J. King Saud Univ., Vol. 22, *Dental Sci.* (1), pp. 1-7, Riyadh (2010/1431H.)

Prediction of Mandibular Growth Potential Using Cervical Vertebral Bone Age in Saudi Subjects

Adel M. Alhadlaq
Assistant Professor and Consultant in Orthodontics,
Director, Saudi Specialty Certificate Program in Orthodontics, KSU
College of Dentistry, King Saud University,
P. O. Box 60169, Riyadh, 11545, Saudi Arabia

(Received 6/4/2009; accepted for publication 6/10/2009)

Keywords: Mandibular growth potential, Cervical vertebral bone age, Growth modification, Saudi, Prediction.

Abstract. Assessment of mandibular growth potential is an essential component of proper diagnosis and treatment planning in orthodontics. The aim of this study was to evaluate the possibility of utilizing the cervical vertebral bone age method to predict the mandibular growth potential in a group of growing Saudi individuals. The sample consisted of the lateral cephalometric radiographs of untreated 84 Saudi subjects (33 male and 51 female) with class I skeletal relationship. The subjects were divided based on the gender and chronological age into four groups: young male (n = 15, 10.06 ± 0.25 years), young female group (n = 30, 12 ± 1.58 years), adult male (n =18, 21.29 ± 3.42 years), and adult female (n =21, 21 ± 3.15 years). The mandibular growth potential in each young subject was calculated using an established cervical vertebral bone age method. No significant difference ($p<0.05$) was found between the mandibular length value predicted by the cervical vertebral bone age and the actual mandibular length in the adult group for both genders. The findings of this study demonstrate the validity and accuracy of the cervical vertebral bone age method in predicting the mandibular growth potential in growing Saudi subjects and can be found clinically useful during treatment planning for jaw growth modification therapy.

Introduction

Orthodontic management of skeletal jaw discrepancies often include growth modification therapy to compensate for the small-sized upper and/or lower jaw. For example, in Class II skeletal relationship due to retrognathic mandible, functional appliance therapy to enhance the growth of the mandible is indicated (McNamara and Brudon, 2001). The best time to treat mandibular deficiency using bite-jumping appliances is during the peak velocity of mandibular growth (Baccetti *et al*., 2000; Kluemper and Spalding, 2001). Generally, the peak in the adolescent growth increments in the mandibular size coincides with the overall body physical maturity and growth peak in height (Björk and Helm, 1967; Taranger and Hägg, 1980). However, other investigators have reported more variable timing of maximum pubertal growth velocity in the mandible than other skeletal elements in the body (Lewis *et al*., 1985; Mitani and Sato, 1992).

Recently, the assessment of individual skeletal maturation using cervical vertebrae from lateral cephalometric radiographs has gained increasing attention (San Roman *et al*., 2002; Grave and Townsend, 2003; Flores-Mir *et al*., 2006). In particular, the accelerated circumpubertal growth increments in the mandible have been linked to the maturational stages of cervical vertebrae (Franchi *et al*., 2000; Baccetti *et al*., 2002; Chen *et al*., 2004). The ability to evaluate skeletal maturation and predict mandibular growth peak from routinely-obtained diagnostic lateral cephalometric radiographs through the assessment of cervical vertebral maturation has the potential to eliminate the need for hand-wrist radiographs; and thus, saving the patient from the additional cost and exposure to radiation.

Cervical vertebral bone age is an objective method of evaluating skeletal maturation from lateral cephalometric radiographs by measuring the natural maturational changes in the vertebral body of the third and fourth cervical vertebrae (Mito *et al*., 2002).

A stepwise multiple regression analysis with the chronological age as a dependent variable and the dimensional changes in the cervical vertebral bodies as independent variables was utilized to derive a mathematical formula to calculate the individual bone age (Mito *et al*., 2002). More recent, the cervical vertebral bone age has been used to estimate the mandibular growth potential in Japanese girls (Mito *et al*., 2003). The use of cervical vertebral maturation method to assess skeletal maturity in Saudi adolescents has been previously reported (Alhadlaq *et al*., 2007). The purpose of this study was to establish the cephalometric cervical vertebral bone age and to assess the use of cervical vertebral bone age to predict mandibular growth potential in a sample of Saudi individuals.

Material and Methods

The sample of this study consisted of standardized lateral cephalometric radiographs of 84 Saudi subjects (33 male and 51 female) attending the Orthodontic Clinic at the College of Dentistry, King Saud University, Riyadh, Saudi Arabia. Subjects were divided for each gender into two groups; young and adult groups. The age range of the young group was 10 to 11 years for the males ((n = 15, average age 10.06 ± 0.25 years) and 10 to 15 years for the females (n = 30, average age 12 ± 1.58 years), while for the adult group was 17 to 26 years for the males (n = 18, average age 21.29 ± 3.42 years) and 17 to 23 years for the females (n = 21, average age 21 ± 3.15 years). All subjects included in this study had to fulfil the following criteria: (1) Saudis by nationality, (2) well-nourished, free of any serious illness, and have normal growth and developmental conditions, (3) have no previous trauma or injury to the head and neck region, (4) have no previous orthodontic treatment, (5) have Class I skeletal pattern (0° ≤ ANB ≤ 4°), (6) have documented date of birth, and (7) availability of standardized and high quality lateral cephalometric radiograph.

The nationality of each subject was verified by the individual national identification card of the subject or the family card. The chronological age was calculated from the birth date documented in the subject's dental chart. Only subjects with a maximum of ± 3 months younger or older than the absolute value of each chronological age were included in the study. All cephalometric radiographs were traced and measured by a single experienced examiner in a darkened room using an illuminated viewing box. The cephalometric landmarks used to evaluate the maxillomandibular relationship (ANB angle) and the total mandibular length (Co-Gn) are shown in Fig. 1. Profilograms of these landmarks in the young and adult groups for both males and females are represented in Fig. 2 and Fig. 3, respectively.

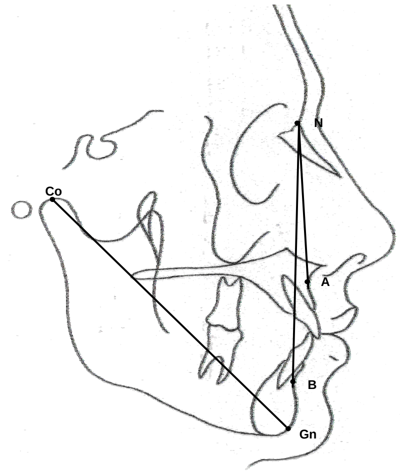

Fig. 1. Cephalometric landmarks and measurements used to determine maxillomandibular relationship (ANB angle) and mandibular length (Co-Gn). Co, condylion; Gn, gnathion.

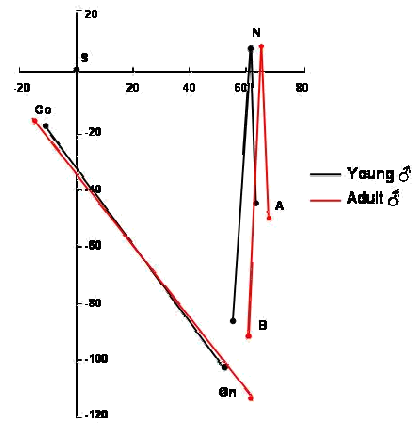

Fig. 2. Profilogram of the cephalometric landmarks and measurements for the young and adult male groups. S: sella; N:nasion; Co, condylion; A, point A; B, point B; Gn, gnathion.

The cervical vertebral bone age was established for each young subject by measuring the geometrical dimensions of the third and fourth cervical vertebral bodies (CV3 and CV4) according to the method described by Mito and co-workers (2002). In brief, the following measurements were performed on the vertebral body of the third and fourth cervical vertebrae: anterior vertebral body height (AH), vertebral body height (H), posterior vertebral body height (PH), and anteroposterior vertebral body length (AP), as demonstrated in Fig. 4. Subsequently,

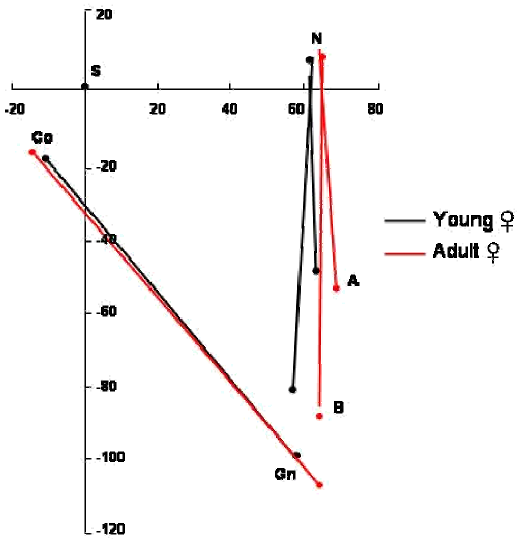

Fig. 3. Profilogram of the cephalometric landmarks and measurements for the young and adult female groups. S: sella; N:nasion; Co, condylion; A, point A; B, point B; Gn, gnathion.

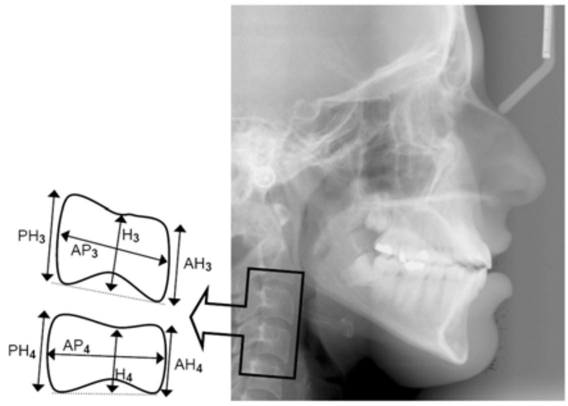

Fig. 4. Measurements performed to calculate the cervical vertebral bone age on the third and fourth cervical vertebrae (C3, C4) appearing on lateral cephalometric radiograph. AH, distance from the most superior to the most inferior point on the anterior surface of the vertebral body; AP, maximum anteroposterior distance at the middle of cervical vertebral body; H, distance from top of the middle part of the vertebral body to a tangent connecting the most inferior points of the lower border; PH, distance from the most superior to the most inferior point on the posterior surface of the vertebral body.

the cervical vertebral bone age for each young subject was calculated based on the following mathematical formula (Mito *et al*., 2002):

$$\text{CVA (years)} = -0.20 + 6.20 \text{ X } AH_3/AP_3 + 5.90 \text{ X } AH_4/AP_4 + 4.74 \text{ X } AH_4/PH_4$$

where CVA is the cervical vertebral bone age, AH_3 is the anterior vertebral body height of CV3, AP_3 is the anteroposterior vertebral body length of CV3, AH_4 is the anterior vertebral body height of CV4, AP_4 is the anteroposterior vertebral body length of CV4, and PH_4 is the posterior vertebral body height of C4 (Fig. 4).

The mandibular growth potential was estimated from the cervical bone age for each young subject by applying the following formula (Mito *et al*., 2003):

$$\text{MGP (mm)} = -2.76 \text{ X CVA} + 38.68$$

where MGP is the mandibular growth potential and CVA is the cervical vertebral bone age. To estimate the mandibular growth potential using the chronological age, the CVA in this formula was substituted with the chronological age for the subject.

The predicted total mandibular length for each subject in the young male and female groups was established by adding the mandibular growth potential value calculated by either the cervical vertebral bone age or the chronological age to the actual mandibular length (Co-Gn) of each subject. The mean value of the resultant predicted mandibular length for each young group was then compared with the mean value of total mandibular length (Co-Gn) in the corresponding adult group.

The intra-examiner reliability of the method was assessed by re-tracing and measurement of 10 randomly selected cephalometric radiographs from the young age groups two weeks after the first evaluation. The correlation coefficient values between the two timely-separated readings were established to determine the reliability of all measurements and calculations.

The mean value of the total mandibular length in the adult groups was statistically evaluated against the corresponding mean value of the predicted total mandibular length (predicted by either the cervical vertebral bone age or the chronological age) to detect any significance between the means using unpaired *t*-test at 95% confidence ($p<0.05$), All statistical analyses were performed using SPSS software package (Version 12, SPSS Inc., Chicago, IL, USA).

Results

The mean value (±*SD*) of the chronological age, ANB angle, and total mandibular length in the young and adult groups for both genders are presented in Table 1. A high reliability of the method was demonstrated by the high correlation values between the first and second measurements and calculations

Table 1. The mean value (±*SD*) of chronological age, ANB angle, and mandibular length (Co-Gn) of the study groups.

	Young ♂ *(n=15)*	**Adult ♂** *(n=18)*	**Young ♀** *(n=30)*	**Adult ♀** *(n=21)*
Age (Years)	10.06 ± 0.25	21.29 ± 3.42	12 ± 1.58	21 ± 3.15
ANB (°)	3.44 ± 0.68	2.79 ± 0.79	3.01 ± 0.61	2.80 ± 0.51
Co-Gn (mm)	113.94 ± 2.70	128.32 ± 7.89	116 ± 12.44	124 ± 6.62

for all parameters. The intra-examiner correlation coefficient value ranged from 0.94 for the cervical vertebral bone age calculation to 0.99 for the total mandibular length (Co-Gn) measurement (average r = 0.982).

No significant difference (*p<0.05*) between the mean cervical vertebral bone age calculated in the young group for both males (10.08 ± 1.91 years) and females (12.01 ± 3.49 years) when compared to the mean chronological age of each respective young group (Fig. 5). The average growth potential predicted by the cervical vertebral bone age was 10.86 ± 2.27 mm for the male young group and 8.02 ± 4.43 mm for the female young group. However, the average mandibular growth potential predicted by the chronological age was 10.91 ± 0.69 mm for the male young group and 6.38 ± 3.50 mm for the female young group.

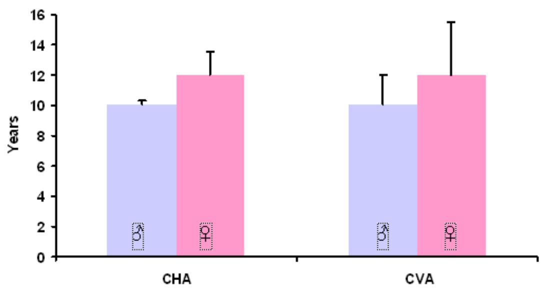

Fig. 5. The mean value (±*SD*) of the chronological age (CHA) and the cervical vertebral bone age (CVA) of the young male and female groups.

The mean values of total mandibular length (Co-Gn) of the adult groups and the mandibular length predicted by both the cervical vertebral bone age and the chronological age for the young groups are represented in Fig 6. No significant difference (*p<0.05*) was found between the mean length of the mandible in the adult male group (128.32 ± 7.89) and the mandibular length predicted by either the cervical vertebral bone age (124.51 ± 6.10 mm) or the chronological age (124.76 ± 3.06 mm) from the young male group (Fig 6). Similarly, no significant difference (*p<0.05*) was detected between the mean length of the mandible in the adult female group (124 ± 6.62 mm) and the mean value of mandibular length predicted by either the cervical vertebral bone age (126.01± 12.53 mm) or the chronological age (121.90 ± 10.17 mm) from the young female group (Fig. 6). However, a significant difference (*p>0.05*) was found between the mean value of the mandibular length predicted by the cervical vertebral bone age (126.01± 12.53 mm) and the mean value of the mandibular length predicted by the chronological age (121.90 ± 10.17 mm) from the young female group only (Fig. 6).

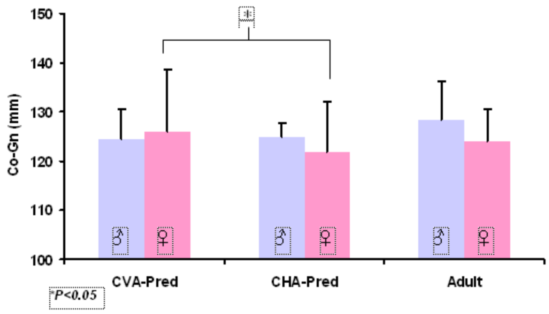

Fig. 6. The mean value (±*SD*) of the predicted mandibular length (Co-Gn) using the cervical vertebral bone age (CV-Pred) and chronological age (CHA-Pred) in the young male and female groups, and the mean value (±*SD*) of the total mandibular length in the adult male and female groups.

Discussion

The use of cervical vertebral maturation to assess skeletal maturity level and forecast the mandibular growth potential is gaining an increased attention in the recent literature (San Román *et al*., 2002; Grave and Townsend, 2003; Flores-Mir *et al*., 2006; Soegiharto *et al*., 2008). The established validity of this method and the ability to evaluate the cervical vertebral maturational changes from routinely-obtained lateral cephalometric radiographs, without the need for an additional hand-wrist radiograph, are few advantages that have contributed to the increasing popularity of this approach. The purpose of the present study was to establish the cervical vertebral bone age and predict the mandibular growth

potential in a group of Saudi young individuals using the cervical vertebral bone age method.

The use of cervical vertebral maturation method to estimate the remaining mandibular growth potential has been demonstrated for several population groups (O'Reilly and Yanniello, 1988; Franchi *et al*., 2000; Baccetti *et al*., 2002; Mito *et al*., 2003; Chen *et al*., 2004). The sexual dimorphism in growth pattern and timing of pubertal growth peak is well-documented (Fishman, 1987; Bogin, 1988; Guo *et al*., 1992). Therefore, evaluation of mandibular growth potential separately in Saudi boys and girls to account for sexual variability in growth timing and maturational changes of cervical vertebrae has been performed in the present study. The simplicity and objectivity of the cervical vertebral bone age approach has contributed to the high reliability of the methodology in this study, as reflected by the high correlation values between the two measurements that were performed two weeks apart. Due to the unavailability of complete records, including hand-wrist radiographs, of the sample included in this study, only the chronological age and not bone age as determined by the hand-wrist radiograph was used for comparison with the cervical vertebral bone age.

In the present study, the difference (absolute value) between the cervical vertebral bone age and the chronological age in the young group for both males (0.02 year) and females (0.01 year) was not statistically significant ($p<0.05$) (Fig 5). In contrast, a significant difference between the two ages (1.17 years) has been reported for the Japanese girls (Mito *et al*., 2002). This discrepancy between the two studies, however, could possibly be explained by the differences in sample size and ethnic background between the two studies. Also, the predicted mandibular length (Co-Gn) for both young male and young female groups in this study using either cervical vertebral bone age or chronological age did not differ significantly ($p<0.05$) from the total mandibular length of the respective adult group (Fig. 6). This finding reflects the validity and accuracy of the cervical vertebral bone age method in predicting the mandibular growth potential in growing Saudi individuals. Similar finding of accurate prediction of the mandibular growth potential using cervical vertebral bone age has been reported for Japanese girls (Mito *et al*., 2003).

In addition, contrary to the common conceptual belief that chronological age is a poor measure of skeletal growth and maturation (Profitt, 2007), this study demonstrated that chronological age, indeed, might be a good predictor of the mandibular growth potential in growing Saudi subjects, as reflected by the non-significant difference ($p<0.05$) between the predicted mandibular length using chronological age and the total mandibular length of the adult group for both genders (Fig. 6). This finding is in agreement with a previous report of close association between chronological age and skeletal maturation assessed by hand-wrist method in Saudi male subjects (Alhadlaq *et al*., 2008). However, the average error (absolute difference) between the mandibular length value predicted by chronological age and the actual mandibular length was found to be significantly higher ($P<0.001$) than that between the value predicted by cervical vertebral bone age and the actual value in Japanese girls (Mito *et al*., 2003). This discrepancy between our study and Mito *et al*.'s study (2003) implies that racial differences may contribute to the usefulness of the chronological age as a predictor of individual skeletal maturation and mandibular growth potential.

Although no significant difference ($p<0.05$) between the mandibular length value of the respective adult group and the values predicted by either the cervical vertebral bone age or the chronological age for both genders was demonstrated, a significant difference ($p<0.05$) between the mandibular length value predicted by the cervical vertebral bone age (126.01± 12.53 mm) and the value predicted by chronological age (121.90 ± 10.17 mm) in girls was found in the present study (Fig 6). Similarly, in Japanese girls, significant difference ($P<0.01$) was reported between the average error (absolute value) of mandibular growth potential predicted by cervical vertebral bone age and chronological age (Mito *et al*., 2003).

Future work on this direction should include more representative sample from other regions of the Kingdom of Saudi Arabia to prove the predictive precision of this method. In addition, although there is no significant difference in mandibular growth rates between various skeletal patterns in general (Bishara *et al*., 1997), future investigations work should rule out any possible shortage of the method to predict mandibular growth potential in other skeletal malformations by applying the cervical vertebral bone age formula to other skeletal patterns such as Class II and Class III subjects.

Conclusions

This study has established the cervical vertebral bone age in a sample of young Saudi male and female subjects. The cervical vertebral bone age method has proven to be applicable and accurate in predicting mandibular growth potential in growing young Saudi

individuals. The chronological age has been shown to be a reasonable predictor of the mandibular growth potential in growing Saudi subjects.

References

Alhadlaq, A.; Al-Qarni, M.; Al-Kahtani, A. and Al-Obaid, A. "Comparative Study between Hand-wrist Method and Cervical Vertebral Maturation Method for Evaluation of Skeletal Maturity in Saudi Boys." *Pak. Oral & Dent. J.*, Vol. 27, No. (2), (2007), 187-192.

Alhadlaq, A.; Hashim, H.; Al-Dosari, M. and Al-Hamad, A. "Interrelationship between Dental Maturity, Skeletal Maturity and Chronological Age in Saudi Male Children." *Egy. Dent. J.*, Vol. 54, No. (1), (2008), 55-65.

Baccetti, T.; Franchi, L.; Toth, L. R. and McNamara, J. A. "Treatment Timing for Twin-block Therapy." *Am. J. Orthod. Dentofacial Orthop.*, Vol. 118, (2000), 159-170.

Baccetti, T.; Franchi, L. and McNamara, J. A. "An Improved Version of the Cervical Vertebral Maturation (CVM) Method for Assessment of Mandibular Growth." *Angle Orthod.*, Vol. 72, No. (4), (2002), 316-323.

Björk, A. and Helm, S. "Prediction of the Age of Maximum Pubertal Growth in Body Height." *Angle Orthod.*, Vol. 37, (1967), 134-143.

Bogin, B. *Patterns of Human Growth*. Cambridge: Cambridge University Press, (1988).

Chen, F.; Terada, K. and Hanada, K. "A New Method of Predicting Mandibular Length Increment on the Basis of Cervical Vertebrae." *Angle Orthod.*, Vol. 74, No. (5), (2004), 630-634.

Fishman, L. S. "Maturational Patterns and Predictions During Adolescence." *Angle Orthod.*, Vol. 57, (1987), 178-193.

Flores-Mir, C.; Burgess, C. A.; Champney, M.; Jensen, R. J.; Pitcher, M. R. and Major, P. W. "Correlation of Skeletal Maturation Stages Determined by Cervical Vertebrae and Hand-wrist Evaluations." *Angle Orthod.*, Vol. 76, No. (1), (2006), 1-5.

Franchi, L.; Baccetti, T. and McNamara, J. A. "Mandibular Growth as Related to Cervical Vertebral Maturation and Body Height." *Am. J. Ortho. Dentofacial Orthop.*, Vol. 118, No. (3), (2000), 335-340.

Grave, K. and Townsend, G. "Cervical Vertebral Maturation as a Predictor of the Adolescent Growth Spurt." *Aust. Orthod. J.*, Vol. 19, No. (1), (2003), 25-32.

Guo, S.; Siervogel, R.; Roche, A. and Chumlea, C. "Mathematical Modeling of Human Growth: A Comparative Study." *Am. J. Hum. Biol.*, Vol. 4, (1992), 93-104.

Kluemper, G. T. and Spalding, P. M. "Realities of Craniofacial Growth Modification." *Atlas Oral Maxillofac. Surg. Clin. North Am.*, Vol. 9, No. (1), (2001), 23-51.

Lewis, A. B.; Roche, A. F. and Wagner, B. "Pubertal Spurts in Cranial Base and Mandible: Comparisons within Individuals." *Angle Orthod.*, Vol. 55, No. (1), (1985), 17-30.

McNamara, J. A. and Brudon, W. L. *Orthodontics and Dentofacial Orthopedics*. Ann Arbor, Michigan: Needham Press Inc., (2001), 78-80 p.

Mitani, H. and Sato, K. "Comparison of Mandibular Growth with Other Variables During Puberty." *Angle Orthod.*, Vol. 62, (1992), 217-222.

Mito, T.; Sato, K. and Mitani, H. "Cervical Vertebral Bone Age in Girls." *Am. J. Orthod. Dentofacial Orthop.*, Vol. 122, No. (4), (2002), 380-385.

Mito, T.; Sato, K. and Mitani, H. "Predicting Mandibular Growth Potential with Cervical Vertebral Bone Age." *Am. J. Orthod. Dentofacial Orthop.*, Vol. 124, No. (2), (2003), 173-177.

O'Reilly, M. T. and Yanniello, G. J. "Mandibular Growth Changes and Maturation of Cervical Vertebrae: A Longitudinal Cephalometric Study." *Angle Orthod.*, Vol. 58, No. (2), (1988), 179-184.

Profitt, W. R. *Contemporary Orthodontics*. St. Louis, Missouri: Mosby, Inc., (2007).

San Roman, P.; Palma, J. C.; Oteo, M. D. and Nevado, E. "Skeletal Maturation Determined by Cervical Vertebrae Development." *Eur. J. Orthod.*, Vol. 24, No. (3), (2002), 303-311.

Soegiharto, B.; Cunningham, S. and Moles, D. "Skeletal Maturation in Indonesian and White Children Assessed with Hand-wrist and Cervical Vertebrae Methods." *Am. J. Orthod. Dentofacial Orthop.*, Vol. 134, (2008), 217-226.

Taranger, J. and Hägg, U. "Timing and Duration of Adolescent Growth." *Acta Odontol. Scand.*, Vol. 38, (1980), 57-67.

استشراف مدى قدرة النمو للفك السفلي باستخدام طريقة العمر العظمي للفقرات العنقية لدى عينة سعودية

عادل مد ا دلق

أستاذ مساعد واستشاري تقويم الأسنان، مدير شهادة الاختصاص السعودية في تقويم الأسنان،
كلية طب الأسنان، جامعة الملك سعود،
ص ب ٦٠١٦٩ ، الرياض ١١٥٤٥ ، المملكة العربية السعودية

(قدم للنشر في ٦/٤/٢٠٠٩م، وقبل للنشر في ٦/١٠/٢٠٠٩م)

ملخص البحث. يعتبر قياس معدل النمو المتبقي للفك السفلي من أهم العناصر لوضع الخطة العلاجية المناسبة في مجال تقويم الأسنان. هدفت هذه الدراسة إلى تقييم إمكانية استخدام طريقة العمر العظمي للفقرات العنقية لتقدير معدل النمو المتبقي للفك السفلي عند مجموعة من الأشخاص السعوديين في فترة النمو. تكونت عينة هذه الدراسة من الأشعة السيفالوميترية الجانبية لعدد ٨٤ ولد وفتاة سعوديين من الصنف التطابقي الأول، حيث تم تقسيم عينة البحث إلى أربع مجموعات على أساس العمر الزمني لكل مشترك: مجموعتي الصغار ومجموعتي الكبار لكلا الجنسين. أوضحت نتائج الدراسة أن تقدير نمو الفك السفلي المتبقي باستخدام طريقة العمر العظمي للفقرات العنقية هو طريقة سائغة ودقيقة، حيث أظهرت الدراسة عدم وجود فرق إحصائي مهم بين مقدار طول الفك السفلي الذي تم تقديره باستخدام طريقة العمر العظمي للفقرات العنقية ومقدار الطول الحقيقي للفك السفلي لدى مجموعة الكبار لكلا الجنسين. يستنتج من خلال هذه الدراسة إمكانية استخدام طريقة العمر العظمي للفقرات العنقية لحساب مقدار نمو الفك السفلي المتبقي عند عملية تشخيص وعلاج حالات اضطراب نمو الفكين لدى الأشخاص السعوديين.