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We hereby approve the thesis of

Austin Phoenix

Candidate for the degree Master of Science

in Dentistry.

Signed: _____ (Chairperson)

Kristin P. Strohl

Suchitra Nelson

D. Beeson DDS MS

Date: 8/22/07

CHANGES IN HYOID BONE POSITION FOLLOWING RAPID PALATAL EXPANSION IN ADOLESCENTS

by

AUSTIN PHOENIX

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry

Thesis Advisor: Mark G. Hans, D.D.S., M.S.D.

Department of Orthodontics

School of Dental Medicine

CASE WESTERN RESERVE UNIVERSITY

January 18, 2008

CHANGES IN HYOID BONE POSITION FOLLOWING RAPID PALATAL EXPANSION IN ADOLESCENTS

Abstract

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Previous studies have shown that rapid palatal expansion decreases nasal resistance and that long tongues and low hyoid bone position are associated with snoring and increased nasal resistance. The purpose of this study was to examine changes in hyoid to mandibular plane distance (H-MP) and tongue length between children who had orthodontic treatment with RPE and children who had orthodontic treatment without RPE.

Lateral and frontal cephalometric radiographs of 138 orthodontic patients treated with RPE and 148 control patients treated without RPE were used to measure pre-treatment (T1) and post-treatment (T2) intermolar distance (IM), lateronasal width (LNW), hyoid bone to mandibular plane position (HMP), and tongue length (TL). Medical history of the same patients was used to collect demographic information, as well as history of mouth breathing, difficulty breathing through nose, and previous adeno-tonsillectomy. The samples were group matched by age and gender. Descriptive statistics were collected at T1 and T2 for all measures. Group

means were compared using t-tests and Chi-square test for categorical variables. A level of $p \leq 0.01$ was used to assign statistical significance. Reliability was estimated using intraclass correlation or Kappa statistics.

At T1, the RPE group showed smaller lateronasal width (24.83 ± 1.99 vs. 26.18 ± 2.05) and maxillary first molar width (50.17 ± 2.3 vs. 51.58 ± 2.83). The distance from Hyoid bone to mandibular plane was longer in the RPE group (15.69 ± 3.95 vs. 13.86 ± 3.4). There were no differences at T1 for the categorical variables (tonsils and adenoids removed, mouth breathing and difficulty breathing through nose) or tongue length. The mean changes (T2-T1) in the RPE group were increased lateronasal width (+2.48±1.38 vs. +0.94 ± 1.11 for the non-RPE group) and increased intermolar width (+3.21 ± 1.72 vs. +0.98 ± 1.67). The mean change (T2-T1) in hyoid bone position for the RPE group was -0.68 ± 3.67 mm compared to a +1.1 ± 2.96 mm change for the non-RPE group. All mean changes were statistically significant except those for tongue length. At T2, there were no significant between group differences for lateronasal width, hyoid bone position or tongue length.

In this sample, RPE produced statistically significant changes in HMP distance. Therefore, RPE may have a beneficial effect on upper airway physiology and may benefit children who suffer from Sleep Disordered Breathing and maxillary transverse deficiency.

ACKNOWLEDGEMENTS

I want to thank Dr. Hans for giving me the chance to become a part of the greatest profession in the world, orthodontics.

I want to thank all members of my committee, Drs. Hans, Beeson, Nelson and Strohl, for helping with my project and guidance in preparation of my thesis document.

I want to thank Dr. Beeson for making the clinical experience rich and meaningful and for realizing Dr. Hans' vision in the most gentle and fatherly manner.

Special thanks to my classmates, John, Boyd and Eric, for making the last two years a wonderful experience.

Special thanks to my big brother Sebastian for all the clinical tips and help with treatment planning new patients.

Special thanks to my big brother Jed, whose arrogant expression of the proverbial "tough love" taught me self-reliance and confidence.

Special thanks to our great clinical staff, Amy, Tina, Alex, and Kim, for taking care of us, the residents.

I want to thank my Mom, my Dad, and God for being with me every step of the way, for believing in me, and for supporting me in my endeavors.

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LITERATURE REVIEW

Orthodontic treatment provides many benefits. Improved esthetics and masticatory function are probably the most well known. Because the anatomic floor of the nose and the roof of the mouth are part of the same bone, there has been much interest in the relationship between oral function and breathing. In the last decade orthodontists have become more involved with the treatment of chronic snoring and obstructive sleep apnea syndrome (OSAS). Both conditions are associated with increased nasal resistance. The lateral cephalometric radiograph, taken by orthodontists before and after treatment to assess skeletal and dental changes associated with treatment, can also be used to assess changes in upper airway anatomy. It has also been shown that rapid palatal expansion (RPE) decreases nasal resistance.

Sleep disordered breathing is a general term that covers several conditions that are characterized by recurrent upper airway obstruction which result in episodes of asphyxia and interruption of normal sleep pattern (Ferguson and Fleetman 1995). These conditions include chronic snoring, obstructive sleep hypopnea, and obstructive sleep apnea syndrome. Patients with OSAS have daytime symptoms of sleepiness, inattention, and fatigue resulting from repetitive episodes of partial or complete airway obstruction lasting at least ten seconds which are followed by fall in oxygen saturation,

rise in carbon dioxide, and increased heart rate (Strohl et al. 1984). Most patients with the syndrome have 20-30 or more episodes per hour of sleep. Obstructive apnea must be differentiated from central apnea. In central apnea both airflow and respiratory effort are absent, while in obstructive apnea absence of airflow is accompanied by increased chest muscle movement which can be detected on a typical polysomnogram.

The causes of obstructive sleep apnea are thought to be related to three major factors: airway geometry, lumen suction pressure and muscle tone. The narrower the airway, the more susceptible it is to closure and the more dependent it is on muscle tone to be patent (Sullivan et al. 1984). Several anatomical features contribute to the narrowing including enlarged adenoids and tonsils in children, mandibular micrognathia resulting in reduced anteroposterior dimension of the oropharynx, enlarged tongue in obese individuals, and any neoplastic growth that may obstruct the lumen (Sullivan et al. 1984). Increased lumen suction pressure is created when the forces generated by inspiratory muscles produce greater positive transmural pressure favoring upper airway collapse. Increased resistance in the nasal airway, for example, will create greater suction pressure in the oropharynx. Finally, muscle tone influences upper airway patency. The tone of the dilator muscles of the oropharynx must remain high in order to maintain the airway patency. Decreased muscle tone can make the airway more susceptible to collapse, and at sleep onset there occurs a reduction in tonic as well as

phasic muscle activation. Several muscles, including genioglossal muscles, tensor palati, and geniohyoid are thought to be important in maintaining upper airway patency (Sullivan et al. 1984).

Sleep apnea is a life-threatening disease. Adult apnea patients exhibit a multitude of cardiac symptoms. Systemic hypertension occurs in 40-60% of these patients, and its severity depends on the severity of apnea (Ferguson and Fleetman 1995). Systemic blood pressure increases by as much as 20% immediately after apneic episode termination. Several mechanisms have been proposed for this phenomenon, including hypoxia, acidosis, increased respiratory effort, and the increased sympathetic activity associated with the awakening. Cardiac output also decreases during apnea because of decrease in heart rate without concurrent increase in stroke volume (Stoohs and Guilleminault 1992). Furthermore, in OSAS, the combined effects of hypertension, hypoxia, and increased sympathetic activity can lead to pulmonary hypertension, cardiac arrhythmia, and ischemic heart disease (Ferguson and Fleetman 1995).

Obstructive sleep apnea significantly decreases cerebral blood flow, thus increasing the chance of another potentially fatal vascular event, stroke (Yaggi et al. 2005). In an observational cohort study of more than a thousand patients, those with high apnea-hypopnea indices had a greater hazard ratio of developing a stroke and death from any cause. Ferguson and Fleetman

(1995) agreed that five-year survival was greatly reduced in patients with untreated OSAS, mainly due to cardiovascular complications.

In children, cognitive and behavioral abnormalities are associated with sleep-disordered breathing. Due to frequent awakening and intermittent hypoxia, daytime function can be impaired. According to El-Ad and Lavie (2005), the most common abnormalities are decreased vigilance, depression, anxiety, and hyperactivity. In a study of 403 children (Mulvaney et al. 2006), the Child Behavior Checklist was used to show that children with high Respiratory Disturbance Index scores were more aggressive, had more social problems, were inattentive, and demonstrated greater oppositional behavior. In a study by Avior et al. (2004), a questionnaire was administered to parents of children with OSAS before and after tonsillectomy-adenoidectomy procedure. The scores for sleep disturbance, physical function, daytime function and caregiver concern improved significantly after adenotonsillectomy procedures (Avior et al. 2004).

Cognitive dysfunction is commonly observed in children with sleep-disordered breathing. In one study (Carvalho et al. 2005), such children were eight times more likely to develop cognitive problems compared to normal children. Academic performance often suffers in children with sleep-disordered breathing (Gozal 1998). Gozal and Pope (2001) studied over 1,500 middle school children who were in the top 25% of their class and the bottom 25% of their class. Those students who had lower grades were more

likely to have snored during early childhood than children with better academic performance. Just like the behavioral problems, cognitive performance improved in children who underwent adenotonsillectomy to treat obstructive sleep apnea (Montgomery-Downs et al. 2005).

Finally, limited evidence suggests that growth may be negatively affected by sleep-disordered breathing. In a small sample of pre-pubertal children (mean age of 4 years) with OSAS, average sleeping energy expenditure decreased and mean weight increased after adenotonsillectomy procedure, while the caloric intake remained the same (Schechter 2002). This case series study, however, evaluated only 14 participants, and did not have a control group.

Despite its severe consequences, sleep-disordered breathing is not an uncommon disorder. The prevalence of this life-threatening condition has been estimated to be as high as 24% in men and 9% in women (Ferguson and Fleetman 1995). In children, due to methodological differences, the range is much greater. The prevalence of snoring in children has been reported between 3.2 and 12.1%, while the prevalence of obstructive sleep apnea syndrome ranged from 0.7% to 10.3% (Schechter 2002). In a German study of 332 students between the ages of 11 and 15, 28% reported either snoring, insomnia, or nightmares. Of those who reported snoring, 15% were accompanied by either insomnia or parasomnia (nightmares, sleepwalking) (Ipsirogu et al. 2001). In another study of orthodontic patients, prevalence of

habitual snoring was 17% (Nelson and Kulnis 2001). From this summary it can be seen that all forms of sleep disordered breathing, ranging from snoring to OSAS, are found in children and adolescents.

Cephalometric Assessment

Numerous studies have found differences in craniofacial anatomy between healthy individuals and individuals with OSAS. Jamieson et al. (1986) compared cephalometric values of 155 adult OSAS patients (defined as having respiratory disturbance index of ten or more apneic episodes per hour of sleep) with normal subjects and the normal values from the literature. Lateral cephalometric radiographs were used to determine seven angular and linear measurements. All but two subjects with OSAS demonstrated at least one abnormal value which was 2 standard deviations greater or smaller than the established normal values. Based on this definition of abnormality, patients with OSAS had the following characteristics: retropositioned mandible, more acute nasion-sella-basion angle, inferior displacement of the hyoid bone, and increased length of the soft palate. The values for hyoid bone to mandibular plane distance in this study were 25 mm (SD 6.8) in patients with OSAS, and 14.6 mm (SD 4.5) in healthy controls. The position of the maxilla was normal compared with the literature values.

Bacon et al. (1990) also used lateral radiographs to compare a group of forty-three adult male OSAS patients (mean age 50.5 years) with a control group of healthy male dental students (mean age 23.4 years). Patients with

ten or more apneas per hour of sleep were included in the study. Fifteen angular and linear values were measured. Several statistically significant differences were found between the two groups. The anterior cranial base, measured from sella to nasion, was decreased in the OSAS group. The bony pharynx opening, measured from basion to posterior nasal spine was reduced and correlated to the anterior cranial base length. Although the length of the mandible was identical in the two groups, the steeper mandibular plane angle in the OSAS group resulted in the increased lower facial height and the reduced position of the chin. The length of the soft palate was greatly increased in the OSAS group. Upper facial height and palatal plane angulation were similar. The discriminant analysis based on the four variables (soft palate length, upper facial height, lower facial height, and anterior cranial base) was then used to correctly classify 93% of the subjects in either the healthy or OSAS group. It should be noted that the control group was significantly younger than the experimental group and therefore changes due to aging may have been overlooked in this study. Hyoid bone position was not measured.

In a similar attempt to discern the craniofacial characteristics of individuals with sleep apnea, Pracharktam et al. (1996) compared radiographs of twenty-eight sleep apnea patients with a mean RDI of 52.92 to a control group of habitual snorers with a mean RDI of 5.1. Twenty-two cephalometric variables were measured and statistical significance was found

in hyoid bone position (more inferior in OSAS) and craniocervical angle (more obtuse in OSAS). Discriminant analysis was used to reduce these variables to thirteen cephalometric predictor variables (including hyoid bone position, tongue length, tongue area, craniocervical angle, soft palate length, and hard palate length) and four anthropometric variables (age, BMI, cranial index to facial index ratio, and natural head position) which were used to generate craniofacial index score. This score correctly classified 82% of OSAS subjects and 86% of control subjects. Furthermore, three variables with the highest predictive value were determined to be hyoid bone position, Body Mass Index and soft palate length.

In a different study (Hans et al. 2001), a stepwise discriminant function was used to combine four variables (age, Body Mass Index, hyoid to mandibular plane distance and tongue length) to produce Craniofacial Risk Index. This index was applied to a group of sixty-six snorers to test the ability of the index to correctly classify subjects into one of two groups: RDI of greater than 20 and less than 20. All subjects completed overnight in-home sleep study. The CRI was found to correctly classify 72.3% of the subjects with low RDI and 78.7% of the subjects with high RDI.

Kulnis et al. (2000) studied differences in craniofacial cephalometric variables between snoring and non-snoring children. Twelve craniofacial measurements were determined for twenty-eight snoring children between the ages of 7-14 and twenty-eight non-snoring children matched by age, sex,

and ethnicity. Several variables showed statistical significance. Hyoid to mandibular plane distance was longer in snoring children; the width of the pharyngeal airway was narrower in snoring children; anterior cranial base, maxilla, and mandibular length were all shortened in snoring children. In addition to these craniofacial values, Body Mass Index was found to be significantly greater in snoring children. Young and McDonald (2004) tested the relationship between severity of sleep apnea and the position of the hyoid bone. Ninety-four subjects underwent polysomnography to determine their apnea hypopnea index (AHI). Vertical position of the hyoid bone was measured from lateral radiograph. It was determined that that there is a significant correlation between the more inferiorly positioned hyoid bone and increased AHI. These relationships were reliable for subjects with AHI of less than 100.

Vertical changes in hyoid bone position with age were investigated by Nelson et al. (2003) in a study of adult Bolton Brush subjects for whom childhood (age 4-5), pubertal (12-13) and adult records were available. It was found that snoring subjects had lower hyoid bone position at all ages, but especially in adulthood. It was also found that hyoid to mandibular plane distance increased with age regardless of the snoring status.

As can be seen many studies have determined that individuals with breathing disturbances have more inferior hyoid bone position. Based on the information presented earlier in this paper, it would appear that the lower

position of the hyoid bone may be an indication of reduced muscle tone, which is one of the three primary causes of obstructive sleep apnea. Reduced muscle tone of oropharyngeal dilator muscles contributes to decreased patency of the airway, and thus, leads to greater degree of collapse. Muscles responsible for the maintenance of the patent airway include geniohyoid, genioglossal muscles and tensor palati.

Treatment of Sleep Apnea

Numerous treatment options, ranging from oral appliances and CPAP to surgery, are available to patients with sleep apnea. These options vary widely in regards to patient acceptance and effectiveness. Brief overview of the treatment alternatives will be provided here, with greater emphasis placed on orthodontic appliances.

Continuous positive airway pressure device applies continuous positive pressure to the upper airway through a mask that covers both the nose and the mouth. The level of pressure needed for each patient can be determined in a sleep laboratory. Because of the inconvenience of the device only forty-six percent of the patients had acceptable compliance with the device, defined as the use of the machine for more than four hours per night for more than 70% of observed nights (Strollo and Rogers 1996). Despite poor compliance, patients treated with CPAP demonstrated improved neuropsychiatric function, reduced daytime sleepiness, and improved cardiac symptoms. In adults, CPAP is the initial treatment of choice, while in children

the use of the device is limited to only those cases who did not respond well to adenotonsillectomy, or in whom this procedure is contraindicated (Schechter 2002). CPAP, however, is efficacious in children and remains a valid option.

Adenotonsillar hypertrophy is the major cause of obstructive sleep apnea in children (Ray and Bower 2005). Therefore, it is not surprising that adenotonsillectomy is the most frequently used treatment of sleep apnea in children (Hoban 2005). Many studies have demonstrated the effectiveness of this procedure. Comparing children with sleep apnea before and after adenotonsillectomy, Stewart et al. (2005) found that after the procedure apnea-hypopnia index decreased significantly. After the procedure, the quality of life scores, as seen in general health perception, behavior and parental impact, improved and were much higher than in children with sleep apnea who did not have the surgery. Similarly, in a different study, children's behavior greatly improved in the areas of aggression, atypicality, depression, and hyperactivity after adenotonsillectomy (Mitchell and Kelly 2005). The mean age of sleep apnea children in this study was seven years.

Effectiveness of uvulopharyngopalatoplasty with genioglossal advancement was examined by Liu et al. (2005). Adult patients with pre-operative apnea/hypopnea index of greater than 40 were evaluated three months after the procedure. The overall success rate of 52% shows that this surgery is a viable option for patients who are unwilling to receive CPAP

treatment. An alternative procedure in adults is uvulopalatal flap, which involves bilateral tonsillectomy, dissection and removal of submucosal adipose tissue of the soft palate, and repositioning of the flap (Li et al. 2005). Eighty-four percent of patients with OSAS who underwent this surgery achieved good results, as defined by at least 50% reduction in RDI and improved oxygen saturation. Three-dimensional CT scan of these patients also revealed a significant increase in retropalatal space.

Advancing the mandible forward is a useful procedure for patient with sleep apnea. Rachmiel et al. (2005) examined young patients (between seven months and twelve years) who underwent bilateral mandibular distraction. CT scan revealed 72% increase in upper airway volume accompanied by improved apnea index, oxygen saturation, and elimination of OSAS symptoms. Conley and Legan (2006) advocated a procedure involving transverse expansion of maxilla and mandible using distraction osteogenesis, followed by mandibular and maxillary advancement to treat obstructive sleep apnea. As can be seen from this brief review, a wide spectrum of surgical options is available to sleep apnea patients. Soft tissue and skeletal surgery may be a viable alternative for patients who are unwilling to use CPAP. Sleep testing showed that CPAP and surgery are equally effective in resolving obstructive sleep apnea (Colin and Duval 2005).

Several studies review the effectiveness of orthodontic appliances for the treatment of sleep apnea and snoring. The majority of these appliances

serve to advance the mandible forward, or to expand maxilla. The goal of such therapy is to modify the position of upper airway structures in efforts to enlarge the airway or to reduce its collapsibility (Schmidt-Nowara et al. 1995).

Mandibular advancing appliances vary greatly in design. Blanco et al. (2005) tested a removable soft elastic silicone positioner that created a 5 mm vertical opening as well as mandibular advancement. After the 36 month therapy with the appliance patients with obstructive sleep apnea showed a mean reduction in AHI from 33 to 9.6; decreased Epworth Sleepiness Scale scores (used to measure daytime sleepiness); and decreased snoring. A Mandibular Advancement Splint was effective in reducing ESS scores and RDI scores in patients with sleep-related breathing disorders (Johal et al. 2005). Twenty-one of twenty-six subjects reported 81% reduction in snoring and 86% of the subjects reported better quality of sleep. Rose et al. (2004) tested efficacy of a two splint mandibular protruding appliance and also found positive results: the mean AHI was reduced from 19 to 3.3, and oxygen saturation showed improvement. Eighty-eight percent of the patients achieved the therapeutically-significant reduction in AHI to below 5. In a prospective, crossover study of sixteen patients with sleep apnea (Lawton et al. 2005), Twin block and Herbst appliances were used in adults. Each subject used both appliances separated by a two-week washout period. AHI, snoring, and oxygen saturation were measured. The results showed that

there was no difference in performance of the two appliances; however, Herbst appliances proved to be more popular with patients.

Kyung et al. (2005) used CT imaging to study changes in airway size of patients undergoing therapy with mandibular protruding appliances. Baseline AHI values were established for fourteen patients. CT scans were taken initially and on the second night with the appliance in place. Apnea indices improved significantly. With the appliance in place, the cross-sectional area of retro-palatal and retro-glossal levels increased, thus producing enlargement of the pharynx. The increase in pharyngeal airway was also observed in a study by Eskafi et al. (2004) which used mandibular advancement device on adult patients with congestive heart failure. In this study, the mean AHI was reduced from 25 to 14, and pharyngeal airway increased in its inferior section. In a case report of two children with craniofacial anomalies involving narrow maxillae, obstructive sleep apnea was successfully treated with rapid palatal expander and Frankel-II appliance (Rose and Schessl 2006).

Orthodontic Expansion and Airway

Several studies examined the relationship between orthodontic expansion and nasal resistance. Hershey et al. (1976) measured nasal resistance and intermolar width in a group of seventeen patients before and after RPE treatment. They found that RPE produced a significant reduction in nasal resistance and this reduction was stable throughout the retention period

of three months. However, there was very low correlation between the amount of maxillary first molar expansion and change in nasal resistance. This study also found that patients requiring RPE for constricted maxillae had significantly higher nasal resistance before the treatment, and as result of RPE treatment the nasal resistance was reduced to that of normal subjects.

Similar conclusions were reached by Hartgerink et al. (1987). Thirty-eight subjects treatment planned for bonded or banded RPE (mean age 11.75 years) were compared to twenty-four normal control subjects (mean age 12 years) before RPE, right after RPE treatment, and 9-12 months after the expansion. It was found that patients receiving RPE had a much higher nasal resistance (6.4 cm H_2O/L/sec) than normal controls (3.8 cm H_2O/L/sec) before the treatment. There was a significant reduction in mean nasal resistance in the RPE subjects after the treatment and 1 year later. The nasal resistance was not significantly different between RPE group and control subjects after the treatment. This study found, however, high individual response variability. The authors speculated that the critical value for the nasal resistance is 5.5 cm H_2O/L/sec, since subjects with values greater than the critical value exhibited clinically observable mouth breathing, and the subjects with lower values had predominantly nasal breathing. In this study the experimental group was compared with normal subjects. Therefore, there were differences in the initial nasal resistance between the two groups. Perhaps, to better isolate the effects of RPE on nasal resistance, the

expansion group could have been compared to subjects with narrow maxillae not receiving RPE treatment.

Warren et al. (1987) conducted similar comparisons between RPE subjects and normal control. Their expansion group had the mean age of 12.5 years and control group had the mean age of 12.6 years. The control group consisted of orthodontic patients not receiving expansion. This study also compared adults undergoing surgical expansion with adult controls. All subjects in RPE group had skeletal maxillary constriction and in most cases a posterior crossbite existed. The RPE group demonstrated reduction in nasal resistance as well as changes in airway size. In the expansion group the nasal cross-sectional area increased from 0.29 cm^2 to 0.46 cm^2 which was comparable to the area of normal controls. One year post-treatment there was no statistical difference in nasal airway size between the treated and the control groups.

Rapid palatal expansion is an effective procedure for reduction of sleep apnea symptoms. This type of treatment may be most beneficial to patients with narrow maxillae and increased resistance to nasal breathing. According to Pirelli et al. (2004), patients with maxillary constriction usually have increased nasal resistance, which results in mouth breathing. They recruited children between the ages of 6 and 12 years with narrow maxilla who were demonstrated to have pathologic nasal resistance of greater than 1.8 Pascals, and sleep apnea with the mean AHI of 12.2. All of the subjects were

treated with rapid maxillary expansion (two turns per day) for the duration of 10-20 days followed by stabilization period of 6-12 months. At the 4 months follow-up all of the children had the apnea-hypopnea index of less than 1 and all of the children demonstrated normal anterior rhinometry. The mean expansion in this sample was 4.32 millimeters, while the intermolar distance increased 3.89 +/- 0.3 mm. This study did not have a comparison group to establish the changes that may occur in non-treated individuals.

Similar results were demonstrated by Cistulli et al. (1998). Ten young adults with sleep apnea who were determined to have maxillary constriction by orthodontic evaluation underwent treatment with rapid palatal expansion. In six cases, the expansion required surgical assistance. The mean AHI after the period of expansion was reduced from 19 to 7.4. Nine of the ten subjects also reported improvement in snoring. A cephalometric study of effects of rapid palatal expansion revealed widened nasal fossae which resulted in restoration of normal nasal airflow and disappearance of obstructive sleep-disordered breathing in a sample of forty-two children (Pirelli et al. 2005).

Effects of rapid palatal expansion in children with OSAS were studied by Villa et al. (2007). Sixteen patients with sleep apnea (mean age 6.6) were treated with RPE to alleviate the symptoms. After the twelve month follow-up, all patients showed significant reduction in the AHI and arousal index. Questionnaires administered to parents before the treatment and at the time of the follow-up showed significant improvement in the severity of the

symptoms. This study shows that RPE may be effective for treatment of OSAS in children. The nasal resistance and the maxillary width were not measured, however. The study had a small sample and no control group.

Compadretti et al. (2006) showed that the effects of RPE on the measurements of nasal cavity. Twenty-seven children undergoing treatment with RPE were evaluated by rhinomanometry and acoustic rhinometry before the treatment and at the twelve month follow-up. Untreated children were used as a control group. The authors did not specify whether the control subjects needed RPE treatment. The results showed a significant increase in total minimum cross-sectional areas and total nasal volume after the expansion compared to the control group. The authors speculated that the nasal breathing may improve as the result of nasal widening and increase in interzygomatic distance.

Hyoid Bone and Airway Resistance

Limited evidence suggests that hyoid bone position may be affected by upper airway resistance. Verin et al. (2002) measured transnasal, transpalatal, and supralaryngeal inspiratory and expiratory resistances in healthy patients, snorers, and patients with OSAS. Cephalometric measurements were recorded in all of these patients. It was found that all types of resistance were higher in patients with OSAS than in healthy patients and snorers. Furthermore, transnasal resistance was strongly correlated with posterior airway space and distance from hyoid to the posterior pharyngeal

wall; transpalatal resistance was correlated with greater hyoid to mandibular plane distance; and supralaryngeal resistance was correlated with pharyngeal airway space and hyoid to posterior pharyngeal wall distance. Although this study does not establish a causal relationship, it shows that there is a correlation between airway resistance and the position of the hyoid bone.

Hicken (1974), as part of his master's thesis, recruited healthy adult male dental students to study the compensatory postural changes in the position of the mandible and the hyoid as the capacity to inspire through the nasal airway decreased. A series of nasal masks were fabricated for each subject with perforations for each naris, decreasing from 7 mm, to 4 mm, to a mask with no perforations. Lateral cephalograms were taken at rest and immediately after the subjects were asked to run eight flights of stairs. Linear and angular measurements were taken to determine the position of the hyoid bone in relationship to the sella-nasion plane and to the mandibular plane. The hyoid bone was displaced inferiorly as the obstruction level increased: the distance from hyoid to the S-N plane was 2.53 mm at rest, and this distance increased to 9.73 mm with total obstruction. The angular measurement between the hyoid-genial tubercles and mandibular plane also increased, indicating more inferior position of the hyoid. There was a 3 mm horizontal displacement of the hyoid in the posterior direction. Progressive occlusion of the nasal airway in this study resulted in compensatory inferior and posterior displacement of the hyoid bone.

Changes Due to Growth

According to Tourne (1991), the hyoid bone descends during growth. This change parallels the behavior of vertebral bodies, as the hyoid bone position remains stable between C3 and C4. The tongue increases in bulk until maturity and becomes larger in relationship to the intermaxillary space. Cohen and Vig (1976) documented the increase in tongue mass in a longitudinal study of fifty individuals. They said that the tongue area, as measured on lateral cephalograms, plotted against age shows a sigmoid curve. The growth rate diminishes as the individual gets closer to 18 years of age. In their study the tongue area was defined as the area enclosed by the outline of tongue shadow above the line connecting the most superior anterior point of the hyoid bone and menton. This area increased from 23.8 sq. cm at age 12 to 27.8 sq. cm at age 15 in boys, and from 23.3 sq. cm at age 12 to 25.1 sq. cm at age 15 in girls.

Taylor (1991), in his master's thesis, studied the radiographs that were used to create Bolton Standards to examine the position of hyoid bone, among other pharyngeal tissues, in growing individuals. The hyoid bone demonstrated a steady descent during adolescent growth. The sella-hyoid distance increased from 96.7 mm at age 12 to 105.5 mm at age 15 to 111.8 mm at age 18. The angle between mandibular plane (Go-Gn) and the hyoid bone increased from 16.1° at age 12 to 18.6° at age 15 to 21.0° at age 18. The distance from articulare to hyoid also increased: 72.5 mm at age 12, 79.4

mm at age 15, 84.6 mm at age 18. Thus, the hyoid bone descends steadily, as well as the tongue size increases during maturation years in both sexes.

Vertical changes in hyoid bone position with age were investigated by Nelson et al. (2003) in a study of adult Bolton Brush subjects for whom childhood (age 4-5), pubertal (12-13), and adult records were available. It was found that snoring subjects had lower hyoid bone position at all ages, but especially in adulthood. It was also found that hyoid to mandibular plane distance increased with age regardless of the snoring status: (7.4 ± 4.5 vs. 5.2 ± 2.5 in childhood; 12.1 ± 4.1 vs. 10.1 ± 4.6 at puberty; and 18.0 ± 6.2 vs. 15.1 ± 6.0 in adulthood).

To summarize, the following main points have been explored in this literature review: 1) Hyoid bone position is low in children with breathing problems; 2) Narrow maxilla is associated with increased nasal resistance; 3) RPE decreases nasal resistance and reduces symptoms of breathing problems; 4) Hyoid bone position is low in individuals with increased airway resistance; and 5) Hyoid bone position becomes progressively lower with age.

STATEMENT OF THE PROBLEM

As evident from the literature review, increased nasal resistance is associated with maxillary transverse deficiency and orthodontic treatment using rapid palatal expansion decreases nasal resistance. Lower hyoid bone position is associated with increased nasal resistance. Based on this information, it is possible that there is a relationship between orthodontic expansion and hyoid bone position. However, no previous study has examined this relationship.

The purpose of this study is to examine the difference in the change in hyoid to mandibular plane distance (H-MP) between children who had orthodontic treatment with RPE and children who had orthodontic treatment without RPE.

CHANGES IN HYOID BONE POSITION FOLLOWING RAPID PALATAL EXPANSION IN ADOLESCENTS

Authors: Austin Phoenix, DMD[a]

Dennis Beeson, DDS, MS[b]

Suchitra Nelson, PhD[c]

Kingman P. Strohl, MD[d]

Mark Hans DDS, MSD[e]

a – Resident, Department of Orthodontics, Case Western Reserve University, Cleveland, OH

b – Assistant Professor, Case Western Reserve University, Cleveland, OH

c – Associate Professor, Case Western Reserve University, Cleveland, OH

d – Professor of Medicine, Anatomy, and Orthodontics; Director, Center for Sleep Disorders Research, Louis Stokes DVA Medical Center, Case Western Reserve University, Cleveland OH

e – Professor and Chairman, Department of Orthodontics, Case Western Reserve University, Cleveland, OH

Corresponding author/
Reprint requests to:
Mark Hans, DDS, MSD
Case Western Reserve University
School of Dental Medicine
Department of Orthodontics
10900 Euclid Ave.
Cleveland, OH 44106-4905

ABSTRACT:

Introduction: Previous studies have shown that rapid palatal expansion decreases nasal resistance and that long tongues and low hyoid bone position are associated with snoring and increased nasal resistance. The purpose of this study was to examine changes in hyoid to mandibular plane distance (H-MP) and tongue length between children who had orthodontic treatment with RPE and children who had orthodontic treatment without RPE.

Materials and Methods: Lateral and frontal cephalometric radiographs of 138 orthodontic patients treated with RPE and 148 control patients treated without RPE were used to measure pre-treatment (T1) and post-treatment (T2) intermolar distance (IM), lateronasal width (LNW), hyoid bone to mandibular plane position (HMP), and tongue length (TL). Medical history of the same patients was used to collect demographic information, as well as history of mouth breathing, difficulty breathing through nose, and previous adeno-tonsillectomy. The samples were group matched by age and gender. Descriptive statistics were collected at T1 and T2 for all measures. Group means were compared using t-tests, and Chi-square statistics test was performed for categorical variables. A level of $p \leq 0.01$ was used to assign statistical significance. Reliability was estimated using intraclass correlation or Kappa statistics.

Results: At T1, the RPE group showed smaller lateronasal width (24.83 ± 1.99 vs. 26.18 ± 2.05) and maxillary first molar width (50.17 ± 2.3 vs. 51.58 ± 2.83). The distance from Hyoid bone to mandibular plane was also longer in the RPE group (15.69 ± 3.95 vs. 13.86 ± 3.4). There were no differences at T1 for the categorical variables (tonsils and adenoids removed, mouth breathing and difficulty breathing through nose) or tongue length. The mean changes (T2-T1) in the RPE group were increased lateronasal width (+2.48±1.38 vs. +0.94 ± 1.11 for the non-RPE group) and increased intermolar width (+3.21 ± 1.72 vs. +0.98 ± 1.67). The mean change (T2-T1) in hyoid bone position for the RPE group was -0.68 ± 3.67 mm compared to a +1.1 ± 2.96 mm change for the non-RPE group. All mean changes were statistically significant except those for tongue length. At T2, there were no significant between group differences for lateronasal width, hyoid bone position or tongue length.

Conclusions: In this sample, RPE produced statistically significant changes in HMP distance. Therefore, RPE may have a beneficial effect on upper airway physiology and may benefit children who suffer from Sleep Disordered Breathing and maxillary transverse deficiency.

Introduction

Orthodontic treatment provides many benefits for patients. Improved esthetics and masticatory function are probably the most well known. However, because the anatomic floor of the nose and the roof of the mouth are part of the same bone, there has been much interest in the relationship between facial anatomy and breathing. Recent evidence suggests that devices designed to protrude the mandible may be effective for the treatment of breathing problems and snoring.[1] The goal of such therapy is to modify the position of upper airway structures in efforts to enlarge the airway to reduce its collapsibility. Another way to reduce upper airway collapsibility is to reduce the resistance to airflow within the airway passage. Maxillary transverse deficiency reduces cross sectional area of the airway leading to increased nasal resistance. Previous studies have demonstrated a reduction in nasal resistance following rapid palatal expansion with banded or bonded appliances.[2,3,4] There is also limited evidence that Rapid Palatal Expansion may reduce the apnea hypopnea index in children with sleep apnea.[5,6,7] Improvement in nasal airflow and disappearance of obstructive sleep-disordered breathing have also been reported in adults undergoing surgically-assisted RPE.[8] It has been suggested that RPE improves nasal breathing by significantly increasing total minimum cross-sectional area and total nasal volume, thus decreasing nasal resistance.[9]

Some evidence suggests that hyoid bone position may be affected by upper airway resistance. Verin et al.[10] found that transpalatal resistance was correlated with greater hyoid to mandibular plane distance. It has also been shown that the hyoid

bone becomes progressively lower as airway resistance increases.[11] Hyoid bone position also changes with age. According to Tourne,[12] the hyoid bone descends during growth and maintains its position between C3 and C4. Taylor et al.,[13] also demonstrated a steady descent of the hyoid bone during adolescent growth. Nelson et al.[14] found that although snoring subjects had lower hyoid bone position at all ages, the hyoid position became lower with increasing age regardless of the snoring status.

Since increased nasal resistance is associated with maxillary transverse deficiency and rapid palatal expansion decreases nasal resistance, it is possible that RPE affects hyoid bone position. In addition, increased tongue length has been associated with obstructive sleep apnea[15] and rapid palatal expansion has been recommended for treatment of OSAS. The purpose of this study was to examine differences in hyoid to mandibular plane distance (H-MP) and tongue length between children who had orthodontic treatment with RPE and children who had orthodontic treatment without RPE.

Materials and Methods

The treatment records of 630 children who were active patients at the CWRU orthodontic clinic between 2001 and 2005 were examined. Most of these patients had completed their treatment within the past three years and their charts are still kept in the clinic. Patients in the surgical, adult, and craniofacial anomalies specialty clinics were excluded. Of the remaining 556 charts, all 156 patients whose treatment plan included Rapid Palatal Expansion (Hyrax, Haas, or Bonded expander activated at

least every other day) followed by fixed appliances were identified and comprised the experimental group. The control group (165 patients) consisting of patients treated with braces only, was randomly chosen from the remaining charts and was group-matched by age and gender.

The inclusion criteria for both groups were: 1) patients under the age of 18 at the beginning of treatment with 2) completely filled out medical history form and 3) complete pre-treatment and post-treatment radiographic records. All patients who had not completed their treatment, had tonsillectomy/ adenoidectomy or any other surgical procedure during the course of the orthodontic treatment, or who appeared to have atypical posture (e.g. teeth not together, or swallowing as evidenced by the morphology of the soft palate on the radiograph) on the lateral radiograph were excluded. Based on these criteria, 53 patients were excluded, primarily because of missing initial or final radiographs.

Confirmation of group-matching by age and gender was supported by the absence of statistical differences in these measurements. The sample treated with RPE consisted of 138 individuals (55 boys and 83 girls). The average age at the start of treatment (T1) was 13 years 2 months +/- 1 year 6 months. The average age at the end of treatment (T2) was 15 years 8 months +/- 1 year 6 months. The sample treated without RPE consisted of 148 children (53 boys and 95 girls). The average age at T1 was 13 years 6 months +/- 1 year 6 months. The average age at T2 was 15 years 10 months +/- 1 year 7 months. The duration of orthodontic treatment in both groups was approximately 2 years and 5 months.

The patient medical history and the treatment record were used to collect the following information:

- Patient's age at the time of initial records
- Age at the time of final records
- Gender
- Race
- Mouth breathing at initial records
- Difficulty breathing through the nose
- Adenoids/ Tonsils removed before treatment

Lateral and frontal cephalograms for each patient in both groups at T1 and T2 were adjusted for magnification. The average magnification for lateral radiographs was 14 percent, and the average magnification for the frontal radiographs was 8 percent. The magnification was calculated by measuring the actual and perceived dimensions of the nasion piece and the ear piece. Tracings of initial and final frontal and lateral radiographs were used to collect the following cephalometric measurements with a digital caliper:

- Pre- and post-treatment shortest perpendicular distance from the most anterior-superior point of the hyoid bone to the mandibular plane (See Figure 1)
- Pre- and post-treatment tongue length measured from the base of epiglottis to the tip of the tongue behind the lower incisors (See Figure 1)

- Pre- and post-treatment intermolar width (the most prominent lateral point on the buccal surface of the upper first molar) measured from the frontal cephalogram (See Figure 2)
- Pre- and post-treatment lateronasal width measured as the distance between the most lateral points of the nasal cavity (See Figure 3)

Error study was performed. Ten percent of the sample was randomly identified and the cephalometric measurements were repeated at a two week or more interval. The categorical data were re-entered for the same 10 percent of the sample. A paired T-test was used to compare the continuous variables and revealed no statistical difference ($P<0.05$). Intraclass correlation coefficients for all continuous variables were above 0.91. Kappa statistics was used to compare categorical variables. All categorical variables had the perfect agreement coefficient of 1, except the race, which had the coefficient of 0.71.

Statistical Analysis:

Histograms of continuous variables showed that they were normally distributed. Descriptive statistics were obtained for all cephalometric measurements at T1 and T2. Independent sample t test for the comparisons of means between the groups was used to evaluate the changes, while paired T-tests were used to examine changes within groups. Chi-square statistics test was performed for categorical variables. For the error study, intraclass correlation coefficients were calculated for

all continuous variables, and kappa statistics - for the categorical variables. Computer software (SPSS version 10, Chicago, Illinois) was used for statistical computations.

Results

Age, gender and race distributions for the two groups are given in Table I. At T1 there were statistical differences between the RPE and the non-RPE groups (Table II). The RPE group showed a deficiency in lateronasal width and in maxillary first molar width when compared with normal subjects. The distance from Hyoid bone to mandibular plane was also longer in the RPE group. Unlike the cephalometric variables, none of the categorical variables (tonsils and adenoids removed, mouth breathing and difficulty breathing through nose) showed significant differences at T1 (Table III).

RPE induced significant changes in transverse dimensions (Tables IV and V). The treatment effect (T2-T1) produced greater increase in lateronasal width and the intermolar width when compared to subjects treated without RPE. RPE also produced different directions in Hyoid bone position: the hyoid bone to mandibular plane distance decreased in RPE group and increased in non-RPE group.

At the end of treatment, T2, there was no statistical difference in lateronasal width between the groups (Table VI). The intermolar width was greater in the RPE group. The between-group difference in hyoid bone position observed at T1 had practically disappeared at T2. Tongue length showed no differences between the groups at either T1 or T2.

Discussion

This retrospective cohort study evaluated the difference in changes in hyoid bone position and tongue length in adolescents undergoing orthodontic treatment with and without RPE. Both groups were similar in regards to age and gender at the beginning of treatment, and there were no statistical differences for these two variables. There was a statistically significant difference in time period between initial and final records between the groups, with the RPE treatment taking about 2 months longer. This difference is consistent with previous reports[16] and makes sense because the RPE appliance is usually activated for about one month and then stabilized for an additional three to six months. This additional time is offset by the beneficial effects of RPE on transverse arch dimensions and dental irregularity. However, clinicians using RPE should be aware that the use of this device will likely increase treatment time.

In our study, we did not find a difference in pretreatment parental assessment of mouth breathing between the two groups. Previous studies[3,4] showed that subjects receiving RPE for orthodontic purposes had a much higher nasal resistance before treatment than subjects not receiving RPE. In those studies the median nasal resistance of RPE group before treatment was well above the value (5.5 H_2O/L/sec) at which clinical mouth breathing was observed, while the subjects receiving orthodontic treatment without RPE had lower nasal resistance well below this value. Comparison[17] of mouth-breathing and nasal-breathing children revealed that narrow upper arch, measured as intermolar distance, had a significant correlation with mouth

breathing. In our study, mouth breathing was recorded from the medical history form filled out by parents. The most logical explanation of our result is that in many instances parents were simply unaware of the child's difficulty breathing through nose, and therefore did not identify them as mouth breathers.

There was no statistically significant difference between the groups in having adenoids and tonsils removed prior to treatment. The overall number of patients reporting these procedures in our sample was too small to reach any conclusions. However, it should be mentioned that enlarged tonsils are associated with lower hyoid bone position,[18] and tonsillectomy leads to reduction in nasal resistance.[19] Because of the possible confounding effect of adeno-tonsillectomy on the airway, patient who had these procedures performed *during* orthodontic treatment were excluded.

The treatment with RPE produced 3.21 mm of intermolar width increase and 2.48 mm in the lateronasal width increase. These changes were significantly greater than in the non-RPE group. There was a significant ($P<0.01$) correlation of 0.464 between intermolar width increase and nasal width increase. Since the maxilla expands in the shape of V with the apex at the nasal floor, it would make sense for the intermolar expansion to be greater than nasal expansion. Although the changes in molar and nasal width are consistent with previous reports on the effects of RPE, the differences in these values at T1 suggest susceptibility bias could have influenced our results. Therefore, although our results are consistent with previous reports, clinicians should be aware that the average increases in nasal width and intermolar

width reported in our RPE group may not be achieved if RPE is used on a patient with normal transverse maxillary width.

There was also a significant difference in hyoid bone position between the groups before the treatment. The hyoid bone was almost 2 mm lower in the RPE group compared to the controls. During the course of the treatment the hyoid to mandibular plane distance increased in the non-RPE group, as might be expected, since hyoid normally descends during maturation.[13,14] In contrast, RPE treatment resulted in a decrease in this distance, to the point that there were no distinguishable differences in hyoid position at T2. Although this difference at T1 suggests susceptibility bias, it is highly unlikely that the clinicians treating these cases used H-MP as a diagnostic criterion to select those cases receiving RPE. Thus, it is more likely that the effect on H-MP observed in the RPE group was the result of the treatment rather than bias.

Airway geometry and lumen suction pressure can lead to obstruction in the area of oropharynx. The narrower the airway, the more susceptible it is to collapse.[20] Several anatomical features contribute to the narrowing including transversely deficient maxilla, enlarged adenoids and tonsils in children, and enlarged tongue in obese individuals. Increased lumen suction pressure is created when the forces generated by inspiratory muscles produce greater positive transmural pressure favoring upper airway collapse. Increased resistance in the nasal airway, for example, will create greater suction pressure in the oropharynx. Previous studies have reported an association between low hyoid bone and long tongues and obstructive apnea and

snoring in adults.[14, 15, 21] Similar finding have been reported for children with Sleep Apnea[22] and snoring.[23] Our results are consistent with the hypothesis that airway resistance is increased in patients with maxillary transverse deficiency, since increasing nasal and intermolar width with RPE normalized hyoid bone position.

Tongue length, may also affect airway size and has been associated with obstruction of the oropharynx.[20] Previous studies have shown that increased tongue length is associated with higher Respiratory Disturbance Index scores.[15] However, our results showed no differences between the groups at either T1 or T2 or in the change from T1-T2. Our results suggest that tongue length is probably not related to maxillary transverse deficiency and that there is no obvious physiologic link between the length of the tongue and the shape of the maxilla. Tongue length increased slightly in both groups. This was likely due to normal growth. Cohen and Vig[24] documented the increase in tongue mass in a longitudinal study of 50 individuals. They found that the growth rate slows down as the individual gets closer to 18 years of age.

Limitations

One limitation of our study was that patients in the RPE group were in the group because the clinicians treating them made a diagnosis of transverse maxillary deficiency and used an RPE appliance for orthodontic expansion. We could neither control how the decision was made, nor do we have knowledge of formal guidelines that were followed. However, the intermolar width and lateronasal width were both

significantly smaller in the RPE group, which is consistent with a diagnosis of transverse maxillary deficiency.

As mentioned previously, another limitation was susceptibility bias. Our control group consisted of orthodontic patients receiving treatment not involving RPE. To better isolate the effects of RPE, patients with maxillary transverse deficiency not receiving any treatment could have been used as controls. However, in the clinic setting records are taken only on patients who are committed to treatment. Also, it would be hard to justify delaying the expansion, since the efficiency of RPE decreases with age, for the duration of the observation period. Using orthodontic patients as controls presents an advantage because it helps to eliminate the effects that orthodontic treatment (other than RPE, such as fixed appliances) may produce.

Final records were taken at the end of orthodontic treatment, which may occur one to two years after the expansion is finished. Perhaps, to better isolate the effects of RPE on hyoid position and tongue length, records immediately after expansion is completed could be useful. However, using the final records has the advantage of showing that changes in hyoid bone position are still present one to two years after the expansion.

Conclusions

The purpose of the present study was to evaluate the changes in hyoid bone position that occur in orthodontic patients treated with and without Rapid Palatal Expansion. After reviewing records of 286 patients, the following can be concluded:

1. The hyoid to mandibular plane distance before treatment is lower in patients with narrow maxillae requiring RPE as compared with orthodontic patients not requiring RPE.
2. During the treatment, the hyoid bone to mandibular plane distance increased in non-RPE subjects, as might be expected with maturation. The hyoid to mandibular plane distance decreased in subjects treated with RPE. The difference between the RPE and non-RPE group from T1 to T2 was statistically significant at the $p<.0.001$ level.
3. At T2 there was no difference in Hyoid bone position between the two groups.
4. The results of the present study show that RPE treatment normalizes hyoid bone position. A potential physiologic explanation of this change is that RPE decreases nasal and/or upper airway resistance.
5. Tongue length does not seem to be related to RPE and/or transverse maxillary deficiency.

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Table I. Demographic Data

	Total Sample		*RPE*		*Non-RPE*		*Significance*
							P Value
N	286		138		148		
Age at T1 (SD)	13y 4m	(1y 6m)	13y 2m	(1y 6m)	13y 6m	(1y 6m)	0.075
Age at T2 (SD)	15y 9m	(1y 7m)	15y 8m	(1y 6m)	15y 10m	(1y 7m)	0.451
Age Difference (SD)	2y 5m	(0y 7m)	2y 6m	(0y 10m)	2y 4m	(0y 8m)	0.04*
Gender							0.542
Boys (%)	108	37.70%	55	40%	53	36%	
Girls (%)	178	62.30%	83	60%	95	64%	
Extractions							0.007*
4 bicuspids (%)	47	16.40%	14	10%	33	22%	
Upper bicuspids (%)	4	1.40%	0	0%	4	2%	
Lower bicuspids (%)	1	0.35%	1	0.70%	0	0%	
Other (%)	1	0.35	0	0%	1	0.60%	
Race							0.009*
Caucasian (%)	240	83.90%	127	92%	113	76.30%	
African American (%)	23	8%	6	4%	17	11.50%	
Asian (%)	1	0.35%	0	0%	1	0.70%	
Hispanic (%)	3	1.05%	1	0.70%	2	1.60%	
Other (%)	196	6.64%	4	2.90%	15	10.10%	

* $P<0.05$

Table II. Comparison of expansion vs. non-expansion group at T1

		Total Sample		*RPE (n=138)*		*Non-RPE (n=148)*		*Group Difference*	
Variables		*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*RPE -NRPE*	*P value*
Hyoid - MP distance	mm	14.74	3.79	15.69	3.95	13.86	3.4	1.83	0.001*
Tongue Length	mm	63.67	5.13	63.81	5.01	63.55	5.24	0.26	0.672
Nasal Width	mm	25.53	2.13	24.83	1.99	26.18	2.05	-1.35	0.001*
Intermolar Width	mm	50.91	2.68	50.17	2.3	51.58	2.83	-1.41	0.001*

* P<0.01

Table III. Categorical variables at T1

	RPE (n=138)		*Non-RPE (n=148)*			*Significance*
Variables	*n*	*%*	*n*	*%*	*P value*	*chi-square*
Tonsils Removed	20	14.50%	13	8.80%	0.131	NS
Adenoids Removed	16	11.60%	13	8.80%	0.431	NS
Difficulty breathing through nose	20	14.50%	21	14.20%	0.942	NS
Mouth Breathing	39	28.30%	33	22.30%	0.246	NS

* P<0.01

NS, not significant

Table IV. Comparison between groups (T2-T1)

		Total Sample		*RPE (n=138)*		*Non-RPE (n=148)*		*Group Difference*	
Variables		*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*RPE -NRPE*	*P value*
Hyoid - MP distance	mm	0.24	3.43	-0.68	3.67	1.1	2.96	-1.78	0.001*
Tongue Length	mm	2.71	4.49	2.69	4.57	2.72	4.42	-0.03	0.966
Nasal Width	mm	1.69	1.46	2.48	1.38	0.94	1.11	1.54	0.001*
Intermolar Width	mm	2.05	2.03	3.21	1.72	0.98	1.67	2.23	0.001*

* P<0.01

Table V. Comparison within groups (T2-T1)

		RPE (n=138)					*Non-RPE (n=148)*				
Variables		*T1*	*T2*	*T2-T1*	*SD*	*P value*	*T1*	*T2*	*T2-T1*	*SD*	*P value*
Hyoid - MP distance	mm	15.69	15.01	-0.68	3.67	0.032	13.86	14.96	1.1	2.96	0.001*
Tongue Length	mm	63.81	66.5	2.69	4.57	0.001*	63.55	66.27	2.72	4.42	0.001*
Nasal Width	mm	24.83	27.32	2.48	1.38	0.001*	26.18	27.12	0.94	1.11	0.001*
Intermolar Width	mm	50.17	53.39	3.21	1.72	0.001*	51.58	52.25	0.98	1.67	0.001*

* P<0.01

Table VI. Comparison of expansion vs. non-expansion groups at T2

		Total Sample		RPE (n=138)		Non-RPE (n=148)		Group Difference	
Variables		*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*RPE -NRPE*	*P value*
Hyoid - MP distance	mm	14.99	3.92	15.01	4.24	14.96	3.59	0.05	0.915
Tongue Length	mm	66.38	5.26	66.5	5.4	66.27	5.14	0.23	0.707
Nasal Width	mm	27.22	1.96	27.32	1.88	27.12	2.03	0.2	0.4
Intermolar Width	mm	52.97	2.43	53.39	2.15	52.25	2.59	1.14	0.004*

* P<0.01

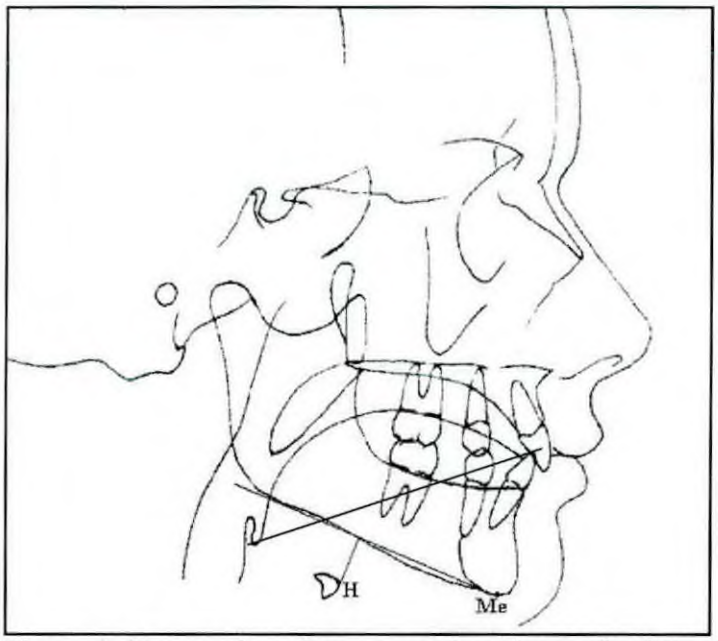


Figure 1. Tongue length measure from base of epiglottis to the tip of the tongue behind the lower incisors. Hyoid distance measured from most anterior superior point of hyoid to mandibular plane.

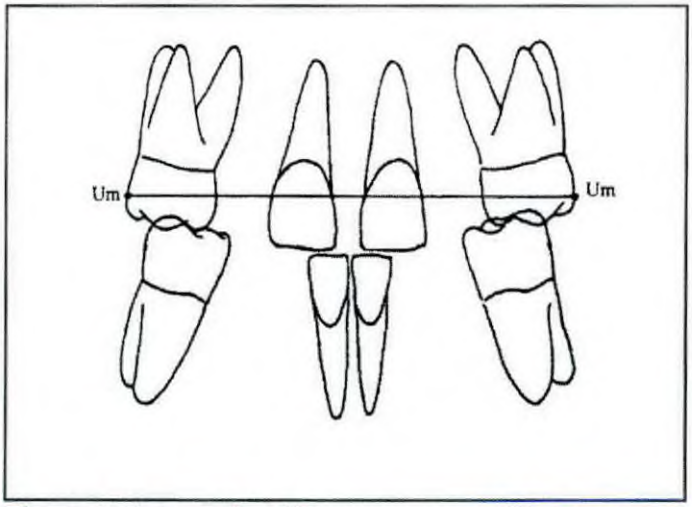


Figure 2. Intermolar distance measured between most prominent lateral surfaces of maxillary first molars.

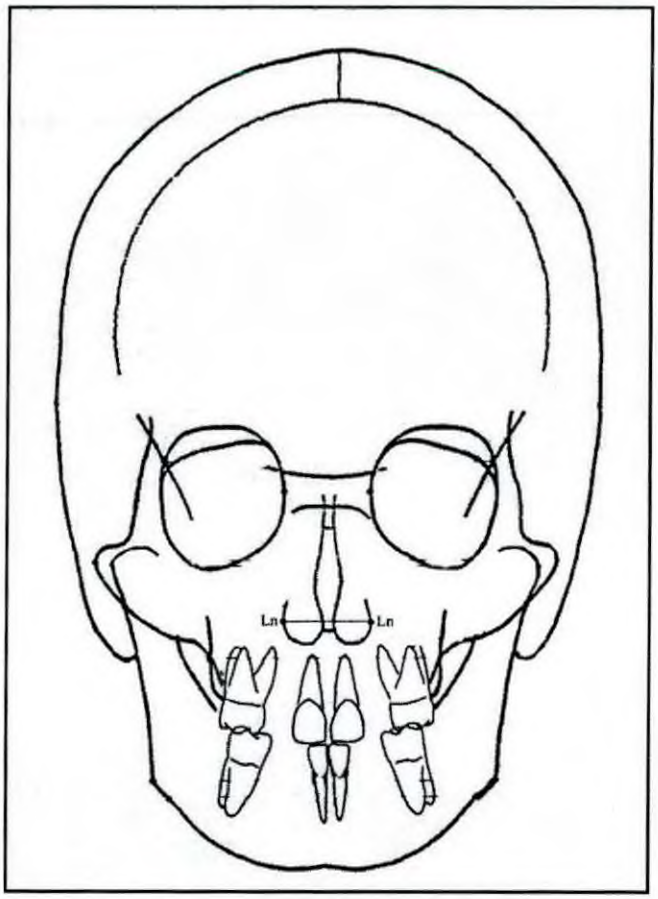


Figure 3. Lateronasal width measured from most lateral points of the nasal cavity.

APPENDICES

APPENDIX 1

Raw Data

TABLE 1.--Abbreviations

ID	Subject identification number
Age T1	Age at T1
Age T2	Age at T2
Age Diff	Age difference between T2 and T1
RPE	Treated with RPE: 1=Yes, 2=No
Extract	Extractions: 1=None, 2=4 bicuspids, 3=upper bicuspids, 4=lower bicuspids, 5=other
Phase	Phase of treatment: 1=Phase I, 2=Phase II
Gender	1=Male, 2=Female
DBN	Difficulty breathing through nose: 1=Yes, 2=No
MB	Mouth Breathing: 1=Yes, 2=No
Tons Rem	Tonsils removed: 1= Yes, 2=No
Aden Rem	Adenoids removed: 1=Yes, 2=No
Race	Race: 1=Caucasian, 2=African American, 3=Asian, 4=Hispanic, 5=Other
H-MP T1	H-MP at T1
H-MP T2	H-MP at T2
H-MP Diff	H-MP difference between T2 and T1
TL T1	Tongue length at T1
TL T2	Tongue Length at T2
TL Diff	Tongue Length difference between T2 and T1
Nasion T1	Nasion piece on T1 film
Nas T2	Nasion piece on T2 film
NW T1	Nasal width at T1
NW T2	Nasal width at T2
NWD	Nasal width difference between T2 and T1
Interm T1	Intermolar width at T1
Interm T2	Intermolar width at T2
Interm Diff	Intermolar width difference between T2 and T1
Ear T1	Earpiece on T1 film
Ear T2	Earpiece on T2 film

TABLE 2.--Raw Data

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
1	12.00	14.92	2.92	2	1	1	2	2	1	2	2	1	19.41	18.44
3	12.25	14.50	2.25	2	1	1	2	2	2	2	2	1	8.78	14.23
4	12.16	14.33	2.17	2	1	1	2	2	2	2	2	1	22.92	18.51
5	13.66	15.75	2.09	1	1	1	1	2	2	2	2	1	12.93	20.68
6	13.25	15.42	2.17	2	2	1	1	1	2	2	2	2	15.96	17.46
7	14.92	17.83	2.91	2	1	1	1	2	2	2	2	1	25.57	23.84
8	13.42	15.58	2.16	1	1	1	2	2	1	1	1	1	12.40	10.84
9	14.33	17.25	2.92	2	1	1	1	2	1	2	2	1	23.46	23.90
10	11.25	14.83	3.58	1	1	1	2	2	2	2	2	1	18.81	18.67
11	18.00	19.50	1.50	2	2	1	1	2	2	2	2	2	17.72	11.37
12	16.58	18.75	2.17	1	1	1	2	2	2	2	2	2	12.11	16.97
14	12.50	16.33	3.83	1	1	1	1	2	2	2	2	1	14.73	27.55
17	12.00	15.16	3.16	1	1	1	2	2	1	1	2	1	20.21	15.49
18	12.08	13.58	1.50	1	1	1	1	2	2	2	2	1	15.28	20.25
19	15.16	17.25	2.09	1	1	1	2	2	2	2	2	1	20.84	12.94
21	9.83	12.25	2.42	1	1	2	2	2	2	1	1	1	14.17	26.83
22	13.60	15.00	1.40	2	1	1	2	2	1	2	2	1	12.22	13.77
23	17.58	19.66	2.08	2	1	1	1	2	2	2	2	1	18.87	18.60
24	12.66	14.75	2.09	2	3	1	1	2	2	1	1	1	16.88	17.44
25	11.83	13.00	1.17	2	1	1	2	2	2	2	2	2	10.07	16.20
26	13.08	16.16	3.08	1	1	1	2	2	2	2	2	2	18.74	15.49
27	13.25	15.42	2.17	2	1	1	2	2	2	2	2	5	13.14	10.75
28	14.58	17.33	2.75	2	3	1	2	2	1	2	2	1	21.98	18.02
29	13.08	15.83	2.75	2	1	1	1	2	2	2	2	1	16.30	22.59
30	16.83	18.33	1.50	1	1	1	1	2	2	2	2	1	17.26	12.54
31	12.50	15.75	3.25	1	1	1	1	1	2	2	2	1	20.28	23.30
32	13.83	18.92	5.09	1	2	1	1	2	1	2	2	1	19.23	22.46
33	12.83	15.75	2.92	2	2	1	1	2	2	2	2	1	20.23	22.51
34	12.16	14.08	1.92	2	1	1	2	2	2	1	1	1	21.18	18.05
36	13.08	16.00	2.92	1	1	1	1	2	2	2	2	1	26.41	29.29
37	12.42	14.50	2.08	1	1	1	2	2	1	2	2	1	18.35	15.01
38	12.42	14.42	2.00	2	1	1	2	2	2	2	2	2	9.35	11.42

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
1	-0.97	83.14	80.76	-2.38	13.80	13.66	28.10	30.68	2.58	59.92	59.25	-0.67	6.01	6.07
3	5.45	71.27	72.22	0.95	13.51	13.37	27.60	27.38	-0.22	61.84	60.52	-1.32	6.29	6.35
4	-4.41	72.42	73.63	1.21	13.00	12.87	30.05	32.20	2.15	55.75	56.33	0.58	6.33	6.39
5	7.75	75.61	87.20	11.59	13.02	12.89	28.61	36.60	7.99	52.87	58.37	5.50	6.05	6.11
6	1.50	81.61	83.65	2.04	13.12	12.99	33.15	34.33	1.18	59.58	56.93	-2.65	6.01	6.07
7	-1.73	80.38	85.82	5.44	13.28	13.15	30.27	30.74	0.47	56.15	58.03	1.88	6.28	6.34
8	-1.56	74.65	75.00	0.35	13.06	12.93	29.69	31.13	1.44	59.64	66.18	6.54	5.82	5.88
9	0.44	63.68	76.43	12.75	13.25	13.12	26.22	26.31	0.09	55.48	54.87	-0.61	5.96	6.02
10	-0.14	68.41	75.15	6.74	12.90	12.77	24.93	34.21	9.28	53.84	60.68	6.84	6.37	6.43
11	-6.35	97.03	89.17	-7.86	13.19	13.06	30.22	30.61	0.39	63.00	62.28	-0.72	6.19	6.25
12	4.86	77.08	84.45	7.37	13.23	13.10	28.05	28.68	0.63	55.11	59.85	4.74	6.05	6.11
14	12.82	65.97	77.87	11.90	13.15	13.02	26.56	30.04	3.48	55.14	59.12	3.98	5.97	6.03
17	-4.72	76.95	77.75	0.80	13.24	13.11	21.89	24.36	2.47	53.72	55.08	1.36	6.05	6.11
18	4.97	77.98	82.55	4.57	13.05	12.92	22.08	26.20	4.12	53.95	58.72	4.77	6.40	6.46
19	-7.90	87.29	76.74	-10.55	13.13	13.00	27.28	28.17	0.89	54.32	57.40	3.08	5.72	5.78
21	12.66	68.08	76.81	8.73	13.04	12.91	26.88	30.49	3.61	57.51	58.99	1.48	6.18	6.24
22	1.55	69.53	74.12	4.59	12.91	12.78	28.32	29.07	0.75	54.58	57.06	2.48	6.47	6.54
23	-0.27	86.12	84.12	-2.00	13.35	13.22	28.03	29.35	1.32	59.63	60.82	1.19	6.44	6.50
24	0.56	82.66	81.77	-0.89	12.92	12.79	22.76	24.80	2.04	53.21	57.49	4.28	5.73	5.79
25	6.13	79.57	79.67	0.10	13.15	13.02	27.37	30.56	3.19	57.71	60.75	3.04	6.55	6.62
26	-3.25	80.21	78.84	-1.37	13.51	13.37	30.24	31.25	1.01	59.58	60.38	0.80	6.05	6.11
27	-2.39	74.39	79.82	5.43	12.91	12.78	27.88	28.38	0.50	59.89	61.36	1.47	6.09	6.15
28	-3.96	79.77	80.92	1.15	13.35	13.22	32.04	33.04	1.00	56.18	58.67	2.49	5.60	5.66
29	6.29	70.80	80.85	10.05	13.47	13.34	26.21	27.26	1.05	58.59	59.91	1.32	6.03	6.09
30	-4.72	80.09	76.77	-3.32	13.51	13.37	31.86	33.75	1.89	53.80	60.05	6.25	6.02	6.08
31	3.02	74.86	82.34	7.48	13.13	13.00	31.59	33.10	1.51	56.30	61.57	5.27	6.12	6.18
32	3.23	66.90	78.68	11.78	13.12	12.99	27.64	29.22	1.58	51.24	54.34	3.10	5.86	5.92
33	2.28	75.55	84.85	9.30	13.10	12.97	28.67	32.15	3.48	58.00	58.27	0.27	5.96	6.02
34	-3.13	68.90	69.99	1.09	12.93	12.80	27.64	30.73	3.09	50.94	53.97	3.03	6.15	6.21
36	2.88	81.76	93.57	11.81	13.25	13.12	24.65	26.84	2.19	54.31	59.02	4.71	6.65	6.72
37	-3.34	80.08	79.44	-0.64	12.85	12.72	26.20	30.19	3.99	54.23	58.38	4.15	6.28	6.34
38	2.07	70.55	67.79	-2.76	12.91	12.78	26.90	28.80	1.90	56.72	57.27	0.55	6.05	6.11

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
39	13.25	16.00	2.75	2	2	1	1	1	1	2	2	2	14.14	20.73
40	12.66	14.16	1.50	1	1	1	2	2	2	2	2	1	14.54	17.23
41	14.25	17.50	3.25	2	1	1	1	1	1	2	2	1	24.15	26.69
42	15.83	17.66	1.83	2	1	1	1	1	1	2	2	1	26.13	29.60
43	13.08	17.33	4.25	2	1	1	2	2	2	2	2	1	14.46	15.28
44	11.16	13.75	2.59	2	1	1	1	2	2	2	2	1	18.62	19.88
45	11.66	14.25	2.59	1	1	1	1	1	1	2	2	1	23.13	24.99
46	11.58	14.00	2.42	1	1	1	2	2	2	2	2	1	13.85	8.40
47	15.66	18.16	2.50	1	2	1	1	1	1	2	2	1	18.51	15.93
48	12.16	14.33	2.17	2	1	1	2	2	2	2	2	1	11.51	11.54
49	12.58	13.92	1.34	1	1	1	2	2	2	1	1	1	22.33	18.38
50	12.83	14.75	1.92	1	1	1	2	2	2	2	2	1	20.37	10.05
51	11.83	14.66	2.83	2	1	1	2	2	2	2	2	1	11.35	15.31
52	13.33	14.75	1.42	2	1	1	2	1	1	2	2	1	18.87	19.86
53	10.42	12.92	2.50	2	2	1	2	2	2	2	2	1	14.19	15.79
54	12.25	15.58	3.33	1	1	1	2	2	2	2	2	1	21.01	20.08
55	11.25	13.42	2.17	2	1	1	2	2	2	2	2	1	12.81	17.63
56	13.58	16.08	2.50	2	1	1	2	2	2	2	2	1	16.07	13.22
57	13.50	16.00	2.50	2	1	1	2	2	2	2	2	2	11.04	5.92
58	13.58	16.50	2.92	1	2	1	1	2	1	2	2	1	19.09	17.24
59	16.33	18.75	2.42	2	1	1	2	1	1	1	1	1	18.08	17.48
60	14.08	16.33	2.25	2	1	1	2	2	2	2	2	1	14.23	16.77
61	15.66	18.66	3.00	2	2	1	2	2	2	2	2	1	15.65	16.25
62	12.00	15.33	3.33	2	2	1	1	2	2	2	2	1	21.74	17.30
63	13.66	15.33	1.67	1	1	1	2	2	1	2	2	1	16.62	15.54
64	12.83	15.83	3.00	2	1	1	2	2	2	1	1	1	18.60	22.95
65	12.50	14.92	2.42	2	2	1	2	2	2	2	2	1	12.29	11.89
66	11.08	13.00	1.92	2	1	1	2	2	1	2	2	1	17.58	16.27
67	14.00	16.16	2.16	1	1	1	1	2	2	2	2	1	17.99	15.97
68	13.25	16.33	3.08	1	2	1	1	2	2	1	1	1	18.61	26.11
69	11.66	13.83	2.17	2	2	1	2	2	2	2	2	1	14.65	18.40
70	14.00	17.42	3.42	2	2	1	1	2	2	2	2	1	11.98	27.92

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
39	6.59	72.58	78.87	6.29	13.40	13.27	28.93	29.27	0.34	58.04	61.15	3.11	5.93	5.99
40	2.69	71.75	77.41	5.66	13.19	13.06	28.82	29.57	0.75	54.28	57.09	2.81	6.07	6.13
41	2.54	75.23	89.47	14.24	13.36	13.23	28.25	30.67	2.42	60.24	60.40	0.16	6.38	6.44
42	3.47	81.36	87.71	6.35	13.33	13.20	27.10	30.01	2.91	59.38	61.45	2.07	5.90	5.96
43	0.82	67.56	74.49	6.93	13.19	13.06	30.36	31.11	0.75	56.23	57.51	1.28	5.99	6.05
44	1.26	71.45	79.72	8.27	13.29	13.16	29.25	31.17	1.92	57.07	61.30	4.23	6.23	6.29
45	1.86	70.34	75.53	5.19	13.24	13.11	27.21	27.72	0.51	55.13	60.01	4.88	6.10	6.16
46	-5.45	75.46	78.18	2.72	12.73	12.60	25.93	27.34	1.41	57.05	58.01	0.96	6.42	6.48
47	-2.58	77.07	81.22	4.15	13.49	13.36	30.05	31.80	1.75	58.60	59.79	1.19	6.30	6.36
48	0.03	66.26	69.47	3.21	13.30	13.17	30.11	32.19	2.08	59.78	63.18	3.40	6.03	6.09
49	-3.95	79.63	87.33	7.70	13.20	13.07	28.76	30.75	1.99	57.60	59.66	2.06	6.73	6.80
50	-10.32	75.92	75.89	-0.03	13.16	13.03	28.80	30.43	1.63	59.64	61.02	1.38	6.32	6.38
51	3.96	68.83	76.01	7.18	13.72	13.58	25.86	27.09	1.23	51.75	57.10	5.35	6.37	6.43
52	0.99	68.31	75.74	7.43	13.57	13.43	31.54	30.09	-1.45	51.93	55.59	3.66	5.95	6.01
53	1.60	63.99	62.19	-1.80	13.14	13.01	30.15	31.94	1.79	53.42	53.81	0.39	6.67	6.74
54	-0.93	83.54	83.88	0.34	13.17	13.04	27.93	31.00	3.07	52.84	53.92	1.08	6.30	6.36
55	4.82	71.33	81.45	10.12	12.89	12.76	27.79	29.88	2.09	54.85	56.21	1.36	6.28	6.34
56	-2.85	72.51	69.91	-2.60	13.20	13.07	29.87	28.75	-1.12	57.72	57.12	-0.60	6.25	6.31
57	-5.12	75.70	80.55	4.85	13.14	13.01	27.96	30.35	2.39	54.53	58.87	4.34	5.94	6.00
58	-1.85	68.49	74.04	5.55	13.46	13.33	26.83	30.26	3.43	55.73	56.01	0.28	6.23	6.29
59	-0.60	80.51	76.27	-4.24	13.23	13.10	29.79	30.52	0.73	54.78	57.70	2.92	6.44	6.51
60	2.54	77.40	78.23	0.83	13.13	13.00	31.75	32.58	0.83	58.76	59.41	0.65	5.86	5.92
61	0.60	75.53	67.70	-7.83	13.31	13.18	29.77	29.91	0.14	57.22	57.69	0.47	5.91	5.97
62	-4.44	78.10	79.20	1.10	13.49	13.36	30.81	29.16	-1.65	55.09	58.75	3.66	6.63	6.56
63	-1.08	75.59	72.83	-2.76	13.34	13.21	27.46	28.24	0.78	56.51	58.72	2.21	6.44	6.38
64	4.35	70.71	74.46	3.75	13.04	12.91	26.16	32.19	6.03	56.99	57.70	0.71	6.45	6.39
65	-0.40	68.63	74.01	5.38	13.25	13.12	28.46	27.88	-0.58	52.49	53.76	1.27	6.14	6.08
66	-1.31	78.24	78.50	0.26	13.10	12.97	29.08	29.73	0.65	51.37	55.27	3.90	6.26	6.20
67	-2.02	84.07	80.99	-3.08	13.45	13.32	25.62	28.46	2.84	58.12	60.74	2.62	6.37	6.31
68	7.50	70.95	78.53	7.58	13.25	13.12	26.15	28.22	2.07	56.20	56.25	0.05	6.29	6.23
69	3.75	68.34	76.29	7.95	13.49	13.36	28.50	29.92	1.42	53.54	55.01	1.47	5.97	5.91
70	15.94	69.36	77.07	7.71	13.38	13.25	24.90	28.96	4.06	59.70	59.58	-0.12	6.06	6.00

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
71	12.25	15.08	2.83	2	1	1	1	1	1	2	2	5	10.35	13.81
72	11.50	14.83	3.33	2	1	1	1	2	2	2	2	1	10.74	17.22
73	16.00	17.58	1.58	1	1	1	2	2	2	2	2	1	19.96	16.69
75	14.08	16.16	2.08	1	1	1	2	1	1	2	2	1	10.89	8.04
76	12.25	14.42	2.17	1	2	1	2	2	1	2	2	2	24.86	14.37
77	11.83	14.16	2.33	1	1	1	2	2	2	2	2	1	12.46	13.93
78	15.08	17.42	2.34	2	2	1	2	2	2	2	2	5	16.11	16.62
80	12.00	15.33	3.33	2	2	1	2	2	2	1	1	1	19.84	18.74
81	14.16	16.16	2.00	2	1	1	1	2	2	2	2	1	18.87	18.05
82	11.83	14.08	2.25	2	1	1	1	2	2	2	2	1	13.02	17.96
83	12.00	14.16	2.16	1	1	1	1	2	2	2	2	1	7.23	10.43
84	14.42	16.58	2.16	1	1	1	1	2	1	2	2	1	24.55	22.34
85	15.83	18.50	2.67	2	2	1	1	2	2	2	2	1	23.78	20.95
86	14.92	17.00	2.08	2	2	1	2	2	2	1	1	1	12.10	12.47
87	17.25	19.25	2.00	1	1	1	1	2	2	2	2	1	16.04	16.98
88	13.42	16.33	2.91	2	2	1	1	2	2	2	2	1	11.49	15.34
89	15.00	17.66	2.66	1	1	1	1	2	2	2	2	1	23.16	20.67
90	15.42	18.00	2.58	2	2	1	1	1	2	2	2	4	6.54	14.22
91	12.75	16.50	3.75	2	1	1	2	1	1	2	2	1	16.61	14.50
92	10.58	13.42	2.84	1	1	1	2	2	2	2	2	1	19.52	17.20
93	13.33	15.50	2.17	1	1	1	1	1	2	2	2	1	13.32	15.29
94	13.75	14.83	1.08	2	1	1	1	2	2	2	2	1	18.05	23.03
95	14.50	17.83	3.33	1	2	1	2	1	1	2	2	2	20.98	16.42
96	13.75	16.66	2.91	2	1	1	2	2	2	2	2	1	18.77	17.80
97	12.50	16.16	3.66	2	1	1	2	2	2	2	2	5	14.30	14.08
99	15.33	17.33	2.00	2	1	1	2	2	2	2	2	1	10.77	11.25
100	12.66	14.83	2.17	2	1	1	2	2	2	2	2	5	16.17	16.63
102	14.08	17.58	3.50	2	2	1	2	2	2	2	2	1	15.20	14.57
103	14.42	16.50	2.08	2	1	1	2	2	2	2	2	5	9.82	12.44
104	12.75	14.75	2.00	2	1	1	2	2	1	2	2	4	14.24	14.98
105	15.92	17.50	1.58	2	2	1	2	2	1	2	2	1	15.37	16.25
106	15.42	17.92	2.50	2	1	1	2	2	1	2	2	3	6.57	8.28

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
71	3.46	65.86	67.32	1.46	13.42	13.29	30.64	30.46	-0.18	63.20	63.60	0.40	5.94	5.88
72	6.48	63.90	72.49	8.59	13.07	12.94	28.09	29.90	1.81	59.02	61.16	2.14	5.97	5.91
73	-3.27	65.62	64.52	-1.10	13.41	13.28	29.96	31.34	1.38	55.58	56.77	1.19	6.31	6.25
75	-2.85	68.19	69.44	1.25	13.27	13.14	28.14	30.54	2.40	57.72	64.25	6.53	6.32	6.26
76	-10.49	82.20	72.38	-9.82	12.82	13.08	29.88	31.65	1.77	55.68	58.62	2.94	6.40	6.34
77	1.47	63.74	68.79	5.05	12.99	13.25	28.72	31.27	2.55	53.22	56.44	3.22	6.03	5.97
78	0.51	75.79	75.60	-0.19	13.21	13.47	29.00	29.54	0.54	56.53	56.03	-0.50	6.55	6.49
80	-1.10	76.59	76.64	0.05	13.15	13.41	28.03	28.06	0.03	53.29	53.26	-0.03	5.97	5.91
81	-0.82	74.34	80.58	6.24	13.25	13.52	29.67	30.14	0.47	57.30	58.89	1.59	6.17	6.11
82	4.94	72.54	75.77	3.23	13.29	13.56	29.54	29.33	-0.21	64.29	67.16	2.87	6.65	6.58
83	3.20	74.85	80.04	5.19	13.38	13.65	26.29	29.32	3.03	55.44	60.04	4.60	5.94	5.88
84	-2.21	78.36	83.31	4.95	13.36	13.63	26.96	28.72	1.76	62.13	61.34	-0.79	6.08	6.02
85	-2.83	76.01	79.62	3.61	13.47	13.74	31.11	31.94	0.83	56.45	56.33	-0.12	6.33	6.27
86	0.37	76.22	72.37	-3.85	13.38	13.65	28.47	28.42	-0.05	60.28	63.19	2.91	5.94	5.88
87	0.94	72.84	70.63	-2.21	13.18	13.44	28.53	30.49	1.96	56.27	60.19	3.92	5.90	5.84
88	3.85	72.93	81.14	8.21	13.49	13.76	25.63	28.84	3.21	56.82	56.83	0.01	6.17	6.11
89	-2.49	76.36	85.34	8.98	13.30	13.57	26.19	30.16	3.97	60.83	64.47	3.64	6.28	6.22
90	7.68	75.50	82.59	7.09	13.38	13.65	28.60	29.00	0.40	53.39	57.39	4.00	6.21	6.15
91	-2.11	67.72	73.54	5.82	13.20	13.46	25.74	25.77	0.03	55.78	57.98	2.20	6.07	6.01
92	-2.32	69.92	73.55	3.63	13.01	13.27	27.00	30.21	3.21	50.27	55.06	4.79	6.11	6.05
93	1.97	75.61	82.93	7.32	13.50	13.77	32.38	34.93	2.55	62.74	65.89	3.15	6.40	6.34
94	4.98	69.17	74.46	5.29	13.29	13.56	32.07	33.09	1.02	60.10	60.67	0.57	6.75	6.68
95	-4.56	76.38	73.60	-2.78	13.38	13.65	26.44	29.34	2.90	55.18	56.61	1.43	6.10	6.04
96	-0.97	74.74	72.14	-2.60	13.42	13.69	27.81	27.94	0.13	55.77	58.96	3.19	6.18	6.12
97	-0.22	66.16	68.95	2.79	13.00	13.26	29.95	30.20	0.25	59.65	63.45	3.80	6.23	6.17
99	0.48	70.73	74.61	3.88	13.37	13.64	33.73	33.13	-0.60	54.73	55.00	0.27	6.14	6.08
100	0.46	74.92	75.28	0.36	13.25	13.52	25.63	26.01	0.38	55.99	55.46	-0.53	6.11	6.05
102	-0.63	85.06	82.14	-2.92	13.17	13.43	30.35	30.55	0.20	56.23	55.11	-1.12	6.18	6.12
103	2.62	77.11	77.24	0.13	13.59	13.86	31.01	32.56	1.55	59.03	58.97	-0.06	6.26	6.20
104	0.74	69.44	72.88	3.44	13.23	13.49	26.17	27.68	1.51	54.82	55.67	0.85	6.11	6.05
105	0.88	72.87	79.48	6.61	13.12	13.38	27.49	31.22	3.73	53.44	55.76	2.32	6.05	5.99
106	1.71	67.65	65.03	-2.62	13.34	13.61	31.02	29.91	-1.11	55.58	54.57	-1.01	6.42	6.36

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
107	14.25	14.92	0.67	2	1	1	2	2	1	2	2	2	11.00	11.42
108	15.83	18.00	2.17	2	1	1	2	2	1	2	2	1	19.55	17.37
109	14.16	16.58	2.42	2	2	1	1	2	2	2	2	2	15.39	19.60
110	13.50	15.92	2.42	2	2	1	1	1	1	2	2	1	20.49	20.64
111	14.42	16.42	2.00	2	1	1	2	2	2	2	2	1	17.12	18.14
112	11.25	14.25	3.00	1	1	1	2	1	1	2	2	2	18.71	17.82
113	14.42	16.25	1.83	1	1	1	1	2	2	1	1	5	12.50	10.80
114	14.08	16.83	2.75	2	1	1	1	2	2	2	2	1	19.32	16.89
115	14.83	17.16	2.33	1	1	1	1	2	2	2	2	1	17.39	17.51
116	13.92	16.08	2.16	2	1	1	1	2	1	2	2	1	11.34	17.26
117	12.92	14.16	1.24	2	1	1	2	2	1	2	2	1	14.76	18.89
118	12.83	14.50	1.67	2	1	1	2	2	2	2	2	1	16.23	12.89
119	15.00	17.00	2.00	1	1	1	1	1	1	2	1	1	28.99	23.76
120	15.00	17.50	2.50	2	2	1	1	2	2	2	2	1	19.60	16.85
122	14.92	16.83	1.91	2	1	1	1	2	2	2	2	1	25.11	18.15
125	12.92	15.25	2.33	1	1	1	2	2	2	2	2	1	17.87	16.64
127	13.83	16.08	2.25	2	1	1	1	2	2	2	2	1	16.98	16.33
128	13.08	16.75	3.67	2	2	1	1	1	2	2	2	5	15.31	12.73
130	12.50	14.66	2.16	2	1	1	2	2	2	2	2	1	11.93	17.03
131	13.42	15.25	1.83	1	1	1	2	2	2	1	2	1	21.82	15.07
135	11.50	14.16	2.66	1	1	1	2	2	2	2	2	1	16.99	14.18
137	14.00	16.50	2.50	2	1	1	1	2	2	2	2	5	15.80	17.43
138	13.42	16.83	3.41	1	1	1	2	2	2	2	2	1	17.94	16.69
139	12.33	14.66	2.33	2	1	1	2	2	2	1	1	1	15.87	12.49
140	14.25	15.83	1.58	2	1	1	2	1	1	2	2	1	18.71	19.75
141	12.83	16.83	4.00	2	1	1	2	2	2	1	1	1	17.14	15.48
142	14.83	16.33	1.50	2	1	1	2	2	2	2	2	2	21.91	26.95
143	11.00	13.50	2.50	2	1	1	2	2	2	2	2	1	18.29	19.90
144	12.58	15.40	2.82	1	1	1	2	2	1	2	2	1	16.48	14.21
145	13.08	15.08	2.00	2	1	1	1	2	2	2	2	1	10.31	23.72
146	13.16	15.33	2.17	2	1	1	1	2	2	2	1	5	16.38	14.89
147	14.66	16.66	2.00	2	1	1	2	2	2	2	2	1	26.05	20.97

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
107	0.42	78.32	74.74	-3.58	12.95	13.21	30.71	31.39	0.68	61.46	62.83	1.37	6.21	6.15
108	-2.18	74.95	71.07	-3.88	13.66	13.93	26.64	28.92	2.28	56.46	55.48	-0.98	6.30	6.24
109	4.21	78.30	78.42	0.12	13.15	13.41	33.95	35.66	1.71	59.66	55.36	-4.30	6.05	5.99
110	0.15	83.06	82.64	-0.42	13.12	13.38	26.76	27.26	0.50	54.20	58.25	4.05	6.19	6.13
111	1.02	71.90	73.35	1.45	13.55	13.82	32.19	31.83	-0.36	60.46	61.69	1.23	6.18	6.12
112	-0.89	73.06	76.45	3.39	13.25	13.52	26.23	30.14	3.91	60.98	62.13	1.15	6.17	6.11
113	-1.70	69.59	76.53	6.94	13.06	13.32	24.92	27.56	2.64	55.07	58.79	3.72	6.09	6.03
114	-2.43	71.36	66.44	-4.92	13.44	13.71	31.73	34.65	2.92	57.91	59.18	1.27	6.34	6.28
115	0.12	71.07	77.20	6.13	13.18	13.44	30.19	33.44	3.25	57.18	61.24	4.06	6.04	5.98
116	5.92	73.27	85.29	12.02	13.13	13.39	29.47	27.45	-2.02	65.50	61.47	-4.03	6.23	6.17
117	4.13	64.54	74.63	10.09	13.09	13.35	29.29	30.82	1.53	55.91	57.75	1.84	6.06	6.00
118	-3.34	81.53	87.11	5.58	13.09	13.35	26.94	26.73	-0.21	57.53	58.17	0.64	6.42	6.36
119	-5.23	85.28	83.73	-1.55	13.32	13.59	28.21	29.17	0.96	51.85	57.20	5.35	6.15	6.09
120	-2.75	64.62	69.28	4.66	13.55	13.82	27.03	29.29	2.26	58.15	57.81	-0.34	6.18	6.12
122	-6.96	78.26	81.74	3.48	13.63	13.90	29.10	31.95	2.85	62.69	63.43	0.74	6.18	6.12
125	-1.23	74.31	72.93	-1.38	13.36	13.63	27.06	28.90	1.84	52.10	54.03	1.93	6.10	6.04
127	-0.65	78.22	84.28	6.06	13.45	13.72	26.42	27.73	1.31	60.24	59.67	-0.57	6.31	6.25
128	-2.58	73.98	77.73	3.75	13.40	13.67	32.03	31.80	-0.23	60.84	61.11	0.27	6.11	6.05
130	5.10	72.76	72.34	-0.42	13.21	13.47	31.35	33.83	2.48	58.77	57.45	-1.32	6.06	6.00
131	-6.75	74.87	67.85	-7.02	13.24	13.50	29.97	32.35	2.38	55.84	58.31	2.47	6.30	6.24
135	-2.81	71.59	71.90	0.31	13.25	13.52	26.86	29.40	2.54	53.55	56.54	2.99	6.05	5.99
137	1.63	81.23	86.46	5.23	13.63	13.90	32.74	32.75	0.01	60.59	60.72	0.13	6.42	6.36
138	-1.25	83.37	87.86	4.49	13.03	13.29	32.39	32.91	0.52	53.54	58.16	4.62	6.08	6.02
139	-3.38	67.65	71.00	3.35	13.22	13.48	29.77	30.89	1.12	53.06	57.07	4.01	6.09	6.03
140	1.04	77.06	75.69	-1.37	13.40	13.67	29.58	30.45	0.87	57.42	56.98	-0.44	6.19	6.13
141	-1.66	77.89	79.77	1.88	13.26	13.53	30.24	30.38	0.14	53.64	55.54	1.90	6.43	6.37
142	5.04	67.66	77.63	9.97	13.11	13.37	28.87	30.34	1.47	60.54	61.84	1.30	6.53	6.47
143	1.61	67.88	75.29	7.41	13.21	13.47	28.57	29.93	1.36	51.30	53.62	2.32	6.11	6.05
144	-2.27	69.93	70.89	0.96	13.25	13.52	29.40	31.08	1.68	58.89	61.07	2.18	6.41	6.35
145	13.41	58.30	80.26	21.96	13.06	13.32	29.76	30.02	0.26	55.93	56.65	0.72	6.51	6.45
146	-1.49	71.11	78.47	7.36	13.11	13.37	29.53	30.08	0.55	59.79	59.88	0.09	6.13	6.07
147	-5.08	68.65	71.19	2.54	13.35	13.62	25.44	26.81	1.37	51.78	56.43	4.65	6.19	6.13

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
148	14.75	18.25	3.50	2	1	1	1	2	2	2	2	1	20.63	29.92
149	14.33	16.50	2.17	2	1	1	1	1	1	2	2	1	19.39	18.98
150	13.83	17.42	3.59	2	1	1	2	2	2	2	2	2	9.89	9.23
151	13.50	15.00	1.50	2	1	1	1	2	2	2	2	1	17.60	17.27
152	15.50	17.42	1.92	2	1	1	1	2	2	2	2	1	25.55	27.53
153	15.16	17.16	2.00	2	1	1	2	2	2	1	1	1	15.44	16.29
154	12.75	15.58	2.83	2	1	1	2	2	2	2	2	1	10.95	10.00
156	17.58	20.66	3.08	2	1	1	2	2	1	2	2	1	17.21	12.76
157	12.50	13.83	1.33	2	1	1	2	2	2	2	2	1	15.31	15.78
158	11.83	14.58	2.75	2	1	1	2	1	1	2	2	1	16.79	15.44
159	15.33	17.08	1.75	2	1	1	2	2	2	2	2	1	17.73	19.82
160	12.92	15.33	2.41	2	1	1	2	1	1	1	2	1	16.35	18.62
161	12.83	15.08	2.25	2	1	1	1	2	2	2	2	1	20.98	20.62
162	13.50	16.92	3.42	2	1	1	2	2	2	2	2	1	15.52	16.14
163	13.08	14.92	1.84	2	3	1	2	2	2	2	2	1	16.36	18.08
164	12.33	14.50	2.17	2	1	1	2	2	2	2	2	2	14.80	16.57
165	14.16	16.08	1.92	2	1	1	2	2	2	2	2	1	17.84	22.24
166	12.83	14.66	1.83	2	1	1	2	2	2	2	2	5	12.57	9.20
167	16.75	18.66	1.91	2	2	1	2	1	2	2	2	1	17.78	17.36
168	14.75	17.16	2.41	2	1	1	2	2	2	2	2	1	15.66	12.83
169	11.83	13.66	1.83	2	1	1	2	2	1	2	2	1	13.29	14.30
170	12.58	14.50	1.92	2	2	1	2	2	2	2	2	1	16.56	14.76
174	13.08	17.66	4.58	2	2	1	1	2	2	2	2	1	16.71	21.01
175	13.25	15.50	2.25	2	2	1	2	2	2	1	1	2	20.64	18.44
176	12.50	14.25	1.75	2	1	1	1	2	2	2	2	1	12.58	17.11
177	12.83	14.50	1.67	2	1	1	2	2	2	2	2	1	19.93	21.47
178	14.00	16.00	2.00	2	1	1	2	1	1	2	2	2	10.60	14.06
179	10.75	12.66	1.91	2	2	1	2	2	2	2	2	1	14.80	16.53
180	14.83	16.58	1.75	1	1	1	2	2	2	2	2	1	19.30	17.72
181	11.83	14.08	2.25	2	1	1	2	2	2	2	2	1	9.80	9.50
182	13.16	15.08	1.92	2	1	1	2	2	2	2	2	5	9.03	11.70
183	11.66	14.33	2.67	2	2	1	2	2	2	2	2	1	13.38	25.13

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
148	9.29	73.29	90.27	16.98	13.38	13.65	31.76	35.37	3.61	60.44	64.07	3.63	6.13	6.07
149	-0.41	71.79	76.52	4.73	13.09	13.35	31.04	32.52	1.48	57.36	57.01	-0.35	6.43	6.37
150	-0.66	92.36	86.94	-5.42	13.32	13.59	32.35	32.30	-0.05	65.13	66.76	1.63	6.24	6.18
151	-0.33	69.75	65.81	-3.94	13.14	13.40	29.66	31.58	1.92	57.89	57.50	-0.39	6.08	6.02
152	1.98	70.12	83.76	13.64	13.40	13.67	32.66	34.71	2.05	57.17	59.79	2.62	6.01	5.95
153	0.85	83.84	83.58	-0.26	13.34	13.61	29.89	31.44	1.55	59.57	61.98	2.41	6.25	6.19
154	-0.95	75.04	77.01	1.97	13.19	13.45	27.09	27.44	0.35	55.13	59.50	4.37	6.23	6.17
156	-4.45	81.05	78.00	-3.05	13.10	13.36	32.58	32.82	0.24	52.71	57.61	4.90	6.11	6.05
157	0.47	74.57	83.98	9.41	13.12	13.38	29.82	30.48	0.66	56.19	55.16	-1.03	6.19	6.13
158	-1.35	74.91	78.29	3.38	12.94	13.20	28.03	28.44	0.41	59.62	59.63	0.01	6.07	6.01
159	2.09	70.38	78.34	7.96	13.62	13.89	25.07	23.65	-1.42	54.32	54.56	0.24	6.26	6.20
160	2.27	71.08	76.27	5.19	13.50	13.77	26.63	28.40	1.77	54.69	56.84	2.15	6.52	6.46
161	-0.36	70.30	70.74	0.44	12.95	13.21	26.93	29.54	2.61	57.92	58.83	0.91	6.38	6.32
162	0.62	62.10	71.68	9.58	13.12	13.38	28.07	28.83	0.76	53.82	53.81	-0.01	6.15	6.09
163	1.72	71.03	66.30	-4.73	13.29	13.56	27.17	31.13	3.96	53.72	55.62	1.90	6.26	6.20
164	1.77	78.58	77.50	-1.08	13.32	13.59	32.22	33.24	1.02	59.90	63.20	3.30	6.25	6.19
165	4.40	75.80	71.58	-4.22	13.35	13.62	29.83	30.09	0.26	57.36	57.53	0.17	6.21	6.15
166	-3.37	72.86	74.36	1.50	13.04	13.30	28.63	28.21	-0.42	58.26	58.11	-0.15	6.30	6.24
167	-0.42	71.60	69.69	-1.91	13.21	13.47	26.54	29.51	2.97	54.02	54.14	0.12	6.43	6.37
168	-2.83	70.72	66.92	-3.80	13.09	13.35	28.58	29.57	0.99	59.35	58.79	-0.56	6.30	6.24
169	1.01	65.50	75.74	10.24	13.27	13.54	28.13	28.55	0.42	55.34	57.45	2.11	6.35	6.29
170	-1.80	69.66	68.74	-0.92	13.36	13.63	27.35	29.94	2.59	53.40	54.26	0.86	6.14	6.08
174	4.30	73.91	82.05	8.14	13.05	13.31	25.48	26.93	1.45	53.12	56.77	3.65	6.09	6.03
175	-2.20	83.38	83.49	0.11	13.13	13.39	26.26	27.32	1.06	54.15	54.60	0.45	6.33	6.27
176	4.53	74.00	78.47	4.47	13.13	13.39	31.26	30.93	-0.33	56.79	58.62	1.83	6.31	6.25
177	1.54	69.98	73.60	3.62	13.47	13.74	32.11	32.98	0.87	60.16	58.54	-1.62	6.54	6.48
178	3.46	73.89	73.80	-0.09	13.25	13.52	30.53	29.50	-1.03	55.86	55.82	-0.04	6.03	5.97
179	1.73	68.64	72.75	4.11	13.16	13.42	29.47	30.58	1.11	53.25	53.47	0.22	6.23	6.17
180	-1.58	78.19	78.24	0.05	13.09	13.35	27.23	29.15	1.92	51.30	54.16	2.86	6.42	6.36
181	-0.30	69.29	77.00	7.71	13.21	13.47	29.58	30.39	0.81	61.28	59.02	-2.26	6.23	6.17
182	2.67	68.55	76.09	7.54	13.18	13.44	28.01	28.62	0.61	61.18	60.84	-0.34	6.47	6.41
183	11.75	67.53	68.94	1.41	13.27	13.54	28.33	29.19	0.86	55.51	56.29	0.78	5.96	5.90

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
184	14.75	16.83	2.08	1	1	1	2	2	2	2	2	1	12.00	10.55
185	13.66	16.25	2.59	1	1	1	2	2	1	2	2	1	22.40	17.71
186	15.42	17.42	2.00	1	1	1	2	1	1	1	2	1	26.60	18.51
187	9.66	14.00	4.34	1	1	1	2	2	2	2	2	5	12.12	16.41
189	13.42	15.50	2.08	1	1	1	1	2	2	2	2	1	9.90	3.36
190	12.66	14.50	1.84	1	1	1	1	2	2	2	2	1	19.61	16.83
191	16.66	18.42	1.76	2	5	1	2	2	2	2	2	1	19.57	20.34
192	11.42	13.66	2.24	2	1	1	2	2	2	2	2	1	17.17	19.06
193	13.58	16.50	2.92	2	1	1	2	2	2	2	2	1	18.12	17.47
195	12.25	14.58	2.33	1	1	1	2	2	2	2	2	1	26.12	17.24
197	13.50	16.66	3.16	1	1	1	2	2	2	2	2	1	17.37	13.13
198	12.00	13.83	1.83	2	1	1	2	2	2	2	2	5	12.62	17.03
199	15.08	17.16	2.08	1	1	1	2	2	2	2	2	1	20.94	17.86
201	11.16	13.58	2.42	1	2	2	2	2	2	2	2	2	19.90	14.49
202	11.50	13.16	1.66	1	1	1	2	2	2	2	2	1	16.47	14.15
203	15.33	17.58	2.25	1	1	1	2	2	2	2	2	1	15.67	9.56
204	13.75	15.92	2.17	2	1	1	2	2	2	2	2	1	19.69	24.13
205	15.42	17.25	1.83	2	1	1	2	2	1	2	2	1	14.49	17.94
206	12.50	14.33	1.83	2	1	1	1	1	1	2	2	1	15.08	16.88
207	12.16	14.42	2.26	2	1	1	1	2	2	2	2	5	12.37	12.68
208	12.16	14.66	2.50	2	1	1	2	2	2	2	2	1	14.56	16.99
209	13.66	15.92	2.26	2	1	1	2	2	2	2	2	1	17.13	16.34
210	14.50	17.66	3.16	2	1	1	2	2	2	2	2	1	16.12	18.51
211	14.25	16.50	2.25	2	1	1	1	1	1	2	2	2	14.88	17.12
212	12.66	14.58	1.92	2	1	1	1	2	2	2	2	1	15.12	17.47
214	10.83	12.58	1.75	2	1	1	2	2	2	2	2	1	12.16	11.42
215	15.83	18.00	2.17	2	2	1	2	2	2	2	2	2	10.41	11.98
216	11.58	13.25	1.67	2	2	1	1	2	2	2	2	1	16.67	22.13
217	16.33	19.58	3.25	2	1	1	1	2	2	2	2	1	18.59	21.47
218	14.25	17.00	2.75	2	2	1	2	2	1	2	2	2	18.05	21.52
220	14.75	17.33	2.58	2	1	1	2	2	2	2	2	1	17.28	19.26
221	11.75	15.66	3.91	2	1	1	2	2	2	2	2	1	11.34	12.95

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
184	-1.45	77.44	72.54	-4.90	13.22	13.09	30.13	31.43	1.30	58.29	60.81	2.52	6.62	6.55
185	-4.69	66.22	64.19	-2.03	13.46	13.33	27.87	30.38	2.51	53.83	58.29	4.46	6.36	6.30
186	-8.09	82.16	81.16	-1.00	13.10	12.97	25.43	29.04	3.61	53.50	58.31	4.81	6.63	6.56
187	4.29	69.30	78.87	9.57	13.12	12.99	29.68	31.54	1.86	56.62	57.78	1.16	6.41	6.35
189	-6.54	79.23	66.03	-13.20	13.31	13.18	26.79	29.45	2.66	60.23	65.93	5.70	6.05	5.99
190	-2.78	74.76	73.00	-1.76	13.19	13.06	29.73	30.77	1.04	58.82	59.56	0.74	6.19	6.13
191	0.77	73.06	78.69	5.63	13.07	12.94	32.01	32.47	0.46	57.02	59.39	2.37	6.49	6.43
192	1.89	73.51	77.23	3.72	13.39	13.26	27.57	27.09	-0.48	53.33	56.39	3.06	6.31	6.25
193	-0.65	67.67	65.23	-2.44	13.25	13.12	29.75	31.67	1.92	53.86	55.13	1.27	5.97	5.91
195	-8.88	82.80	79.45	-3.35	13.12	12.99	26.70	29.37	2.67	54.80	57.07	2.27	6.25	6.19
197	-4.24	69.87	79.96	10.09	13.37	13.24	25.60	31.19	5.59	54.99	56.86	1.87	6.11	6.05
198	4.41	63.05	76.40	13.35	13.35	13.22	30.69	30.13	-0.56	53.76	55.30	1.54	6.26	6.20
199	-3.08	75.54	76.85	1.31	13.21	13.08	28.32	31.01	2.69	55.57	58.90	3.33	6.61	6.54
201	-5.41	68.91	76.68	7.77	13.48	13.35	28.16	32.47	4.31	56.42	63.64	7.22	6.43	6.37
202	-2.32	72.07	71.42	-0.65	13.16	13.03	30.88	32.30	1.42	53.87	58.06	4.19	6.43	6.37
203	-6.11	72.99	76.08	3.09	13.28	13.15	31.73	31.93	0.20	56.22	58.18	1.96	6.05	6.17
204	4.44	72.31	70.76	-1.55	13.45	13.32	27.50	28.48	0.98	57.38	58.02	0.64	5.93	6.05
205	3.45	75.58	76.25	0.67	13.20	13.07	30.61	31.65	1.04	56.29	57.51	1.22	5.93	6.05
206	1.80	76.14	79.89	3.75	13.05	12.92	30.60	30.11	-0.49	55.34	55.88	0.54	5.97	6.09
207	0.31	69.27	79.73	10.46	13.51	13.37	27.62	29.93	2.31	57.42	62.80	5.38	5.96	6.08
208	2.43	74.72	83.99	9.27	13.21	13.08	30.00	31.82	1.82	55.59	57.47	1.88	6.08	6.20
209	-0.79	71.15	73.12	1.97	13.19	13.06	27.12	28.00	0.88	55.73	56.05	0.32	5.87	5.99
210	2.39	84.30	87.72	3.42	13.38	13.25	31.83	32.04	0.21	59.34	59.36	0.02	6.12	6.24
211	2.24	85.06	86.05	0.99	13.37	13.24	33.77	33.75	-0.02	65.43	64.35	-1.08	6.06	6.18
212	2.35	67.55	68.85	1.30	13.09	12.96	29.67	31.11	1.44	55.27	57.10	1.83	5.86	5.98
214	-0.74	62.82	65.34	2.52	12.99	12.86	25.08	27.47	2.39	57.72	57.49	-0.23	6.02	6.14
215	1.57	82.47	73.43	-9.04	13.36	13.23	23.83	25.28	1.45	55.09	55.48	0.39	6.32	6.45
216	5.46	75.69	75.67	-0.02	13.33	13.20	24.77	25.92	1.15	56.88	58.01	1.13	5.93	6.05
217	2.88	74.71	80.16	5.45	13.10	12.97	28.84	30.45	1.61	59.77	60.34	0.57	6.51	6.64
218	3.47	74.58	75.73	1.15	13.02	12.89	27.36	29.08	1.72	58.53	58.12	-0.41	5.85	5.97
220	1.98	76.41	74.61	-1.80	13.44	13.31	33.82	33.78	-0.04	56.28	59.27	2.99	6.08	6.20
221	1.61	69.55	74.89	5.34	13.46	13.33	29.50	32.12	2.62	54.11	57.18	3.07	6.11	6.23

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
224	13.58	16.83	3.25	2	1	1	2	2	2	2	2	1	15.73	18.71
226	10.08	11.33	1.25	2	1	2	1	2	2	2	2	5	16.68	17.58
227	12.83	15.33	2.50	2	1	1	1	2	1	1	1	1	15.64	18.13
228	12.16	13.66	1.50	2	1	1	2	2	2	2	2	1	15.71	18.51
229	12.92	15.33	2.41	1	1	1	2	2	2	2	2	1	33.38	23.66
230	13.25	15.66	2.41	1	1	1	2	1	1	1	1	1	14.21	14.46
231	12.42	17.33	4.91	1	1	1	2	2	2	2	2	1	18.34	12.96
232	10.16	14.50	4.34	1	1	1	2	2	1	2	2	1	11.01	12.49
235	12.25	14.75	2.50	1	1	1	2	2	2	2	2	1	15.87	18.26
237	12.42	15.33	2.91	1	1	1	1	2	2	2	2	1	25.97	26.78
238	13.33	16.58	3.25	1	1	1	2	2	1	2	2	1	21.59	17.18
239	14.08	16.58	2.50	1	1	1	2	2	2	2	2	1	13.46	11.46
240	14.16	17.25	3.09	1	1	1	1	2	2	2	2	1	12.31	13.50
241	12.00	14.42	2.42	1	1	1	2	2	2	2	2	1	11.11	8.31
242	12.75	15.25	2.50	1	1	1	1	1	1	1	1	1	14.61	21.16
243	9.33	11.75	2.42	1	1	1	2	2	2	1	1	1	15.47	18.65
244	13.92	16.00	2.08	1	1	1	2	2	2	2	1	1	13.27	9.42
246	12.33	14.58	2.25	1	1	1	1	2	2	2	2	1	15.30	23.66
247	13.92	16.58	2.66	1	1	1	1	2	2	1	1	1	20.95	19.33
248	15.06	18.25	3.19	1	1	1	2	2	2	2	2	1	22.89	20.61
249	12.66	15.83	3.17	1	1	1	1	2	1	2	2	1	13.02	20.78
250	14.25	16.66	2.41	1	1	1	1	1	1	2	2	1	15.98	17.71
252	12.00	14.50	2.50	1	1	1	2	2	2	2	2	1	17.56	15.25
253	11.75	14.92	3.17	1	1	1	1	2	2	2	2	4	16.25	21.72
254	12.83	15.08	2.25	1	1	1	2	1	2	2	2	1	22.04	18.97
255	13.50	15.92	2.42	1	1	1	2	2	2	2	2	1	9.71	9.01
256	13.00	15.25	2.25	1	1	1	1	2	2	2	2	1	24.51	21.91
257	16.83	19.72	2.89	1	1	1	1	2	2	2	2	5	17.00	16.56
258	15.08	18.58	3.50	1	2	1	1	2	2	2	2	1	27.13	26.63
260	13.50	15.33	1.83	1	1	1	2	2	2	1	2	1	24.26	21.51
261	14.83	17.33	2.50	1	1	1	1	2	2	2	2	1	18.07	13.75
262	13.25	16.25	3.00	1	1	1	2	2	2	2	2	5	18.99	16.02

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
224	2.98	74.19	70.94	-3.25	13.16	13.03	28.98	29.30	0.32	56.31	56.39	0.08	6.11	6.23
226	0.90	68.92	70.02	1.10	13.12	12.99	27.95	28.16	0.21	56.97	57.24	0.27	6.01	6.13
227	2.49	72.58	82.01	9.43	13.27	13.14	30.80	31.02	0.22	55.92	57.00	1.08	6.14	6.27
228	2.80	61.75	70.78	9.03	13.28	13.15	27.28	28.86	1.58	53.54	56.76	3.22	5.85	5.97
229	-9.72	76.49	76.81	0.32	13.38	13.25	27.39	31.19	3.80	57.15	60.74	3.59	6.33	6.46
230	0.25	73.97	77.70	3.73	13.31	13.18	27.76	28.85	1.09	57.63	58.64	1.01	6.31	6.44
231	-5.38	68.17	71.95	3.78	13.11	12.98	26.86	29.02	2.16	55.74	58.89	3.15	5.97	6.09
232	1.48	63.20	73.15	9.95	13.29	13.16	25.72	27.20	1.48	55.49	58.48	2.99	6.11	6.23
235	2.39	64.24	61.43	-2.81	13.46	13.33	29.08	31.09	2.01	52.74	57.45	4.71	5.96	6.08
237	0.81	73.82	84.06	10.24	13.17	13.04	30.11	32.00	1.89	52.51	56.98	4.47	5.80	5.92
238	-4.41	89.35	92.29	2.94	13.43	13.30	24.12	28.68	4.56	54.40	57.78	3.38	6.29	6.42
239	-2.00	76.81	75.29	-1.52	13.29	13.16	25.34	28.45	3.11	54.59	58.54	3.95	6.35	6.48
240	1.19	67.83	80.22	12.39	13.13	13.00	29.94	33.75	3.81	55.99	62.53	6.54	6.03	6.15
241	-2.80	63.96	67.48	3.52	13.43	13.30	23.94	25.86	1.92	54.78	58.37	3.59	6.05	6.17
242	6.55	71.26	70.66	-0.60	13.48	13.35	31.19	34.35	3.16	59.26	61.78	2.52	5.99	6.11
243	3.18	77.51	82.02	4.51	13.53	13.39	27.64	29.92	2.28	54.28	58.04	3.76	6.00	6.12
244	-3.85	82.58	86.63	4.05	13.33	13.20	27.93	29.85	1.92	53.92	58.35	4.43	6.08	6.20
246	8.36	65.00	73.47	8.47	13.12	12.99	25.23	27.88	2.65	58.36	60.09	1.73	6.31	6.44
247	-1.62	81.87	78.90	-2.97	13.05	12.92	29.79	30.90	1.11	58.06	61.21	3.15	6.34	6.47
248	-2.28	82.69	82.57	-0.12	13.17	13.04	28.27	31.83	3.56	56.43	64.01	7.58	6.28	6.41
249	7.76	73.12	77.36	4.24	13.13	13.00	26.08	28.69	2.61	55.22	60.33	5.11	6.08	6.20
250	1.73	72.02	78.21	6.19	13.02	12.89	28.21	31.35	3.14	53.43	59.72	6.29	6.34	6.47
252	-2.31	69.25	58.10	-11.15	13.10	12.97	23.73	28.34	4.61	52.56	58.33	5.77	6.01	6.13
253	5.47	68.80	77.86	9.06	12.95	12.82	29.87	30.45	0.58	56.74	60.45	3.71	6.06	6.18
254	-3.07	77.90	76.08	-1.82	13.19	13.06	24.88	27.89	3.01	51.40	54.56	3.16	6.11	6.23
255	-0.70	65.29	67.42	2.13	13.06	12.93	26.10	30.21	4.11	54.11	56.85	2.74	6.31	6.44
256	-2.60	72.31	79.42	7.11	13.15	13.02	25.89	30.42	4.53	56.05	58.30	2.25	6.11	6.23
257	-0.44	75.88	83.33	7.45	13.10	12.97	29.81	33.37	3.56	60.02	64.91	4.89	6.10	6.22
258	-0.50	82.28	85.64	3.36	13.20	13.07	29.20	30.65	1.45	55.56	60.99	5.43	6.01	6.13
260	-2.75	76.92	80.07	3.15	13.21	13.08	29.20	32.21	3.01	55.48	57.57	2.09	6.24	6.37
261	-4.32	74.98	71.25	-3.73	13.14	13.01	24.61	28.02	3.41	57.49	59.45	1.96	6.31	6.44
262	-2.97	74.55	75.00	0.45	13.39	13.26	29.20	31.39	2.19	55.87	57.25	1.38	5.98	6.10

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
266	13.92	17.25	3.33	1	2	1	2	2	2	2	2	1	15.65	11.22
267	11.75	14.50	2.75	1	1	1	2	1	1	2	2	1	26.29	24.52
268	13.42	15.42	2.00	1	1	1	1	2	1	2	2	1	14.17	18.87
269	12.83	15.33	2.50	1	1	1	2	2	2	2	2	1	17.64	18.11
270	11.83	16.16	4.33	1	1	1	1	1	1	2	2	1	20.60	24.51
271	14.92	17.16	2.24	1	1	1	1	2	2	2	2	1	13.23	19.51
273	12.42	14.58	2.16	1	1	1	2	2	2	2	2	1	19.23	18.17
274	14.50	18.00	3.50	1	2	1	1	1	1	2	2	1	28.34	28.32
275	11.00	14.25	3.25	1	1	1	2	2	2	1	1	1	12.65	15.43
276	12.92	15.42	2.50	1	1	1	1	2	2	2	2	1	22.83	24.90
277	13.42	15.00	1.58	1	1	1	2	2	2	2	2	1	14.97	10.92
278	12.58	14.66	2.08	1	1	1	1	2	2	2	2	1	17.15	14.38
279	13.16	15.50	2.34	1	1	1	1	2	2	2	2	1	20.55	18.27
280	14.50	16.42	1.92	1	1	1	2	2	2	2	2	1	14.60	18.20
281	11.42	14.83	3.41	1	1	1	1	1	1	2	2	1	12.83	14.04
282	12.66	17.83	5.17	1	1	1	1	2	1	2	2	1	20.76	18.41
283	12.75	14.42	1.67	1	1	1	1	1	1	2	2	1	26.55	28.63
285	15.08	16.08	1.00	1	1	1	2	2	2	2	2	1	17.43	16.39
286	12.66	15.25	2.59	2	1	1	1	2	2	2	2	1	19.83	20.05
287	13.75	16.00	2.25	2	1	1	1	2	2	2	2	2	15.54	16.48
289	11.33	14.50	3.17	2	2	1	2	2	2	2	2	1	14.90	21.47
290	15.33	17.08	1.75	2	1	1	2	1	1	2	2	1	17.83	18.37
291	15.08	17.08	2.00	2	1	1	2	2	2	2	2	1	14.23	16.11
293	12.25	13.66	1.41	2	1	1	1	2	2	2	2	5	13.92	14.23
295	14.08	16.25	2.17	2	3	1	2	2	2	2	2	1	13.13	14.35
297	14.83	17.83	3.00	2	1	1	2	1	2	1	1	1	18.13	15.64
299	13.75	15.92	2.17	2	2	1	1	2	2	2	2	1	15.11	20.33
300	13.33	15.42	2.09	2	1	1	2	2	2	2	2	1	18.75	19.18
302	12.42	15.25	2.83	2	1	1	1	2	2	2	2	1	12.78	15.12
304	13.75	16.83	3.08	1	1	1	1	2	1	2	2	1	19.07	22.41
305	11.58	15.08	3.50	1	1	1	2	2	1	2	2	1	15.14	12.60
306	12.75	14.25	1.50	1	1	1	2	2	1	2	2	1	16.11	12.96

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
266	-4.43	72.32	73.77	1.45	13.12	12.99	29.06	31.00	1.94	54.95	57.25	2.30	5.90	6.02
267	-1.77	80.65	82.61	1.96	13.24	13.11	25.42	28.00	2.58	54.26	58.00	3.74	6.33	6.46
268	4.70	67.02	77.74	10.72	13.24	13.11	26.35	28.02	1.67	56.03	59.45	3.42	6.10	6.22
269	0.47	70.33	73.67	3.34	13.16	13.03	29.59	32.66	3.07	58.79	58.93	0.14	6.19	6.32
270	3.91	73.65	79.84	6.19	13.38	13.25	27.45	31.36	3.91	55.01	60.75	5.74	6.13	6.25
271	6.28	65.61	73.62	8.01	13.18	13.05	29.25	31.39	2.14	57.74	61.98	4.24	6.24	6.37
273	-1.06	70.85	72.47	1.62	13.21	13.08	27.74	30.24	2.50	52.95	59.23	6.28	6.12	6.24
274	-0.02	74.68	83.16	8.48	13.13	13.00	26.11	33.20	7.09	49.12	59.90	10.78	6.10	6.22
275	2.78	68.46	76.43	7.97	13.03	12.90	28.41	31.70	3.29	55.11	59.36	4.25	6.41	6.28
276	2.07	62.57	75.59	13.02	13.24	13.11	24.80	27.77	2.97	57.50	60.19	2.69	6.36	6.24
277	-4.05	64.83	72.88	8.05	13.22	13.09	29.77	31.86	2.09	59.99	61.98	1.99	6.29	6.17
278	-2.77	71.36	68.65	-2.71	13.26	13.13	30.36	32.02	1.66	59.98	61.25	1.27	6.39	6.26
279	-2.28	71.99	78.74	6.75	13.28	13.15	29.09	31.07	1.98	57.79	61.57	3.78	6.15	6.03
280	3.60	71.87	81.37	9.50	13.15	13.02	23.54	25.14	1.60	58.46	59.27	0.81	6.32	6.20
281	1.21	68.08	69.75	1.67	13.16	13.03	27.55	30.92	3.37	52.74	59.59	6.85	6.17	6.05
282	-2.35	71.20	72.81	1.61	13.18	13.05	28.78	30.00	1.22	56.85	59.02	2.17	6.62	6.49
283	2.08	79.73	79.59	-0.14	13.12	12.99	28.58	29.74	1.16	53.47	58.14	4.67	6.24	6.12
285	-1.04	73.22	64.53	-8.69	13.09	12.96	28.55	30.13	1.58	54.30	58.97	4.67	6.15	6.03
286	0.22	75.46	79.39	3.93	13.42	13.29	28.51	30.39	1.88	54.20	58.02	3.82	6.55	6.42
287	0.94	76.82	80.01	3.19	13.40	13.27	30.44	30.91	0.47	64.14	63.91	-0.23	6.25	6.13
289	6.57	67.78	72.30	4.52	13.34	13.21	26.46	27.48	1.02	54.50	53.56	-0.94	6.14	6.02
290	0.54	73.97	78.27	4.30	13.47	13.34	26.52	26.11	-0.41	52.43	53.14	0.71	6.29	6.17
291	1.88	64.38	69.98	5.60	13.21	13.08	30.57	31.92	1.35	57.81	57.34	-0.47	6.24	6.12
293	0.31	82.75	91.69	8.94	13.11	12.98	30.48	31.09	0.61	61.14	62.02	0.88	6.24	6.12
295	1.22	71.82	75.02	3.20	13.26	13.13	25.42	26.01	0.59	55.38	56.00	0.62	6.24	6.12
297	-2.49	80.74	76.19	-4.55	13.13	13.00	30.41	31.30	0.89	62.28	56.49	-5.79	6.22	6.10
299	5.22	67.74	63.94	-3.80	13.52	13.38	30.82	31.86	1.04	52.42	53.22	0.80	6.39	6.26
300	0.43	65.12	67.09	1.97	13.13	13.00	24.35	25.58	1.23	54.37	54.17	-0.20	6.23	6.11
302	2.34	72.37	75.14	2.77	13.12	12.99	24.82	25.80	0.98	61.15	61.44	0.29	6.35	6.23
304	3.34	83.60	97.09	13.49	13.08	12.95	28.31	32.17	3.86	55.95	59.98	4.03	6.43	6.30
305	-2.54	74.70	75.70	1.00	13.17	13.04	29.71	30.97	1.26	57.11	58.17	1.06	6.47	6.34
306	-3.15	73.52	70.76	-2.76	13.19	13.06	27.93	29.39	1.46	56.59	60.35	3.76	6.42	6.29

TABLE 2.--Raw Data (continued)

ID	Age T1	Age T2	Age Diff	RPE	Extract	Phase	Gender	DBN	MB	Tons Rem	Aden Rem	Race	H-MP T1	H-MP T2
307	10.25	12.42	2.17	1	1	1	2	2	1	2	2	1	12.63	12.80
308	13.66	15.42	1.76	1	1	1	2	2	2	2	2	1	21.02	19.37
309	13.33	15.60	2.27	1	1	1	2	2	1	2	2	1	17.64	11.65
310	14.66	17.16	2.50	1	1	1	1	2	2	2	2	1	16.59	17.63
311	10.83	13.33	2.50	1	1	1	2	2	2	1	1	1	14.63	15.12
312	11.92	13.83	1.91	1	1	1	2	2	2	2	2	1	16.07	16.64
313	11.33	15.33	4.00	1	2	1	2	2	2	2	2	1	16.52	17.90
314	15.83	18.00	2.17	1	1	1	2	2	2	2	2	1	19.92	15.80
316	12.08	18.50	6.42	1	1	1	2	2	2	2	2	1	14.29	20.21
317	15.83	17.50	1.67	1	1	1	1	2	2	1	1	1	18.21	21.34
318	13.58	15.00	1.42	1	1	1	2	2	2	2	2	1	20.79	17.90
320	15.66	16.83	1.17	1	1	1	1	2	2	2	2	1	19.94	23.01
321	12.66	16.16	3.50	1	1	1	1	2	2	2	2	1	21.63	22.49
322	9.30	11.58	2.28	1	1	2	2	2	2	2	2	1	16.50	15.88
323	11.66	13.08	1.42	1	1	1	2	2	2	2	2	1	15.36	14.65
324	13.58	15.92	2.34	1	1	1	1	1	1	2	2	1	27.00	21.16
325	12.16	15.66	3.50	1	2	1	2	2	2	2	2	1	16.46	7.63
326	12.33	14.42	2.09	1	1	1	1	2	2	1	2	1	15.07	12.57
327	10.92	12.25	1.33	1	1	1	2	2	2	2	2	1	16.12	16.61
328	14.42	16.42	2.00	1	1	1	2	2	2	2	2	1	13.22	9.43
329	11.33	13.58	2.25	1	1	1	1	2	2	2	2	1	13.51	12.95
330	14.08	16.42	2.34	1	1	1	2	2	2	2	2	1	24.42	21.47
331	15.92	18.16	2.24	1	1	1	1	2	1	2	2	1	25.61	26.69
333	13.08	15.75	2.67	1	1	1	2	2	2	2	2	1	18.78	18.37
335	15.42	18.33	2.91	1	2	1	1	2	2	1	2	1	15.33	19.06
336	14.42	16.58	2.16	1	4	1	2	2	1	2	2	1	20.26	16.14
337	13.42	16.25	2.83	1	2	1	1	2	2	2	2	1	11.86	18.68
338	11.92	13.58	1.66	1	1	1	2	2	2	1	1	1	18.45	25.38
339	11.66	13.75	2.09	1	1	1	2	2	2	1	1	1	19.34	18.01

TABLE 2.--Raw Data (continued)

ID	H-MP Diff	TL T1	TL T2	TL Diff	Nasion T1	Nas T2	NW T1	NW T2	NWD	Interm T1	Interm T2	Interm Diff	Ear T1	Ear T2
307	0.17	67.61	75.80	8.19	13.34	13.21	24.37	28.30	3.93	55.53	58.71	3.18	6.24	6.12
308	-1.65	70.93	71.25	0.32	13.23	13.10	27.69	28.60	0.91	55.88	58.32	2.44	6.35	6.23
309	-5.99	80.25	82.04	1.79	13.11	12.98	24.43	26.09	1.66	55.22	58.98	3.76	6.42	6.29
310	1.04	68.27	79.23	10.96	13.44	13.31	29.07	33.26	4.19	58.51	61.05	2.54	6.21	6.09
311	0.49	74.16	81.50	7.34	13.25	13.12	28.10	33.74	5.64	57.36	59.44	2.08	6.24	6.12
312	0.57	66.56	73.06	6.50	13.49	13.36	25.75	28.99	3.24	54.77	56.01	1.24	6.38	6.25
313	1.38	70.11	72.55	2.44	13.51	13.37	27.36	30.74	3.38	53.02	55.66	2.64	6.42	6.29
314	-4.12	77.71	74.09	-3.62	13.32	13.19	26.05	27.15	1.10	52.65	55.47	2.82	6.43	6.30
316	5.92	61.84	71.97	10.13	13.12	12.99	23.06	29.54	6.48	50.86	56.90	6.04	6.27	6.15
317	3.13	82.82	85.59	2.77	13.13	13.00	30.74	32.49	1.75	54.46	59.23	4.77	6.48	6.35
318	-2.89	77.01	78.87	1.86	13.28	13.15	24.16	25.11	0.95	53.27	55.50	2.23	6.18	6.06
320	3.07	78.98	81.84	2.86	13.11	12.98	25.66	28.31	2.65	56.28	59.17	2.89	6.33	6.21
321	0.86	75.09	79.19	4.10	13.54	13.40	25.84	30.73	4.89	54.41	59.81	5.40	6.69	6.56
322	-0.62	69.44	70.34	0.90	13.27	13.14	24.93	30.09	5.16	55.40	61.19	5.79	6.18	6.06
323	-0.71	66.32	74.10	7.78	13.30	13.17	27.28	29.23	1.95	52.72	53.80	1.08	6.55	6.42
324	-5.84	81.97	83.80	1.83	13.12	13.25	25.86	30.61	4.75	54.26	59.19	4.93	6.24	6.12
325	-8.83	67.35	71.22	3.87	13.12	13.25	21.37	26.86	5.49	52.61	57.37	4.76	6.14	6.02
326	-2.50	73.74	79.91	6.17	13.14	13.27	25.10	29.38	4.28	53.14	59.26	6.12	6.24	6.12
327	0.49	65.45	67.11	1.66	13.39	13.52	26.65	28.12	1.47	52.66	56.52	3.86	6.19	6.07
328	-3.79	78.08	83.29	5.21	13.21	13.34	27.60	30.37	2.77	58.47	60.20	1.73	6.24	6.12
329	-0.56	67.94	63.68	-4.26	13.21	13.34	29.83	33.74	3.91	58.73	59.14	0.41	6.23	6.11
330	-2.95	73.02	73.98	0.96	13.20	13.33	25.69	29.06	3.37	52.00	58.86	6.86	6.24	6.12
331	1.08	75.06	79.25	4.19	13.25	13.38	28.39	32.00	3.61	52.72	59.31	6.59	6.22	6.10
333	-0.41	64.71	72.20	7.49	13.44	13.57	27.26	29.20	1.94	55.88	59.15	3.27	6.35	6.23
335	3.73	77.88	86.39	8.51	13.20	13.33	28.14	31.87	3.73	54.18	60.74	6.56	6.38	6.25
336	-4.12	75.73	70.79	-4.94	13.25	13.38	28.22	31.49	3.27	53.36	57.63	4.27	6.45	6.32
337	6.82	70.83	82.21	11.38	13.14	13.27	26.21	31.86	5.65	56.32	60.37	4.05	6.36	6.24
338	6.93	71.00	76.20	5.20	13.25	13.38	25.22	30.16	4.94	52.28	58.01	5.73	6.49	6.36
339	-1.33	63.72	71.54	7.82	13.13	13.26	22.38	27.97	5.59	52.25	56.67	4.42	6.29	6.17

APPENDIX 2

IRB Approval

Case Western Reserve University
Institutional Review Board
NOTICE OF APPROVAL

Responsible Investigator: **Mark Hans**
Department: **Dentistry - General**
IRB Protocol #: **20060525**
Title: ***Sleep Disordered Breathing and Orthodontic Treatment in Adolescents***
Co-Investigator: **Austin Phoenix**

Approval Date: **July 11, 2006**
Continuing Review Deadline: **June 26, 2007**
Expiration Date: **July 10, 2007**

The Institutional Review Board (IRB) has APPROVED the above new protocol through the expedited review process.

It has been determined that this study involves minimal risk, and that the following vulnerable populations will be involved: minors.

As an investigator of human subjects, your responsibilities include the following (see full description of responsibilities at our website):

1. Report all adverse events and unanticipated problems involving human subjects to the IRB Office, located in the Office of Research Compliance (ORC), within three (3) business days of your knowledge of the occurrence.
2. Provide the IRB with a complete Continuing Review form (available at the CWRU IRB Web Pages, or from the ORC) by the continuing review deadline noted above, and when the study is terminated.
3. Discontinue all work pertaining to this protocol if a continuing review approval is not finalized by the expiration date noted above.
4. Submit all proposed changes to the protocol to the IRB, and receive approval from the IRB, before implementation of the change.
5. Keep all research data and original consent documents in your possession for at least three (3) years after the study is terminated.

Questions? Please visit our website: http://ora.ra.cwru.edu/orc_humansubjects_CWRU_IRB.asp

OR
contact our administrative office...

Isabel Sanchez, IRB Administrator
216.368.6993
Maureen Dore-Arshenovitz, IRB Assistant
216.368.6925
Fax: 216.368.3737

CASE Institutional Review Board
Office of Research Compliance

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