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ORIGINAL ARTICLE

Evaluation of relationship of hand wrist radiograph, cervical vertebral maturation with mandibular growth as skeletal maturity indicators in children

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ABSTRACT

Objective: To study the correlation between mandibular growth variables using linear measurements of ramus, body of the mandible and total mandibular length with skeletal maturity indicators such as hand wrist radiographs and cervical vertebral maturation. **Materials and Methods:** A total of 315 patient-records (lateral cephalograms and hand-wrist radiographs) in the age group of 10–13 years were involved. The cephalometric measurements, representative of the mandibular growth, Condylion-Gonion (Co-Go), Condylion-Gnathion (Co-Gn), Gonion-Gnathion (Go-Gn), and posterior-most point of the mandibular condyle-pogonion (Fg-Pg) were traced (McNamara method). The correlation of mandibular growth variables with hand wrist parameters and cervical vertebrae maturation were assessed separately in male and female. Pearson's correlation was used for analysis (Statistical Package for Social Sciences version 17). **Results:** Only 80 subjects were included in final analysis. A highly significant correlation was found among hand wrist parameters, and mandibular growth variables ($P < 0.001$) in both genders. Among males, there was a highly significant correlation between cervical vertebral maturation and mandibular growth variables ($P < 0.001$), whereas Co-Go has a significant correlation with C2Conc, C3Conc, and C4Conc ($P < 0.05$). In females, Co-Gn, Co-Go, Go-Gn, and Fg-Pg were significantly correlated with C3Conc and C4Conc ($P < 0.001$). **Conclusion:** Both the cervical vertebral maturation and mandibular growth variables can be accessed on the lateral cephalogram itself for the evaluation of the skeletal maturity, as effective as a hand wrist radiograph in males and females.

Key words
Cervical vertebral maturation, hand wrist radiograph, lateral cephalogram, mandibular growth, skeletal maturity indicators

INTRODUCTION

Management of skeletal discrepancies in children and adolescents is a challenge. It is very difficult to expect the timing and quantity of active growth in the craniofacial complex. Typically, the skeletal maturation pattern of an individual varies among individuals, and the assessment of the same individually can support the clinician in the diagnosis and treatment planning. Early intervention of the problems may result in the successful outcome of the treatment. Biological indicators such as chronological, dental, height, secondary sexual characteristics, skeletal ages, and weight measurements were used to identify the stages of growth and maturation.[1] Assessment of skeletal maturation to quantify growth spurt using hand wrist radiograph is considered to yield best results.[2] Fishman[3] used a skeletal maturity assessment based on

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four stages of maturation at six anatomic sites located on the thumb, third finger, fifth finger, and radius hand wrist radiograph to quantify pubertal growth spurt.[3,4] Hägg and Taranger,[4] described a method using the hand wrist radiograph to correlate certain maturity indicators to the pubertal growth spurt.

Most of the studies[5-7] concluded that the assessment of individual skeletal maturity in the cervical vertebral analysis is highly reliable and comparable to that of the hand wrist bone analysis. It has been evident that the skeletal maturity of cervical vertebrae and bones in hand wrist are more reliable tools for assessment of growth.[8] Few studies have evaluated the independent association of (i) mandibular growth[9] (ii) maturation of cervical vertebrae on lateral cephalogram[10] and (iii) phalanx of the third finger and distal epiphysis of the radius on a hand wrist radiograph.[11] There are many studied exist in the literature. Nonetheless, the quantitative relationship among them was not clearly documented in Indian children. Therefore, the objective of this study was to establish a quantitative interrelationship among all the three parameters and evaluating the association of mandibular growth with skeletal maturity indicators. The aim of this study was to assess the correlation between mandibular growth variables and skeletal maturity indicators represented by cervical vertebrae on lateral cephalogram and hand wrist parameters on the hand-wrist radiograph. The hypothesis of the present study was mandibular growth variables are not correlated with skeletal maturity indicators such as hand wrist radiographs and cervical vertebral maturation.

MATERIALS AND METHODS

A total of 315 records of the patients who attended the Department of Pedodontics and Preventive Dentistry and the Department of Orthodontics and Dentofacial Orthopedics, Sri Sai College of Dental Surgery, Vikarabad, Hyderabad, Telangana, India, between January 2011 and September 2012, were retrospectively screened. Those records which included both lateral cephalogram and hand-wrist radiographs with adequate clarity, children in the age group of 10–13 years with Class-I malocclusion and with no history of previous extractions or orthodontic treatment were included. The patients with presence of supernumerary teeth, deep bite, crossbite, and missing teeth were excluded. Only 80 records which fulfilled the criteria were selected and uniformly distributed into eight groups based on the age, each with 10 males and 10 females. Ethical clearance was obtained from the Institutional Review Committee, Sri Sai College of Dental Surgery, Vikarabad, Hyderabad, Telangana, India.

The assessment, analysis, and measurements of all the records were carried out by a single examiner using 0.003 inches lacquered polyester matte acetate tracing paper, 0.3 mm diameter lead pencil under radiographic viewer illumination and digital Vernier calipers (aerospace) with 0.01 mm precision. A Planmeca Ceph Model Proline EC X-ray Machine, (Planmeca, Helsinki, Finland calibrated at 70 kVp and 10 mA), with exposure time ranging from 1.2 to 1.4 s and Kodak film (T-Mat G Cephalometric Film, manufactured by Kodak) size 8 × 10 inch, equipped with a Lanex intensifier screen was used for all the lateral cephalograms. The same equipment was used to obtain the left-hand wrist radiograph (60 kVp, 10 mA, and 1.2 s) with hands outstretched and centered on the (8 × 10 inch Kodak film).

Hand wrist radiographs [Figure 1] were evaluated by Eklöf and Ringertz,[2] method. After tracing the outlines of the proximal phalanx of the 3rd finger and the distal epiphysis of the radius, the length of the proximal phalanx and width of the distal epiphysis were measured and recorded.

Based on McNamara[12] observations, the dentoskeletal and tegumental structure landmarks, Menton, Gonion (Go), Pogonion (Po), Gnathion (Gn), the most superior point on the head of the condyle - Condylion (Co), and the posterior-most region of the mandibular condyle (Fg) were identified on the lateral cephalogram [Figure 2].

Following the principles of McNamara[12] the following linear distances were measured and recorded to assess mandibular growth:

- Co-Gn: Effective mandible length
- Co-Go: Mandibular ramus height
- Go-Gn: Mandibular body length
- Fg-Pg: Total mandibular length - obtained through the orthogonal projection of both the Pg and the Fg onto the mandibular plane.

The concavity in the lower border of the cervical vertebrae was considered an accurate indicator of skeletal maturity when used with Hassel and Farman classification.[6] On

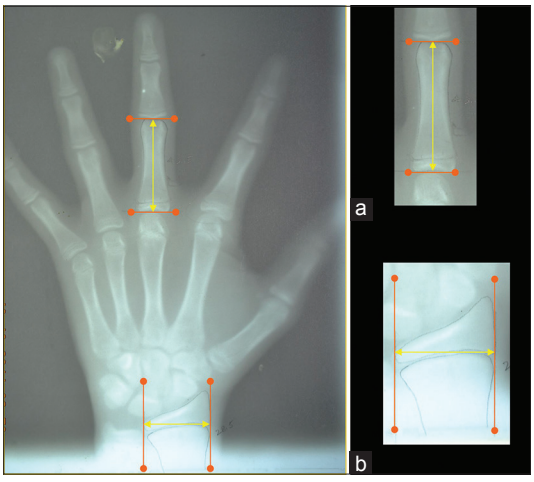

Figure 1: Hand wrist parameters traced on hand wrist radiograph. (a) Height of the proximal phalanx of the 3rd finger, (b) width of the epiphysis of the radius

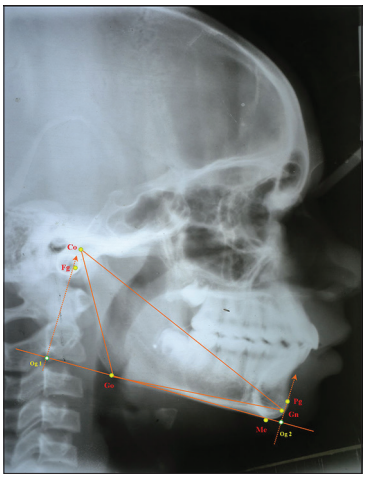

Figure 2: Mandibular anatomical landmarks and linear measurements traced on lateral cephalogram

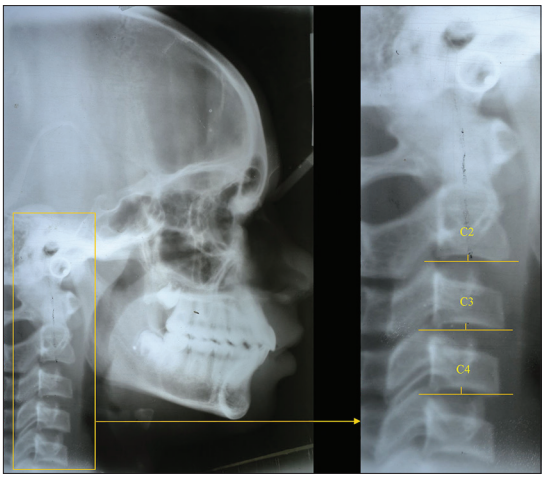

Figure 3: Inferior border of C2Conc, C3Conc, and C4Conc traced on lateral cephalogram

the lateral cephalogram, the following points were traced with Hassel and Farman's[6] method and the indications described by Hellsing[13] [Figure 3].

With the help of these landmarks, the following measurements were performed and recorded:

- C2Conc: A measure of the concavity depth at the lower border of C2 (distance from the line connecting C2p and C2a to the deepest point on the lower border of the vertebra, C2m)
- C3Conc: A measure of the concavity depth at the lower border of C3 (distance from the line connecting C3lp and C3la to the deepest point on the lower border of the vertebra, C3m)
- C4Conc: A measure of the concavity depth at the lower border of C4 (distance from the line connecting C4lp and C4la to the deepest point on the lower border of the vertebra, C4m).

Data analysis was obtained by mean, standard deviation (SD) and minimum and maximum values for each variable, and each of the age groups with gender variations were evaluated separately. The data were compared using Pearson's correlation to detect the liner correlation between mandibular growth variable, hand wrist variables, and cervical vertebral variables. All the statistical analyses were set with a significance level of $P < 0.05$. The recorded values were statistically evaluated with software SPSS version 21 (IBM, Corp 2008, Armonk, NY, Chicago, IL, USA).

RESULTS

The mean and SD for each variable with age 10 years, 11 years, 12 years, and 13 years were 10.49 ± 0.24, 11.51 ± 0.21, 12.43 ± 0.17, and 13.48 ± 0.21, respectively. The mean age of all the children in the group is 11.97 years. Comparison of mandibular growth variables with age [Table 1] highest mean 116.0 ± 2.27 while

Table 1: Comparison of mandibular growth variables with age

Mandibular growth variables (mean±SD)	Age (years)			
	10	11	12	13
Effective mandible length (Co-Gn)	98.72±4.15	105.60±3.41	110.90±2.27	116.03±2.80
Mandibular ramus height (Co-Go)	48.65±6.72	53.25±5.02	55.75±3.88	59.13±4.59
Mandibular body length (Go-Gn)	64.57±6.30	68.75±2.51	72.45±2.80	75.15±3.99
Total mandibular length (Fg-Pg)	94.65±4.07	100.90±3.71	106.98±2.49	112.28±3.15

SD – Standard deviation, Co-Go – Condylion-Gonion, Co-Gn – Condylion-Gnathion, Go-Gn – Gonion-Gnathion, Fg-Pg – Posterior most point of the mandibular condyle-pogonion

lowest mean 48.65 ± 6.72, as the age increases the linear mandibular growth parameters were increases. Comparison of hand wrist parameters with age [Table 2] highest mean 42.18 ± 1.60, and the lowest mean 20.87 ± 0.90, the hand wrist parameters showed increases with age. Comparison of cervical vertebrae maturation with age [Table 3] highest mean and SD 1.53 ± 0.35 and lowest mean and SD 0.45 ± 0.35, comparison of various parameters with respect to gender [Table 4] were determined and the mean and SD was high in males than the females. The data were compared using Pearson's correlation to detect the correlation between mandibular growth variables, hand wrist parameters, and cervical vertebral maturation. Highly significant correlation was evident between the length of the proximal phalanx of the 3rd finger and width of the distal epiphysis of the radius as well as with the mandibular growth variables, i.e. Co-Go, Co-Gn, Go-Gn, and Fg-Pg in both males and females ($P < 0.001$). Among males, there was a highly significant correlation between cervical vertebral maturation (C3Conc and C4Conc) and mandibular growth variables (Co-Gn, Fg-Pg) ($P < 0.001$), whereas Co-Go has significant correlation with C2Conc, C3Conc and

Table 2: Comparison of hand wrist parameter among different age groups

Hand wrist parameters (mean±SD)	Age (years)			
	10	11	12	13
Length of the proximal phalanx of the 3rd finger	34.15±1.43	37.48±1.39	39.75±1.2	42.18±2.45
Width of the distal epiphysis of the radius	20.87±1.60	23.78±0.94	24.53±0.9	26.10±1.36

SD – Standard deviation

Table 3: Comparison of cervical vertebral maturation among different age groups

Cervical vertebral maturation (mean±SD)	Age (years)			
	10	11	12	13
C2Conc: A measure of the concavity depth at the lower border of C2	1.05±036	1.23±0.38	1.38±0.48	1.50±0.49
C3Conc: A measure of the concavity depth at the lower border of C3	0.80±0.47	1.04±0.35	1.20±038	1.53±0.5
C4Conc: A measure of the concavity depth at the lower border of C4	0.45±0.43	0.80±0.41	1.00±0.43	1.27±0.44

SD – Standard deviation

Table 4: Comparison of various parameters with respect to gender

Parameters (mean±SD)	Gender	
	Males	Females
Mandibular growth		
Effective mandible length (Co-Gn)	108.60±7.37	107.03±7.01
Mandibular ramus height (Co-Go)	55.28±4.96	53.11±7.41
Mandibular body length (Go-Gn)	69.93±6.38	70.54±5.05
Total mandibular length (Fg-Pg)	104.39±7.84	103.01±7.04
Hand wrist parameters		
Length of the proximal phalanx of the 3rd finger	38.60±3.04	38.18±3.76
Width of the distal epiphysis of the radius	24.26±2.16	23.37±2.29
Cervical vertebral parameters		
C2Conc: A measure of the concavity depth at the lower border of C2	1.24±0.42	1.34±0.49
C3Conc: A measure of the concavity depth at the lower border of C3	1.11±0.45	1.17±0.55
C4Conc: A measure of the concavity depth at the lower border of C4	0.90±0.38	0.86±0.63

SD – Standard deviation, Co-Go – Condylion-Gonion, Co-Gn – Condylion-Gnathion, Go-Gn – Gonion-Gnathion, Fg-Pg – Posterior most point of the mandibular condyle-pogonion

C4Conc ($P < 0.05$), and Go-Gn has significant correlation with C3Con, C4Con only ($P < 0.05$). Among females, Co-Gn, Co-Go, Go-Gn, and Fg-Pg were significantly correlated with C3Conc and C4Conc ($P < 0.001$), whereas Co-Gn, Co-Go, and Fg-Pg were significantly correlated with C2Con ($P < 0.05$).

DISCUSSION

Eklöf and Ringertz[2] was used since it is quick, relatively easy to learn and perform, reliable, and reproducible for examiners using well-defined parameters. Human growth has shown that the timing of the peak pubertal growth is closely related to the peak in statural height, the growth of mandible as well as specific events of ossification observed in the hand wrist radiograph.[9,14] Interpretation of ossification events of the phalanges, carpal bone, and the radius obtained from the hand wrist radiograph was compared with a mandibular pubertal growth spurt, and the very close relation was observed among the sequences of hand wrist ossification and mandibular growth status.[10,11] The present study showed a highly significant correlation between mandibular growth parameters (Co-Gn, Co-Go, and Go-Gn) and hand wrist parameters. The total mandibular length (Fg-Pg) also had a highly significant correlation with the proximal phalanx of the 3rd finger and the width of the distal epiphysis of the radius supporting the previous studies.[1,9]

The height of the ramus is very important in the determination of posterior facial height and subsequent relation to anterior facial height. The ramus tends to be longer in horizontal growing patterns and shorter in vertical growing patterns. Functional appliances are ideally indicated in horizontal growing patterns and are contraindicated in vertical growing patterns as they worsen facial esthetics. Length of the mandibular body is important in the determination of anteroposterior discrepancy of the mandible. A retrognathic mandible may have either a short or long body and if, the length of the mandibular body is short, the cause of the retrognathism is probably a growth deficiency.

Clinical judgment is based on relative length of the mandible, and this decision is important in the consideration of etiology and treatment for each patient. The prognosis of functional and orthopedic appliance therapy is good only when a favorable growth direction is identified.[15] Deficiency of mandibular ramus height can be improved significantly in children with increased vertical facial height when functional treatment is performed at the peak of mandibular growth. The increase in total mandibular length was associated with a significant supplementary increase in the height of the mandibular ramus. It is favorable when condylar growth is more in the backward direction.[10,16]

The mandibular ramus height (Co-Go) and mandibular body length (Go-Gn) had a significant correlation with the length of the proximal phalanx of the 3rd finger and the width of the distal epiphysis of the radius. This shows that increase in hand wrist parameters will increase mandibular ramus height and mandibular body length. In males, the growth of the mandibular body length was

closely correlated to the phalanx of 3rd finger and width of the distal epiphysis of the radius, compared to growth of the ramus height. In females, the growth of mandibular ramus height was very closely correlated to the phalanx of third finger and width of the distal epiphysis of the radius compared to growth of the mandibular body length.

It is possible to evaluate skeletal maturity by assessing the cervical vertebrae in a detailed and objective manner on a lateral cephalogram. It is simple, easy to use and its validity is comparable to a hand wrist radiograph.[6,16-22] In the current study, effective mandibular length (Co-Gn) had a significant correlation with C2Con, C3Con, and C4Con, in agreement with Baccetti *et al.*[10] findings. A highly significant correlation with C4Con was observed similar to the investigations.[9,23] There was no correlation between the mandibular body length (Go-Gn) and C2Con in males and females. The stage of appearance of a definite concavity at the lower border of C2Con is not advisable for functional therapy, as a peak in the mandibular growth will occur on an average 1 year after the establishment of the definite concavity of C2Con. However, the mandibular body had a significant correlation with C3Con and C4Con.

Mandibular ramus height is significantly correlated with C2Con and highly significant correlation with C3Con, C4Con. Though, total mandibular length (Fg-Pg) had a highly significant correlation with C3Con, C4Con, less correlation exists with C2Con. The maximum increment of mandibular growth was most frequently appreciated in the vertebral stages with C3Con and C4Con. The present study showed C3Con and C4Con cervical vertebral stages are the best for growth modulation. The duration of the treatment could be reduced considerably if the growth modulation was done in this period.[10,22] The mandibular growth was increased with hand wrist parameters; similarly the cervical vertebral concavities were increased, supporting the previous investigations.[24] The C3 and C4 concavities are much more correlated than C2, which support the previous investigations.[10,16,20,21,23] In males, the linear measurements of mandibular parameters and hand wrist measurements are slightly high compared to females, except Go-Gn. The probable reason is the growth direction of Gn is more horizontally directed for females than males.[25] Growth increments of males were revealed in their larger spurt and postadolescent overall size in each dimension. The C2, C3 concavity was established earlier in females than males, indicating that maturational status of females is ahead of males as reported findings.[26,27] The adolescent spurt was late in males but more pronounced in bigonial width, body length, maximum length, and ramus height.[28] The present study shows that C3Con and C4Con represent ideal stages to begin functional jaw orthopedics.

The hand wrist parameters are very closely coinciding with the mandibular growth variables and cervical vertebral parameters at any given age. Cervical vertebral maturation and mandibular growth variables in a lateral cephalogram could be used with the same efficacy as that of a hand wrist radiograph for assessment of the skeletal maturity. The effective radiation dose for hand wrist radiograph 0.16 microsieverts (μSv) and lateral cephalogram 1.73 μSv with thyroid shield. Adding the effective dose of hand wrist radiograph to lateral cephalogram resulted, cumulative effective dose 3.46 μSv it is more at risk for growing child. It could be possible to minimize the radiation dose with the elimination of hand wrist radiograph for evaluation of skeletal maturation. A lateral cephalogram was explored as an alternative to establish the skeletal maturation.[29] An age group of 10–13 years was chosen because males and females have their maximum circumpubertal growth spurt during this period.[6] Mandibular growth along with cervical vertebral maturation assessed on a lateral cephalogram can be considered as a skeletal maturity indicator over the most routinely used hand-wrist radiographs. Knowledge and assessment of skeletal growth and maturation in a routine lateral cephalogram help us in appropriate treatment planning and timing for functional jaw orthopedics. This is the first study as for your knowledge done in southern Indian population. Further research with larger samples and longitudinal studies on the mandibular skeletal maturity indicators will be extremely helpful in functional jaw orthopedics, and we could not factor in socioeconomic status, nutritional status.

CONCLUSION

Mandibular growth variables have a highly correlated with the hand wrist parameters and cervical vertebral parameters in males and females. In light of this study, the lateral cephalogram alone can be used as an effective and efficient tool to evaluate the skeletal maturity in a growing child, preventing an additional radiograph, further reducing radiation exposure, and minimizing the cost for the patient.

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Conflicts of interest
There are no conflicts of interest.

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