30** |
| **STZY - STGO** | mm | 13.75 | 6.47 | 8.44 | 5.24 | **0.014*** | 17.55 | 6.27 | 9.70 | 10.55 | **0.008** | 15.21 | 8.29 | 10.87 | 7.54 | **0.105** |
| **Ratio STU/STME** | mm | 0.33 | 0.03 | 0.34 | 0.03 | **0.512** | 0.34 | 0.03 | 0.34 | 0.02 | **0.98** | 0.33 | 0.03 | 0.33 | 0.04 | **0.504** |
| **UR1I - LR1I** | mm | 2.64 | 0.86 | 2.27 | 0.90 | **0.237** | 2.67 | 1.55 | 2.46 | 1.09 | **0.615** | 2.72 | 1.21 | 2.49 | 1.26 | **0.57** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **UL1I - LL1I** | mm | 2.77 | 1.04 | 2.33 | 0.87 | **0.193** | 2.69 | 1.30 | 2.63 | 1.00 | **0.885** | 2.65 | 0.99 | 2.49 | 1.34 | **0.69** |
| **DIFF U-L3C** | mm | 7.00 | 1.19 | 5.81 | 1.49 | **0.015*** | 6.65 | 2.35 | 5.66 | 1.81 | **0.148** | 6.17 | 2.48 | 6.39 | 1.68 | **0.76** |
| **DIFF U-L6CF** | mm | 0.07 | 0.97 | -0.47 | 1.21 | **0.155** | -0.97 | 1.33 | -1.56 | 2.12 | **0.304** | -0.69 | 1.76 | -0.72 | 0.96 | **0.95** |

- *P-values were calculated using MANOVA: Multi-variate analysis of variance*
- *NS: non-significant >0.05, S: significant <0.05*