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3-Dimensional Comparison Of Hard And Soft Tissue Asymmetry In

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3-DIMENSIONAL COMPARISON OF HARD AND SOFT TISSUE ASYMMETRY IN ADULT CHINESE SKELETAL CLASS III MALOCCLUSIONS

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ABSTRACT

Class III malocclusions are particularly prevalent in the Asian population. Three-dimensional imaging has improved the ability to portray the three-dimensional characteristics of soft tissue face and underlying skeletal hard tissue. While soft tissue reflects the underlying hard tissue structures, soft tissue may either provide a compensation for hard tissue asymmetry or potentially exacerbate the asymmetry. The current study is novel in that the hard tissue and soft tissue asymmetries are both analyzed relative to the same reference point, and using 3D imaging, we have attempted to elucidate a compensation tendency between the hard and soft tissues. The sample was comprised of 38 adults with Class III malocclusions from a population in Xi'an, China. In accordance with other studies, there appeared to be a left-sided laterality for hard tissue but a greater soft tissue compensation on the right hemiface. The same holds true in the other 2 dimensions, vertical and axial. This study reiterates the importance of proper diagnosis and treatment planning for skeletal asymmetries, and demonstrates the capabilities of using three-dimensional imaging to compare hard and soft tissue simultaneously.

Keywords: 3D imaging, asymmetry, soft tissue compensation, Class III malocclusion

DEDICATION

I would like to take this opportunity to remember my grandfather on mom's side. At the conclusion of my research trip, I took a short detour to Hong Kong, where I was able to visit my grandfather for the first, and unbeknownst to me, the last time in over 15 years.

ACKNOWLEDGEMENTS

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God, for
A man's heart plans his way,
But the Lord directs his steps.
Proverbs 16:9

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CHAPTER 1

INTRODUCTION/REVIEW OF LITERATURE

A skeletal Class III malocclusion can be diagnosed by one of six possible combinations of the antero-posterior relationship between the maxilla and the mandible. Skeletal Class III relationships can be defined as mandibular protrusion with a normal maxilla, maxillary retrusion without mandibular protrusion, maxillary retrusion with mandibular protrusion, normal sized maxilla and mandible, bimaxillary protrusion, and bimaxillary retrusion[1]. A vertical maxillary deficiency can also contribute to a Class III, as the mandible rotates upward and forward, resulting in the appearance of mandibular protrusion. In this instance, the Class III diagnosis is attributed more to the position of the mandible rather than the size[2]. Several studies have found different types of skeletal patterns among different populations. Sanborn found that 45.2% had mandibular protrusion with a normal maxilla, and 33% had solely maxillary retrusion[3]. Dietrich concluded that 37.5% had maxillary retrusion alone, and 31% had mandibular protrusion alone[4]. Ellis and McNamara found the most common problem was a combination of maxillary retrusion and mandibular protrusion, present in 30% of adult Class III subjects[5]. Spalj et al determined the most common skeletal combination in Croatian population was mandibular prognathism with a normal maxilla[1]. The study of four different age groups by Guyer et al concluded that individuals with Class III malocclusions present a spectrum of abnormalities, and no typical facial pattern exists in children and adolescents with a Class III malocclusion. They did find, however, that most of the characteristic anomalies associated with adult Class III malocclusions were present at an early age[6]. Cephalometric radiographs enhance the diagnosis and treatment planning of skeletal malocclusions. Several analysis have different ways of classifying the relationship of the jaws, including the Steiner analysis, Wits appraisal, and McNamara analysis to name a few. Yet with the amount of variation within each individual and within the location of landmarks, the idea of comparing an individual to average norms is an abstraction and open to interpretation[7]. The relationships of the apical bases in the antero-posterior and vertical dimension are the basis of classifying various Class III malocclusions.

In orthodontics, Class III malocclusions are sometimes associated with the Asian ethnicity, and vice versa. This generalization may contain some partial truth, as class III malocclusions are particularly prevalent in the Asian population. However, most of the Asian population are not classified as a skeletal Class III, but a skeletal I, as are most Caucasians. While these ethnicities both have a majority of skeletal class I relationships, there are differences between them. Studies comparing the Chinese and Caucasian cephalometric measurements report distinct characteristics in that the Chinese have a shorter cranial base and a larger ANB, smaller midfaces and shorter mandibles, and greater bimaxillary alveolar protrusion, with a decreased interincisal angle; the Chinese soft-tissue profile shows a less prominent nose, with a less obtuse nasolabial angle, and more protrusive lips[8,9]. These comparisons emphasize the point that individuals cannot be aligned to simple patterns based on average cephalometric measurements and suggest the need for ethnicity-specific cephalometric norms[10]. Soh et al compared three ethnic groups of Asian males and found that Class I malocclusions were most common, followed by

Class II and then Class III relations, based on both Angle's molar relationship and the British Standard Incisor classification[11]. However, the prevalence of Class III malocclusion was much higher compared with data from Caucasian samples. The distribution of incisor relations consist of 48.1% class I, 29.5% class II, and 22.4% class III. The molar relationship based on Angle classification ranged from 49.9-52.1% class I, 24.5-25.1% for class II, and 21.2-24.2% for class III. Tang also found Class I molar relationships to be most common, but they were followed by Class III and then Class II relationships[12]. He calculated molar relationships in Hong Kong adult males to be 64.8% Class I, 15.7% Class II, and 19.4% Class III. These studies suggest that the orthodontic management of Class III malocclusions would be more commonly encountered in an Asian community. A wide range of skeletal dysplasias can be camouflaged by tooth movement. Burns et al determined that when compensating Class III malocclusions, the upper and lower limits for incisal movement are 120° to the sella-nasion line and 80° to the mandibular plane, respectively[13]. However, the sagittal jaw relationship does not improve with camouflage treatment.

Traditional strategies for orthopedic correction of developing class III malocclusions include chin cup therapy and the protraction facemask protocol, with or without rapid maxillary expansion. The rationale for the chin cup is to inhibit or redirect mandibular growth by applying pressure to the temporomandibular joints. Abdelnaby and Nasser examined the application of two different force magnitudes with chin cup therapy[14]. They found that the treatment groups experienced a decrease in SNB angle, ramus height and mandibular incisor inclination, with an increase in the ANB angle, Wits appraisal, anterior facial height, and mandibular plane angle. They concluded that the use of chin cup improved the apical base relationships but had little skeletal effect, regardless of the force magnitude. Liu et al analyzed four cohort studies in a systematic review on the short term effects of chin cup therapy[15]. The results showed a decrease in SNB angle and an increase in ANB angle. Two studies showed an increase in gonial angle but no significant change in mandibular length. One study indicated that mandibular growth continued after treatment in a downward direction. The conclusions were that there is insufficient data to make recommendations for the use of chincup therapy for retarding mandibular growth. The protraction facemask is a common orthodontic protocol for class III malocclusion. Macdonald et al analyzed the cephalometric changes that occurred during and after protraction compared with class I and class III untreated controls[16]. Facemask therapy resulted in more convexity of the facial profile, anterior displacement and a downward and backward rotation of the maxilla, and clockwise rotation of the mandible. Dentoalveolar movement showed the maxillary teeth moving forward and the lower incisors retruded. Mandibular growth was similar for treatment and control groups. Masucci et al studied the long-term stability of patients treated with facemask therapy followed by comprehensive fixed appliances[17]. He found no significant differences in the maxillary changes over time, but there were favorable outcomes in skeletal changes for 73% of the patients due to improvements in the sagittal position of the mandible. Turley et al stated that facemask therapy does not normalize growth; rather the treated patients resume a class III growth pattern[18]. Though there is not strong evidence for the use of chin cup or facemask therapy for orthopedic correction, the studies advocate overcorrection of the malocclusion to compensate for future growth deficiency of the maxilla. Overcorrection may not circumvent additional treatment as growth continues.

Skeletal class III discrepancies tend to worsen with age, and therefore the difficulty of treating a developing class III malocclusion increases with time[13]. In severe cases where orthognathic surgery is required for severe skeletal discrepancies, there is a hierarchy of stability as described by Bailey[19]. Advancement of the maxilla is stable. Forward movement of moderate distances has an 80% chance of less than 2 mm change, a 20% chance of 2-4 mm relapse, and almost no chance of more than 4 mm change. The combination of maxilla forward plus mandible back for class III correction can be considered stable only if rigid internal fixation (RIF) is used. A mandibular set back alone falls in the problematic category, with 40%-50% chance of 2-4 mm postsurgical change and a significant chance of more than 4 mm change. Three-dimensional imaging would be a beneficial treatment planning aid in preparation for patients undergoing orthognathic surgery, as in a severe skeletal Class III malocclusion.

Conventional two-dimensional images such as facial photographs and lateral cephalometric radiographs have been, and continue to be, used in orthodontics for diagnosis, monitoring growth, and visualizing treatment changes in hard and soft tissues. Conventional radiographic images can be misleading because a complex 3-dimensional structure is projected onto a flat 2-D surface, creating possible distortion and magnification errors[20]. The advent of three-dimensional imaging has improved the ability to communicate the three-dimensional characteristics of the face. Orthodontists can better visualize and describe the topography and surface area of the face with more precision and depth compared with a two-dimensional image. Three-dimensional bone beam computed tomography (CBCT) images are able to show dental root inclination and torque, positions of impacted and supernumerary teeth, and thickness of bone at sites of mini-implants for anchorage[21]. Soft tissue morphology is more complex, being affected by changes in muscular tone, nasal breathing, and head posture. Kau et al evaluated the reliability of three-dimensional soft tissue analysis using a laser scanning system, and found soft tissue morphology capture to be clinically reproducible within a week. 90% of the facial morphology was accurate to within 0.7-0.8 mm[22]. Virtual faces can be superimposed for a variety of analyses, such as to produce an average face, to identify deviations in facial morphology, and to calculate distances between 3D soft tissue landmarks. Kau et al demonstrated the ability of 3D image analysis by comparing five different populations to identify morphologic similarities and large variations in concentrated areas of the face[23]. They suggested that based on their findings, there may be a place for establishing baselines for facial morphologic norms for each population, especially in the field of orthodontics. Some of the vision-based scanning techniques include Moiré topography, structured light techniques, stereophotogrammetry, and 3D facial morphometry (3DFM), all of which are non-invasive[24,25]. These techniques of imaging are applied to surgical simulations, orthognathic surgical planning, model scanning, prefabrication of arch wires involving robotics, and construction of 3D aligners. Advantages of 3D imaging include better assessment of dentoskeletal relationships, soft tissue facial esthetics, 3d treatment planning, and improved communication with patients and doctors.

Bozic et al used the 3-dimensional imaging to compare an average facial template with Class III subjects in male and female Slovenian subjects[26]. Using a laser scanning system, they compiled a number of facial shells to create a population-specific average of subjects with a Class I occlusion, divided by gender. They aligned the facial shells of a second group of Class III subjects with the average template and compared their differences. They concluded that Class III subjects differed from the average face mainly in the lower two-thirds, but in more than half the sample, the Class III subjects also differed in the upper third of the face. They found that morphologic face heights were significantly higher in the males than the females in both average and Class III subjects. Their study also indicated a tendency for a left-side chin deviation in Class III Slovenian subjects. Class III malocclusions can have physical, psychological and social effects[27]. Three-dimensional facial imaging is beneficial in evaluating facial morphology of soft tissue, and population-specific analyses are valuable diagnostic tool for management of Class III malocclusions.

Asymmetry is defined as any deviation from perfect symmetry, and during development imbalances in growth will result in some degree of asymmetry[28]. The magnitude of asymmetry ranges from nearly undetectable to a gross abnormality. The threshold of acceptable asymmetry is subjective, and there is an allowable amount of asymmetry in a "normal face". According to Farkas, up to 3 mm of deviation is indiscernible in a normal face, while Peck and Peck state that the difference between right and left orbits can be up to 4 mm without the appearance of facial asymmetry[29,30]. Mild facial asymmetries are common in typical growth patterns. Previously documented proportions of facial asymmetry are 25% and 34% in the United States[31,32] and 25% in China[33]. Severt and Proffit reported that greater than 85% of their sample of patients with dentofacial deformity had a laterality toward the left side. Severe and pathologic asymmetries are a feature of disordered growth as a consequence of congenital or environmental causes such as anomalies or trauma. Accurate evaluation of facial asymmetry is crucial in orthodontic practice. In most cases, the presence and degree of facial asymmetry can be diagnosed using postero-anterior cephalometry (PA) [34,35], but does not always provide accurate information due to possible distortion and magnification errors. It is recommended that a 3-dimensional analysis be performed when postero-anterior cephalometry does not provide the information for a thorough and accurate diagnosis. A systematic review advised caution against using panoramic radiographs for assessing mandibular asymmetry[36]. While the vertical measurements were more accurate than horizontal or angular measurements, they were still not true presentations of the objects they corresponded to. Clinicians need to be aware of the limitations and applications of the specific images they are using.

Haraguchi et al investigated the correlation of skeletal facial laterality in patients with a skeletal class III with postnatal factors[37]. 220 Japanese adults needing combined orthodontic treatment and orthognathic surgery were divided into two groups. The group classified as the postnatal factor group had either received treatment with a chin cap previously, exhibited clinical symptoms of TMJ disorders, or reported a history of trauma to the face or jaws. They defined asymmetry as any landmark deviating more than 2 mm from the midline using PA cephalometry. The lower jaw showed more asymmetry than the upper jaw, and left-sided facial laterality occurred more often than the right side. In the Nonpostnatal factor group, 80.6% had an asymmetry showing chin deviation to the left side, whereas 68.1% showed asymmetry in the Postnatal factor group. The subjects with TMJ problems showed equal chances of left and right side chin deviation. They concluded that the postnatal factors do not increase the chance of chin deviation to the left, but rather may mask this tendency for left sided laterality. In this sample, a high proportion of skeletal class III patients manifested a visible facial asymmetry.

There are different methods for calculating facial asymmetry. One method is to divided the face into right and left hemifaces to compare them using morphometric measurements[38]. However, this often fails to represent the complete spatial arrangement. Alternatively, asymmetry can be assessed by comparing a complete face with a mirror image of itself. The asymmetry can be quantified using anthropometric mask mapping (land-marking) and robust superimposition which provides color maps for measuring the magnitude of the spatial discrepancy. The robust superimposition eliminates the orientation and position differences of the original and mirrored configuration. Claes et al used this protocol on a data set of facial images to determine that the asymmetry was mainly located on the lower two-thirds of the face[39]. Males tended to have more extensive asymmetry due to the larger size and more prominent features. Huang et al visually depicted facial asymmetry using an asymmetry index. They looked at 60 Chinese adults, equal numbers for male and female. They digitized 16 landmarks as defined by Farkas[40] and plotted the asymmetry index on a facial symmetry diagram[41]. Distances to each landmark from references planes going through nasion were measured in three dimensions. The differences between the right and left side indicated the discrepancy, and this was plotted as a visual diagram. The mean asymmetry index varied from 0.76 to 2.82 mm, with a standard deviation from 0.42 to 1.50. They found that facial asymmetry was more evident when moving downward on the face. There was greater variation in the lower face than the upper face. They suggested that a facial scan of soft tissue should be matched with a hard tissue scan to study the correlation between soft and hard tissue. The asymmetry index was first proposed by Katsumata et al for the assessment of facial asymmetry in 3D CT images[42]. Facial asymmetry is determined by both hard and soft tissue. While soft tissue reflects the underlying hard tissue structures, soft tissue may provide a compensation for hard tissue asymmetry. On the other hand, it could potentially exacerbate the asymmetry. The impact of facial asymmetry in visual perception was studied by Meyer-Marcotty[43]. They analyzed the degree and localization of facial asymmetry in adult patients with cleft lip and palate and its impact on the visual perception of faces. It was found that the greatest asymmetry was in the midface in the cleft lip and palate patients. The greater the facial asymmetry near the midline of the face, the more negative the evaluation of the faces. Symmetry is therefore a decisive factor in visual perception and rating.

Hwang et al[44] used cone beam computed tomography (CBCT) to evaluated soft tissue asymmetry between the right and left face. They found a high variability in mean difference values, ranging from 0.6 – 4.6 mm. There was an increase in lower and lateral positioning of the landmarks. Transverse, sagittal, and vertical differences contributed to the overall differences. They found no significant sex differences, and the midline landmarks showed smaller values compared to bilateral landmarks. These studies support the use of 3D-CT imaging technique as a practical method of evaluating the morphology of facial asymmetry.

Much of the focus has been on soft tissue analysis. Some have used 3D imaging to analyze hard tissue asymmetry in the mandible. You et al investigated dimensional changes in patients with facial asymmetry and mandibular prognathism[45]. Subjects were divided into the symmetry group and the asymmetry group according to the degree of deviation of menton. They found the asymmetry group to have significantly longer condylar and body unit lengths, and significantly shorter coronoid unit length on the non-deviated side. They concluded that both condylar and body units contribute to mandibular asymmetry. Hwang et al also described the use of 3D images in diagnosis asymmetry of the mandible[46]. They evaluated six factors (maxillary height, ramus length, frontal ramal inclination, lateral ramal inclination, mandibular body length, and mandibular body height) on a 3D spiral CT image and compared it to a PA cephalogram of the same patient. All factors contributed to chin deviation, but the difference in ramal inclination had masked the difference in ramus length in the PA cephalometry. They noted the inherent limitations of 2-dimensional imaging and recommended further comprehensive analysis with 3D imaging for complete and correct diagnosis. Previous studies have described soft tissue asymmetry of the face and hard tissue asymmetry of the jaws, but few have investigated the interaction between them. The aim of this study is to evaluate hard tissue asymmetry and soft tissue asymmetry within the same patient in a specific population group, adult Chinese with skeletal class III malocclusions. In addition to determining the presence of hard and soft tissue asymmetry, other objectives are to identify a tendency for laterality of hard and soft tissue and to explore the relationship between hard and soft tissue in regards to facial asymmetry.

CHAPTER 2

MATERIALS AND METHODS

Selection of Subjects

Subjects were voluntarily recruited from the Stomatology Hospital, in Xi'an Jiaotong University, Department of Orthodontics. The inclusion criteria were: 1) of Chinese descent, 2) between 16-35 years of age, 3) no restriction on body mass index, 4) diagnosed skeletal Class III malocclusion determined by an ANB angle of less than 0°, and 5) no gross craniofacial anomalies or other forms of pathology. The study was approved by the Institutional Review Board at University of Alabama at Birmingham. Informed consent was obtained from all subjects in the study. All consenting patients were subject to a 3D soft tissue image and a CBCT taken within two weeks of the soft tissue image.

Imaging Systems

The imaging system used was the portable 3dMD face system (3dMD LLC, Atlanta, Ga). This is a structured light system with a combination of stereo-photogrammetry (a technique used to acquire 3D objects from stereoscopic images) and the structured light technique[47]. The 3dMD system is set up in a multi-camera configuration, with 3 cameras on each side (1 color, 2 infrared) to capture photo-realistic quality pictures. The image is captured with a random light pattern projected onto the subject and the multiple synchronized digital cameras set at various angles in an optimum configuration. The system is able to capture full facial images from ear to ear and under the chin in 1.5 ms at the highest resolution. The accuracy is less than 0.5 mm, according to the manufacturer, and the quoted clinical accuracy is 1.5% of the total observed variance[48]. Three -dimensional surface images captured by surface acquisition systems are easily repeatable, and 3D landmark data can be acquired with a high degree of precision[49,50]. This imaging system has been validated in terms of its accuracy and reliability[48,51]. Prior to image capture, camera alignment was confirmed on the 3dMD unit using a calibration board and a simple user calibration routine. The images were acquired with the subjects in natural head position. The subjects sat in an adjustable chair and were asked to look into a mirror, located centrally between the two cameras, at their own eyes (Figure 1). Appropriate adjustments to the seat height and angle were carried out to achieve proper natural head position. The subjects were asked to relax such that their facial musculature was neutral and also to remain still while the image was captured.

Figure 1. Two stereo camera viewpoints captured by the 3dMDface system. The subject's facial musculature should be relaxed.

Each participant was also required to have a CBCT taken (PaX-Zenith3D, EWOO-VATECH, Korea). The cone beam scan was captured at 90 kV, 4 mA with the patient in an upright position in maximum intercuspation and Frankfort horizontal plane parallel to the floor.

Image Segmentation

Both hard and soft tissue images were analyzed using 3dMD Vultus software. The 3dMD images were first segmented to create a skin. Segmentation separates a part from its surrounding structures. The skin and the DICOM image of the CBCT were manually aligned for best fit. The images were then registered together achieving a root mean square of 0.5 or less (Figure 2).

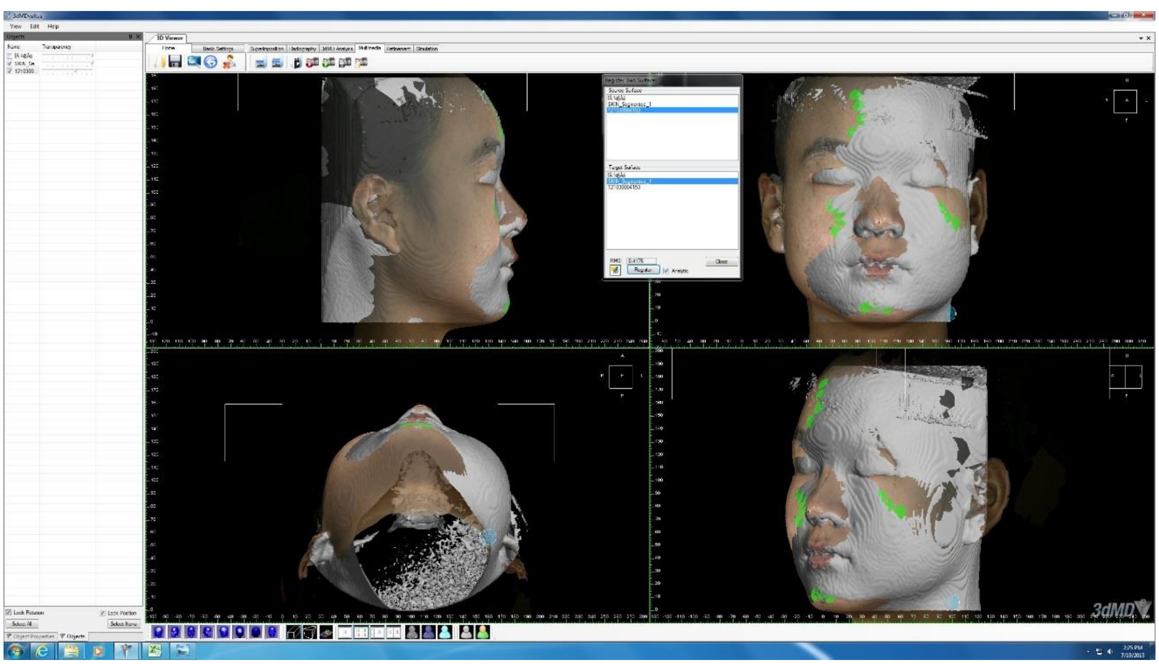

Figure 2. Best fit registration of the soft tissue skin and DICOM image in 3dMD Vultus. RMS values must be less than 0.5 mm.

Land-marking

The registered images were aligned to the axes of the coordinate planes to account for any deviations in head position, such as rotation or tip (Figure 3). Once the orientation of the faces was standardized, the landmarks could be plotted on the coordinate system.

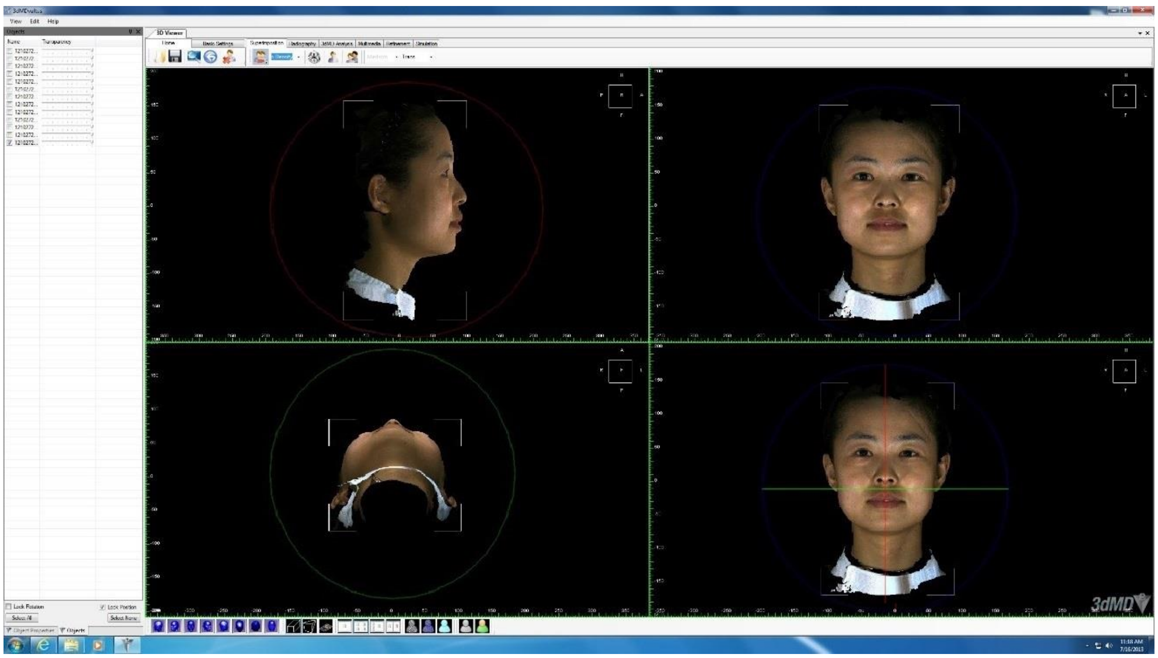

Figure 3. Alignment of the registered image to the coordinate axes (reference planes). The face is made as parallel to the axes in all dimensions to eliminate positioning errors during image capture.

Using soft tissue nasion as a base reference point, a template of midline and paired landmarks were plotted on hard tissue and soft tissue images (Table 1). For each hard tissue landmark, a corresponding soft tissue landmark was chosen that was in close proximity to the hard tissue landmark. There was not always a direct relationship between the hard and soft tissue landmarks, but a soft tissue point was chosen that was readily identifiable and could be compared to the nearest hard tissue landmark (Figures 4, 5).

Figure 4. Plotting hard tissue landmarks viewed in three planes of space.

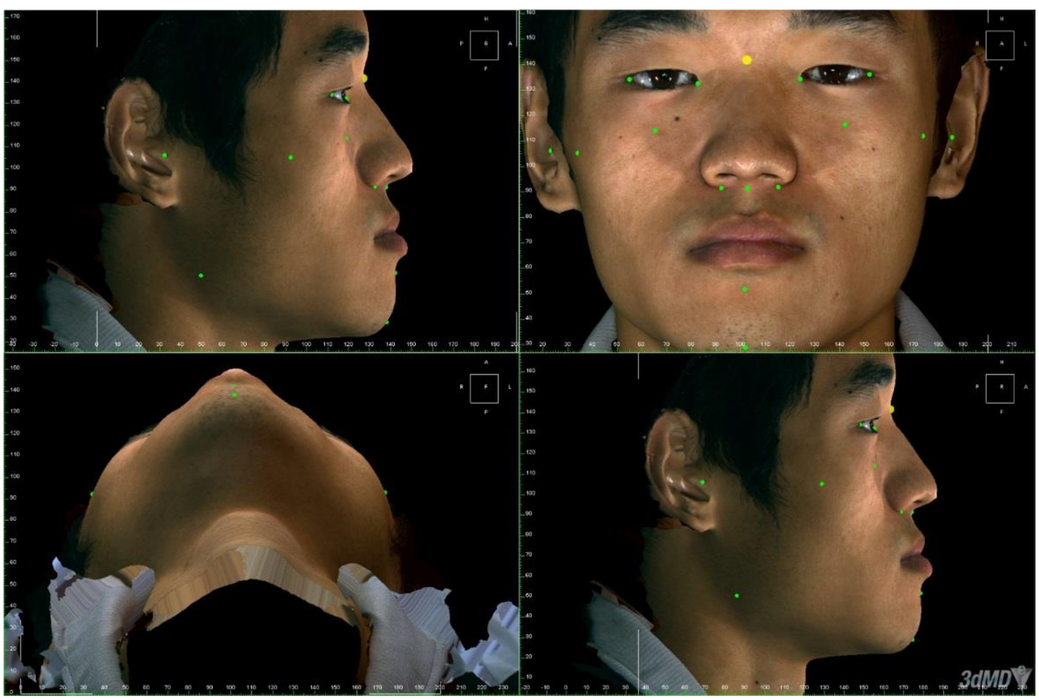

Figure 5. Plotting hard tissue landmarks viewed in three planes of space.

All landmarking was performed by one operator/orthodontist (FP) to maintain consistency, taking advantage of the different views to accurately plot the landmarks. The distance of each landmark to the reference planes is measured as x, y, z. Each landmark produces coordinates in the x, y, and z direction, as described by a three-dimensional Carestian coordinate system. In the X direction, a positive value indicates the left side of the subject's face, and a negative value the right hemiface. For the Y-axis, a positive value is superior and a negative value inferior. For the Z direction, a negative value indicates posterior positioning, and a positive value the opposite (Figure 6).

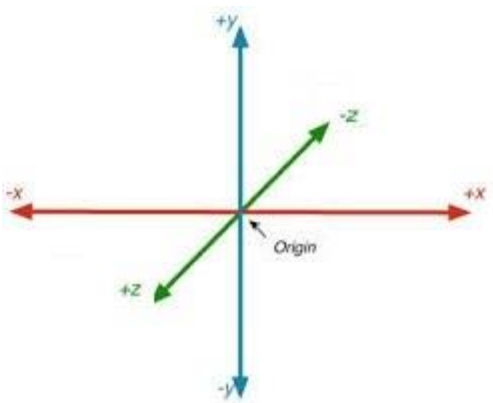

Figure 6. Three-dimensional coordinate system for landmarking

The x, y, and z values for the reference point soft tissue nasion were all zero. Once the hard tissue and soft tissue points were plotted, the values for the landmarks were then exported into Microsoft Excel spreadsheets for analysis. The coordinates in each plane of space were averaged for all the patients to be used in the evaluation of facial asymmetry. The distance of each landmark to the vertical reference plane running through nasion were measured in all three planes of space. For bilateral landmarks, the difference between the left and right side indicated the discrepancy in three dimensions. A positive value of Left x – Right x indicates that the landmark is more deviated to the left. If this value were negative, the landmark would be more towards the right. The most interesting part of this study is the comparison of the differences between hard tissue deviation and soft tissue deviation on the same image. Not only could we calculate the measurement of deviation from the reference plane of nasion, but also the difference between soft tissue and hard tissue for a given point, indicating the degree of soft tissue compensation.

Table 1. Hard tissue landmarks defined and their soft tissue counterpart.

Hard tissue point	Name	Description	Proposed Soft Tissue Counterpart Point
N	Nasion	The most anterior point on the fronto-nasal suture in the sagittal plane.	N'
Mo_R	Medial Orbitale Right	The most medial part of the orbital rim in the frontal view.	En_R
Mo_L	Medial Orbitale Left	The most medial part of the orbital rim in the frontal view.	En_L
FZ_R	Frontozygomatic Point Right	Most medial and anterior point of each frontozygomatic suture at the level of the lateral orbital rim.	Ex_R
FZ_L	Frontozygomatic Point Left	Most medial and anterior point of each frontozygomatic suture at the level of the lateral orbital rim.	Ex_L
Or_R	Orbitale Right	The most inferior point of the right infraorbital rim.	Or'_R
Or_L	Orbitale Left	The most inferior point of the left infraorbital rim.	Or'_L
ZT_R	Zygotemporal Right	The most superior part of the zygotemporal suture, seen from a lateral view.	Zy'_R
ZT_L	Zygotemporal Left	The most superior part of the zygotemporal suture, seen from a lateral view.	Zy'_L
Al_R	Alare Right	The most lateral and inferior points on the nasal aperature in the frontal view.	Sbal_R

Al_L	Alare Left	The most lateral and inferior points on the nasal aperature in the frontal view.	Sbal_L
ANS	Anterior Nasal Spine	The anterior tip of the sharp bony process of the maxilla at the lower margin of the anterior nasal opening.	Sn
Point B	Supramentale	The innermost point on the contour of the mandible between the incisor tooth and the bony chin.	B'
Gn	Gnathion	A point located by the taking the midpoint between the anterior (pogonion) and inferior (menton) points of the bony chin.	Gn'
Go_R	Gonion Right	A point on the curvature of the angle of the mandible located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible.	Go'_R
Go_L	Gonion Left	A point on the curvature of the angle of the mandible located by bisecting the angle formed by lines tangent to the posterior ramus and the inferior border of the mandible.	Go'_L
LCo_R	Lateral Mandibular Condyle Right	Middle-lateral-most point on the external surface of the condyle from a frontal view.	Tr_R
LCo_L	Lateral Mandibular Condyle Left	Middle-lateral-most point on the external surface of the condyle from a frontal view.	Tr_L

CHAPTER 3

RESULTS

180 Chinese adults volunteered to participate in the study and consented to having their images taken. Out of these, 38 subjects were diagnosed, through CBCT-generated lateral cephalograms, to have a skeletal Class III malocclusion, defined by an ANB angle of less than 0°. These 38 patients, 14 females and 24 males, would constitute the sample size for data analysis. The average age was 21.3 years (range 16 – 29 years) and an average BMI of 21.4 (range 16.8 – 30.5). Normal Asian body mass index is 18.5 – 24, based on the Asian American Diabetes Initiative at the Joslin Diabetes Center[52].

Hard Tissue Data

The landmarks were averaged for all patients, and the mean value for each coordinate was used for the calculations. In the X-direction, the amount of deviation for midline structures and the difference between the right and left points for bilateral landmarks ranged from 0.345 - 2.993 mm for hard tissue and 0.240 - 2.018 mm for soft tissue (Table 2). A positive value for the difference between the Left minus the Right landmark represents a larger left side. Overall, it appears that is the left hemiface is larger for both hard tissue and soft tissue. The majority of patients demonstrated left-sided laterality for both hard tissue Gnathion (86.84%) and B point (65.79%) and their soft tissue counterparts (68.42% and 73.68%, respectively).

Table 2. Right and left deviations in the X-axis.

X-direction	Hard Tissue	Soft Tissue
[N]	0.535	0
[MO-L]-[MO_R]	1.214	0.744
[FZ_L]-[FZ_R]	1.722	0.240
[Or'_L]-[Or'_R]	2.547	2.018
[ZT_L]-[ZT_R]	1.651	1.15
[Al_L]-[Al_R]	1.282	0.297
[Go_L]-[Go_R]	2.993	1.164
[LCo_L]-[LCo_R]	1.128	0.452
[ANS]	0.345	0.251
[Point B]	1.337	1.025
[Gn]	1.497	1.915

Soft Tissue Data

Compared with soft-tissue, the hard-tissue landmarks are more deviated from the midline except for Gnathion. In general, there was greater difference between hard tissue and soft tissue for points further from the midline, particularly the lateral condyle and tragion and gonion. These observations indicated that there is more underlying hard tissue asymmetry than what the soft tissue reveals, and this is especially true for more lateral areas. Most of the points show a negative value for the compensation difference. This is calculated by subtracting the soft tissue compensation of the right side from the soft tissue compensation on the left side. The soft tissue compensation is calculated by subtracting the difference between hard tissue and soft tissue points. Therefore, although the left face is larger, there is more soft tissue compensation on the right side (Table 3).

Table 3. Soft tissue compensation for midline landmarks and the differences for bilateral landmarks. Compensation is the difference between the hard tissue landmark and the overlying soft tissue point.

X-direction	Compensation difference	Compensation
[N]		0.5345
[MO-L]-[MO_R]	-0.4698	
[FZ_L]-[FZ_R]	-0.0508	
[Or'_L]-[Or'_R]	-0.5287	
[ZT_L]-[ZT_R]	-0.4996	
[Al_L]-[Al_R]	-0.9842	
[Go_L]-[Go_R]	-1.8284	
[LCo_L]-[LCo_R]	-0.6764	
[ANS]		0.0938
[Point B]		0.3122
[Gn]		-0.4180

Midline hard tissue landmarks were positioned more to the left than their soft tissue counterparts, and therefore the soft tissue compensation was much greater to the right. In the Y axis, the differences between left and right hard tissue landmarks were mostly negative, indicating that the left side of the face is lower than, or inferior to, the right side of the face. Conversely, the soft tissue differences were mainly positive, indicating that the right of the soft tissue face was more superior. Thus there appears to be a soft tissue compensation mechanism for hard tissue disproportion within the vertical dimension (Table 4). Structures lower in the face, Gonion and Gnathion, had greater variation in this dimension than landmarks of the midface. In the antero-posterior dimension, or Z axis, the more posterior a landmark, the more negative the value. All midline hard tissue structures are located more posterior, and have a negative value, to the corresponding soft tissue landmark. The difference lies in the variability of the overlying soft tissue thickness. The negative values for the difference between absolute values of the right and left sides demonstrate left-sided dominance and more protrusiveness of the left hemiface. Both hard tissue and soft tissue are more protrusive for the left side than for the right side in this sample of patients (Table 5).

Table 4: Hard and soft tissue deviation in the vertical dimension, as well as the difference between the two tissues.

Y-direction	Hard Tissue	Soft Tissue	Difference
[N]	6.0384	0	
[MO-L]-[MO_R]	-0.0753	-0.3210	-0.2457
[Or'_L]-[Or'_R]	-0.5171	0.0239	0.5411
[FZ_L]-[FZ_R]	-0.2809	0.0853	-0.1957
[ZT_L]-[ZT_R]	-0.3479	-0.8269	-0.4790
[Al_L]-[Al_R]	-0.1324	0.1499	0.2823
[Go_L]-[Go_R]	-1.0795	0.1678	1.2473
[LCo_L]-[LCo_R]	0.4258	-0.6084	-1.0342
[ANS]	-46.035	-50.8414	4.8064
[Point B]	-88.7627	-89.2315	0.4688
[Gn]	-108.222	-113.949	5.7267

Table 5: Hard and soft tissue deviation in the sagittal (Z) dimension, as well as the difference between the two tissues.

Z-direction	**Hard**	**Soft**	**Difference**
[N]	-4.7449	0	
[MO-L]-[MO_R]	-0.0733	-0.1835	0.1102
[Or'_L]-[Or'_R]	-0.7513	-0.3260	-0.4253
[FZ_L]-[FZ_R]	-0.4976	-0.6086	0.1111
[ZT_L]-[ZT_R]	-0.8652	-0.0634	-0.8019
[Al_L]-[Al_R]	-0.1117	0.3074	0.1957
[Go_L]-[Go_R]	-0.6749	-0.4421	-0.2329
[LCo_L]-[LCo_R]	-1.1763	-1.5787	-0.4024
[ANS]	-1.9832	8.8333	-10.817
[Point B]	-3.0301	7.6332	-10.6634
[Gn]	-3.0296	4.0188	-7.0484

CHAPTER 4

DISCUSSION

In his article, Spalj describes maxillary and mandibular sagittal skeletal discrepancies and the resulting dental compensation mechanisms[1]. This study identifies the presence of soft tissue camouflage for hard tissue asymmetries in all three planes of spacing using 3D hard and soft tissue imaging.

180 Chinese adults volunteered for the study. There were 96 Class I, 46 Class II, and 38 Class III subjects. Only the 38 Class III subjects were used in the current study, representing 21.1% of the random population who consented for imaging. The prevalence of class III malocclusions in our sample is significantly higher than the Caucasian population, consistent with the findings by Soh et al and Tang et al[11,12].

Patients with a class III malocclusion have a higher prevalence of facial asymmetry[53]. Ko et al found that more than 85% of their patients with skeletal Class III had facial asymmetry and deviated structural midlines[54]. Therefore it was appropriate to select class III malocclusions for the study. One of the difficulties in quantifying asymmetry and determining its effect on treatment is the subjectivity of how much deviation from absolute symmetry is acceptable. In other words, the threshold for tolerable asymmetry is variable, and the decision to address the issue in the treatment plan is contingent upon the severity as seen by the individual and its effect on the quality of life. While it is difficult to specify a range of “normal” asymmetry, the values of soft tissue landmark variation were, in general, larger than the variation in hard tissue landmarks. The larger values may indicate that the acceptable scope of soft tissue asymmetry is wider than in hard tissue. In this group of Class III subjects, patients with craniofacial syndromes were excluded to minimize any extraneous variables that might contribute to gross asymmetries. Therefore the sample consisted of people who might be considered “acceptable” in terms of facial balance. The results may have been more pronounced or altered given a population with more extreme asymmetrical disharmony.

Previous studies have reported on the presence of soft tissue asymmetry while some studies attempted to quantify the amount of asymmetry in normal populations. Still others evaluated asymmetry of the hard tissue mandible and face. The current study is novel in that the hard tissue and soft tissue asymmetries are both analyzed relative to the same reference point, and we have attempted to elucidate a compensation mechanism for the interaction between the hard and soft tissues. The findings indicate that there is indeed a common prevalence of skeletal asymmetry, although mild. The soft tissue compensation appears to mask the discrepancy in an attempt to maintain soft tissue esthetic proportions, but is not perfectly successful. While the hard tissue deviation favors the left side and the soft tissue compensation is greater on the right side, there still remains a proportionally larger left hemiface.

Selection of a proper reference plane is critical in the evaluation of asymmetry[55]. The results will differ depending on the position of the reference plane. Some of the commonly used reference points are soft tissue nasion and landmarks of the eye. Meyer-Marcotty, Ferrario, and Ras et al used a constructed plane passing through soft tissue nasion and perpendicular to the plane connecting the two exocanthi[38,43,56]. Other studies have used hard tissue landmarks to construct their reference planes, using points such as opisthion, orbitale, nasion, and porion[37,44,46]. In our study, we chose to use a single reference point, soft tissue Nasion, from which to measure the remaining landmarks. The face was oriented according to the coordinate planes built into the software. This would eliminate variability in measurements as a result of head positioning. As an example, if a patient's head was tipped to one side and the image was measured off a standard vertical reference plane, then there would be an artificial asymmetry introduced all three planes of space.

The existence of facial asymmetry is well-documented in literature, but the specific etiology remains unclear. The proposed contributing factors are environmental, genetic, and a combination of both. Some of these include disc displacement, joint pathologies[36], trauma[37], myogenic problems, growth disorders, and a possible disruption of neural crest cell migration. There also may be an inherent potential for dominant growth on one side in humans, as suggested by the positioning of the heart and the spleen, the relative independence of individual mandibular skeletal units, and the identification of genes that contribute to the establishment of left and right polarity in mice.

According to the literature, mandibular asymmetry favors the left side and the lower third of the face. Like other studies, we determined a laterality towards the left side of the face and a resulting larger left hemi-face. The hard tissue landmarks were deviated to the left, as well as being more inferior and protrusive on the left side. In all planes of space, the soft tissue exhibited the opposite pattern, in what appears to be an attempt at compensation. We noticed greater differences between hard and soft tissue for points further from the midline, particularly the lateral condyle and tragion. In all points, we found that the soft tissue exhibited some form of compensation, albeit not to the extent of complete elimination of the asymmetry.

There were several limitations to the study. First, the sample was fairly selective. This study included 38 skeletal class III patients, a relatively small number compared to the vast Chinese population. A large number of the subjects were recruited from the medical center, and therefore the sample may not be truly representative of the average Chinese population. The study was limited to Chinese participants. Other ethnic groups need to be studied in order to delineate their own range of variation. Our sample did not contain any subjects with craniofacial anomalies or gross asymmetries. Therefore any asymmetry that was detected could be considered mild, and ready compensated for by the soft tissue. In order to appreciate the true effects of asymmetry on facial esthetics and possibly the underlying compensation mechanisms, a sample consisting of subjects with more readily noticeable facial asymmetry could be studied in the same manner as the present study. Another limitation is the assumption that the subjects were positioned properly during both the soft tissue and hard tissue image capture. Changes in muscular tone or any hint of facial expression could have affected the soft tissue image and affected the registration of the soft and hard tissue images. It is important that the images are taken with the musculature completed relaxed.

This study reiterates the importance of proper diagnosis and planning for skeletal asymmetries, and demonstrates the capabilities of using three-dimensional imaging to compare hard and soft tissue simultaneously. We have noted a common prevalence of hard tissue asymmetry in Chinese skeletal class III malocclusions and described the overlying soft tissue compensation in three planes of space. This has important implications for the orthodontist. It is not uncommon to see patients with an asymmetric occlusion within a seemingly symmetrical extraoral face, and in moderate to severe case, surgery may be the best treatment option. Likewise, we have shown that an underlying skeletal asymmetry may be compensated for by the soft tissue. A misdiagnosis of skeletal asymmetry may lead to a difficult treatment, extended treatment time, or compromised result. Three-dimensional imaging allows a more thorough evaluation of the asymmetry. Future studies in this area of interest would benefit from having a larger sample size and patients with more severe asymmetries. It would also be useful to analyze gender-specific compensations, as previous studies have noted more asymmetry in males[39]. Furthermore, it would be interesting to find out if these patterns of asymmetry and soft tissue compensation exist in class I and class II malocclusions.

REFERENCE MATERIAL

1. Spalj S, Mestrovic S, Lapter Varga M, Slaj M. Skeletal components of class III malocclusions and compensation mechanisms. J Oral Rehabil 2008;35:629-637.

2. Henry W. Fields Jr. DMSWRP. By William R. Proffit - Contemporary Orthodontics: 4th (fourth) Edition. Elsevier Health Sciences; 2007.

3. Sanborn RT. Differences Between the Facial Skeletal Patterns Of Class III Malocclusion and Normal Occlusion*. The Angle Orthodontist 1955;25:208-222.

4. Dietrich UC. Morphological variability of skeletal Class 3 relationships as revealed by cephalometric analysis. Rep Congr Eur Orthod Soc 1970:131-143.

5. Ellis E, 3rd, McNamara JA, Jr. Components of adult Class III malocclusion. J Oral Maxillofac Surg 1984;42:295-305.

6. Guyer EC, Ellis EE, 3rd, McNamara JA, Jr., Behrents RG. Components of class III malocclusion in juveniles and adolescents. Angle Orthod 1986;56:7-30.

7. Jacobson A. Radiographic Cephalometry: From Basics to 3-d Imaging. Quintessence Pub Co; 2006.

8. Moate SJ, Darendeliler MA. Cephalometric norms for the Chinese: a compilation of existing data. Aust Orthod J 2002;18:19-26.

9. Gu Y, McNamara JA, Jr., Sigler LM, Baccetti T. Comparison of craniofacial characteristics of typical Chinese and Caucasian young adults. Eur J Orthod 2011;33:205-211.

10. Lew KK, Ho KK, Keng SB, Ho KH. Soft-tissue cephalometric norms in Chinese adults with esthetic facial profiles. J Oral Maxillofac Surg 1992;50:1184-1189; discussion 1189-1190.

11. Soh J, Sandham A, Chan YH. Occlusal status in Asian male adults: prevalence and ethnic variation. Angle Orthod 2005;75:814-820.

12. Tang EL. Occlusal features of Chinese adults in Hong Kong. Aust Orthod J 1994;13:159-163.

13. Burns NR, Musich DR, Martin C, Razmus T, Gunel E, Ngan P. Class III camouflage treatment: what are the limits? Am J Orthod Dentofacial Orthop 2010;137:9.e1-9.e13; discussion 19-11.

14. Abdelnaby YL, Nassar EA. Chin cup effects using two different force magnitudes in the management of Class III malocclusions. http://dx.doi.org/10.2319/022210-110.1 2010.

15. Liu ZP, Li CJ, Hu HK, Chen JW, Li F, Zou SJ. Efficacy of short-term chincup therapy for mandibular growth retardation in Class III malocclusion. Angle Orthod 2011;81:162-168.

16. Macdonald KE, Kapust AJ, Turley PK. Cephalometric changes after the correction of class III malocclusion with maxillary expansion/facemask therapy. Am J Orthod Dentofacial Orthop 1999;116:13-24.

17. Masucci C, Franchi L, Defraia E, Mucedero M, Cozza P, Baccetti T. Stability of rapid maxillary expansion and facemask therapy: a long-term controlled study. Am J Orthod Dentofacial Orthop 2011;140:493-500.

18. Turley PK. Managing the developing Class III malocclusion with palatal expansion and facemask therapy. Am J Orthod Dentofacial Orthop 2002;122:349-352.

19. Bailey L, Cevidanes LH, Proffit WR. Stability and predictability of orthognathic surgery. Am J Orthod Dentofacial Orthop 2004;126:273-277.

20. Bergersen EO. Enlargement and distortion in cephalometric radiography: compensation tables for linear measurements. Angle Orthod 1980;50:230-244.

21. Cevidanes LH, Styner MA, Proffit WR. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. Am J Orthod Dentofacial Orthop 2006;129:611-618.

22. Kau CH, Richmond S, Savio C, Mallorie C. Measuring adult facial morphology in three dimensions. Angle Orthod 2006;76:773-778.

23. Kau CH, Richmond S, Zhurov A, Ovsenik M, Tawfik W, Borbely P et al. Use of 3-dimensional surface acquisition to study facial morphology in 5 populations. Am J Orthod Dentofacial Orthop 2010;137:S56.e51-59; discussion S56-57.

24. Hajeer MY, Millett DT, Ayoub AF, Siebert JP. Applications of 3D imaging in orthodontics: part I. J Orthod 2004;31:62-70.

25. Hajeer MY, Millett DT, Ayoub AF, Siebert JP. Applications of 3D imaging in orthodontics: part II. J Orthod 2004;31:154-162.

26. Bozic M, Kau CH, Richmond S, Ovsenik M, Hren NI. Novel method of 3-dimensional soft-tissue analysis for Class III patients. Am J Orthod Dentofacial Orthop 2010;138:758-769.

27. Bernabe E, Sheiham A, de Oliveira CM. Condition-specific impacts on quality of life attributed to malocclusion by adolescents with normal occlusion and Class I, II and III malocclusion. Angle Orthod 2008;78:977-982.

28. Hamada H, Meno C, Watanabe D, Saijoh Y. Establishment of vertebrate left|[ndash]|right asymmetry. Nature Reviews Genetics 2002;3:103-113.

29. Farkas LG, Cheung G. Facial asymmetry in healthy North American Caucasians. An anthropometrical study. Angle Orthod 1981;51:70-77.

30. Peck S, Peck L, Kataja M. Skeletal asymmetry in esthetically pleasing faces. Angle Orthodontist 1991;61:43-48.

31. Proffit WR, Phillips C, Dann Ct. Who seeks surgical-orthodontic treatment? Int J Adult Orthodon Orthognath Surg 1990;5:153-160.

32. Severt TR, Proffit WR. The prevalence of facial asymmetry in the dentofacial deformities population at the University of North Carolina. Int J Adult Orthodon Orthognath Surg 1997;12:171-176.

33. Samman N, Tong AC, Cheung DL, Tideman H. Analysis of 300 dentofacial deformities in Hong Kong. Int J Adult Orthodon Orthognath Surg 1992;7:181-185.

34. Letzer GM, Kronman JH. A posteroanterior cephalometric evaluation of craniofacial asymmetry. Angle Orthod 1967;37:205-211.

35. Hwang HS LK, Park JY, Kang BC, Park JW, Lee JS. Development of posteroanterior cephalometric analysis for the diagnosis of facial asymmetry. J Korean Dent Assoc 2004;42:219-231.

36. Van Elslande DC, Russett SJ, Major PW, Flores-Mir C. Mandibular asymmetry diagnosis with panoramic imaging. Am J Orthod Dentofacial Orthop 2008;134:183-192.

37. Haraguchi S, Takada K, Yasuda Y. Facial asymmetry in subjects with skeletal Class III deformity. Angle Orthod 2002;72:28-35.

38. Ferrario VF, Sforza C, Ciusa V, Dellavia C, Tartaglia GM. The effect of sex and age on facial asymmetry in healthy subjects: a cross-sectional study from adolescence to mid-adulthood. J Oral Maxillofac Surg 2001;59:382-388.

39. Claes P, Walters M, Vandermeulen D, Clement JG. Spatially-dense 3D facial asymmetry assessment in both typical and disordered growth. J Anat 2011;219:444-455.

40. Farkas LG. Anthropometry of the head and face. Raven Press; 1994.

41. Huang CS, Liu XQ, Chen YR. Facial asymmetry index in normal young adults. Orthod Craniofac Res 2013;16:97-104.

42. Katsumata A, Fujishita M, Maeda M, Ariji Y, Ariji E, Langlais RP. 3D-CT evaluation of facial asymmetry. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;99:212-220.

43. Meyer-Marcotty P, Alpers GW, Gerdes AB, Stellzig-Eisenhauer A. Impact of facial asymmetry in visual perception: a 3-dimensional data analysis. Am J Orthod Dentofacial Orthop 2010;137:168.e161-168; discussion 168-169.

44. Hwang HS, Yuan D, Jeong KH, Uhm GS, Cho JH, Yoon SJ. Three-dimensional soft tissue analysis for the evaluation of facial asymmetry in normal occlusion individuals. Korean J Orthod 2012;42:56-63.

45. You KH, Lee KJ, Lee SH, Baik HS. Three-dimensional computed tomography analysis of mandibular morphology in patients with facial asymmetry and mandibular prognathism. Am J Orthod Dentofacial Orthop 2010;138:540.e541-548; discussion 540-541.

46. Hwang H-S, Hwang CH, Lee K-H, Kang B-C. Maxillofacial 3-dimensional image analysis for the diagnosis of facial asymmetry. American Journal of Orthodontics and Dentofacial Orthopedics 2006;130:779-785.

47. Kau CH, Richmond S, Incrapera A, English J, Xia JJ. Three-dimensional surface acquisition systems for the study of facial morphology and their application to maxillofacial surgery. Int J Med Robot 2007;3:97-110.

48. Aldridge K, Boyadjiev SA, Capone GT, DeLeon VB, Richtsmeier JT. Precision and error of three-dimensional phenotypic measures acquired from 3dMD photogrammetric images. Am J Med Genet A 2005;138a:247-253.

49. Kau CH, Hunter LM, Hingston EJ. A different look: 3-dimensional facial imaging of a child with Binder syndrome. Am J Orthod Dentofacial Orthop 2007;132:704-709.

50. Kau CH, Zhurov A, Richmond S, Cronin A, Savio C, Mallorie C. Facial templates: a new perspective in three dimensions. Orthod Craniofac Res 2006;9:10-17.

51. Weinberg SM, Naidoo S, Govier DP, Martin RA, Kane AA, Marazita ML. Anthropometric precision and accuracy of digital three-dimensional photogrammetry: comparing the Genex and 3dMD imaging systems with one another and with direct anthropometry. J Craniofac Surg 2006;17:477-483.

52. Center JD. BMI for Asian and Asian American Adults; 2011.

53. Vasconcelos BC, Goncalves F, Andrade A, Guillen M, Landim F. Mandibular asymmetry: literature review and case report. Braz J Otorhinolaryngol 2012;78:137.

54. Ko EW-C, Huang CS, Chen YR. Characteristics and Corrective Outcome of Face Asymmetry by Orthognathic Surgery. Journal of Oral and Maxillofacial Surgery 2009;67:2201-2209.

55. Vig PS, Hewitt AB. Asymmetry of the Human Facial Skeleton. The Angle Orthodontist 1975;45:125-129.

56. Ras F, Habets LL, van Ginkel FC, Prahl-Andersen B. Method for quantifying facial asymmetry in three dimensions using stereophotogrammetry. Angle Orthod 1995;65:233-239.

APPENDIX A

IRB APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on January 24, 2017. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56.

Principal Investigator:	KAU, CHUNG HOW
Co-Investigator(s):	
Protocol Number:	**X120813003**
Protocol Title:	*3–Dimensional Soft – Tissue analysis for adult Chinese patients with Class II malocclusion*

The IRB reviewed and approved the above named project on 10-2-12. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 10-2-12

Date IRB Approval Issued: 10-2-12

Marilyn Doss

Marilyn Doss, M.A.
Vice Chair of the Institutional Review
Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

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