A Comparison of Modified MP3 Stages and the Cervical Vertebrae as Growth Indicators

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The developmental status of a child can be assessed with various growth indicators, including chronological age, dental development, height and weight, secondary sexual characteristics, and skeletal age. The key issue with any of these growth assessment methods is reliability. Orthodontists need an accurate method, based on a cross-sectional study, that does not require a long observation period.

Because skeletal age has been considered the most reliable method developed to date, the current study was devised to determine the feasibility of using radiographs of the MP3 (the middle phalanx of the middle finger) as an indicator of skeletal maturity. Hagg and Taranger have described five stages of MP3 growth, based primarily on epiphyseal changes, although distinct changes were also observed in the metaphyseal region.[1] We have added an additional bone stage between MP3-H (deceleration of the curve of the pubertal growth spurt) and MP3-I (end of the pubertal growth spurt), which we called the MP3-HI stage, resulting in a total of six stages of MP3 growth.

The objectives of the present study were to:

- Determine whether the six modified MP3

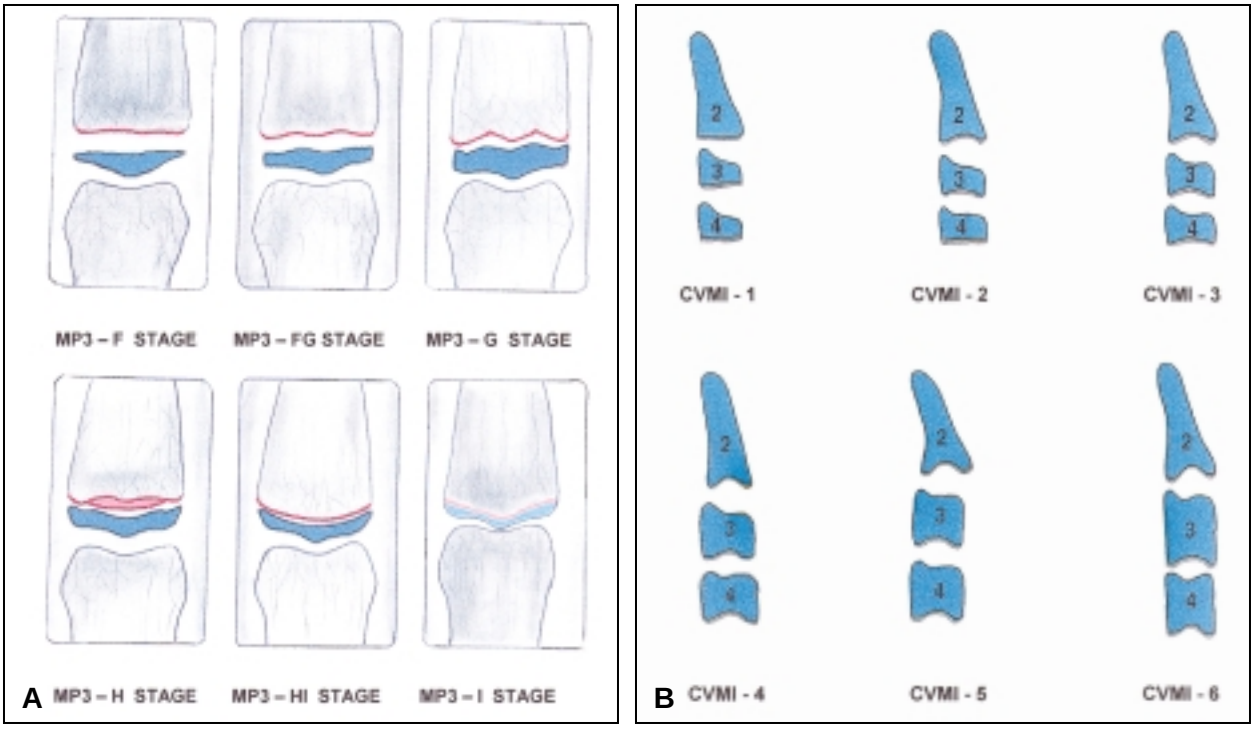

Fig. 1 A. Six modified stages of MP3 development. B. Six stages of cervical vertebrae maturation indices (CVMI).[2]

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stages could be correlated with the six stages of cervical vertebrae maturation indices (CVMI), as described by Hassel and Farman[2] (Fig. 1).

• Evaluate the feasibility of recording MP3 stages using standard dental x-ray film.

Materials and Methods

The sample consisted of 75 females and 75 males age 9 to 17, with an equal distribution of males and females in each age group. The subjects were selected randomly from patients visiting the Departments of Orthodontics, Pediatric Dentistry, and Oral Medicine and Radiology at Saveetha Dental College and Hospital. These patients included some with normal occlusions, some with malocclusions, and some already undergoing orthodontic treatment.

Fig. 2 Cephalometer used to record CVMI stages.

Lateral cephalograms for recording the CVMI stages were taken in natural head position following standard procedure, with patients standing erect and instructed to look straight into their own eyes in a mirror placed on the wall (Fig. 2).

Periapical radiographs for recording the

Fig. 3 Recording of MP3 stages using periapical dental x-ray film.

MP3 stages[3] were taken using the following procedure (Fig. 3):
1. The subject was instructed to place the right hand with the palm downward on a flat table.
2. The middle finger was centered on a 31mm × 41mm periapical dental x-ray film, parallel with the long axis of the film.
3. The cone of the dental x-ray machine was positioned in slight contact with the middle phalanx, perpendicular to the film.

All radiographs were carefully examined by the radiologist, and any patients who presented with congenital or acquired abnormalities of the cervical vertebrae or phalanges were eliminated from the study.

Evaluation

Comparative evaluation of the modified MP3 stages and CVMI produced the following findings.

MP3-F stage: Start of the curve of pubertal growth spurt (Fig. 4A)
Features observed by Hagg and Taranger[1]:
1. Epiphysis is as wide as metaphysis.
Additional features observed in this study:
2. Ends of epiphysis are tapered and rounded.
3. Metaphysis shows no undulation.
4. Radiolucent gap (representing cartilageous epiphyseal growth plate) between epiphysis and metaphysis is wide.

CVMI-1: Initiation stage of cervical vertebrae[2] (Fig. 4B)
1. C_2, C_3, and C_4 inferior vertebral body borders are flat.
2. Superior vertebral borders are tapered from posterior to anterior (wedge shape).
3. 80-100% of pubertal growth remains.

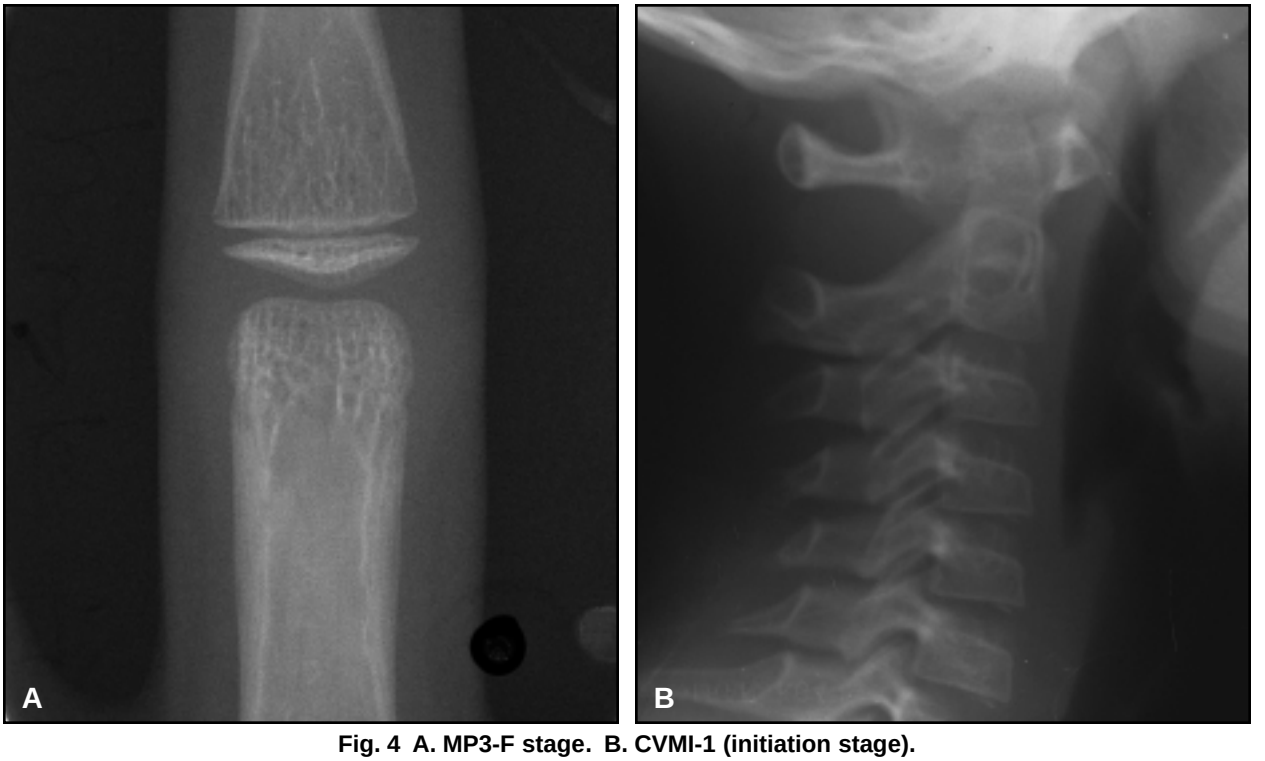

Fig. 4 A. MP3-F stage. B. CVMI-1 (initiation stage).

MP3-FG stage: Acceleration of the curve of pubertal growth spurt (Fig. 5A)
Features observed by Hagg and Taranger:
1. Epiphysis is as wide as metaphysis.
2. Distinct medial and/or lateral border of epiphysis forms line of demarcation at right angle to distal border.
Additional features observed in this study:
3. Metaphysis begins to show slight undulation.
4. Radiolucent gap between metaphysis and epiphysis is wide.

CVMI-2: Acceleration stage of cervical vertebrae (Fig. 5B)
1. Concavities are developing in lower borders of C_2 and C_3.
2. Lower border of C_4 vertebral body is flat.
3. C_3 and C_4 are more rectangular in shape.
4. 65-85% of pubertal growth remains.

MP3-G stage: Maximum point of pubertal growth spurt (Fig. 6A)
Features observed by Hagg and Taranger:
1. Sides of epiphysis have thickened and cap its metaphysis, forming sharp distal edge on one or both sides.
Additional features observed in this study:
2. Marked undulations in metaphysis give it "Cupid's bow" appearance.
3. Radiolucent gap between epiphysis and metaphysis is moderate.

CVMI-3: Transition stage of cervical vertebrae (Fig. 6B)
1. Distinct concavities are seen in lower borders of C_2 and C_3.
2. Concavity is developing in lower border of C_4.
3. C_3 and C_4 are rectangular in shape.
4. 25-65% of pubertal growth remains.

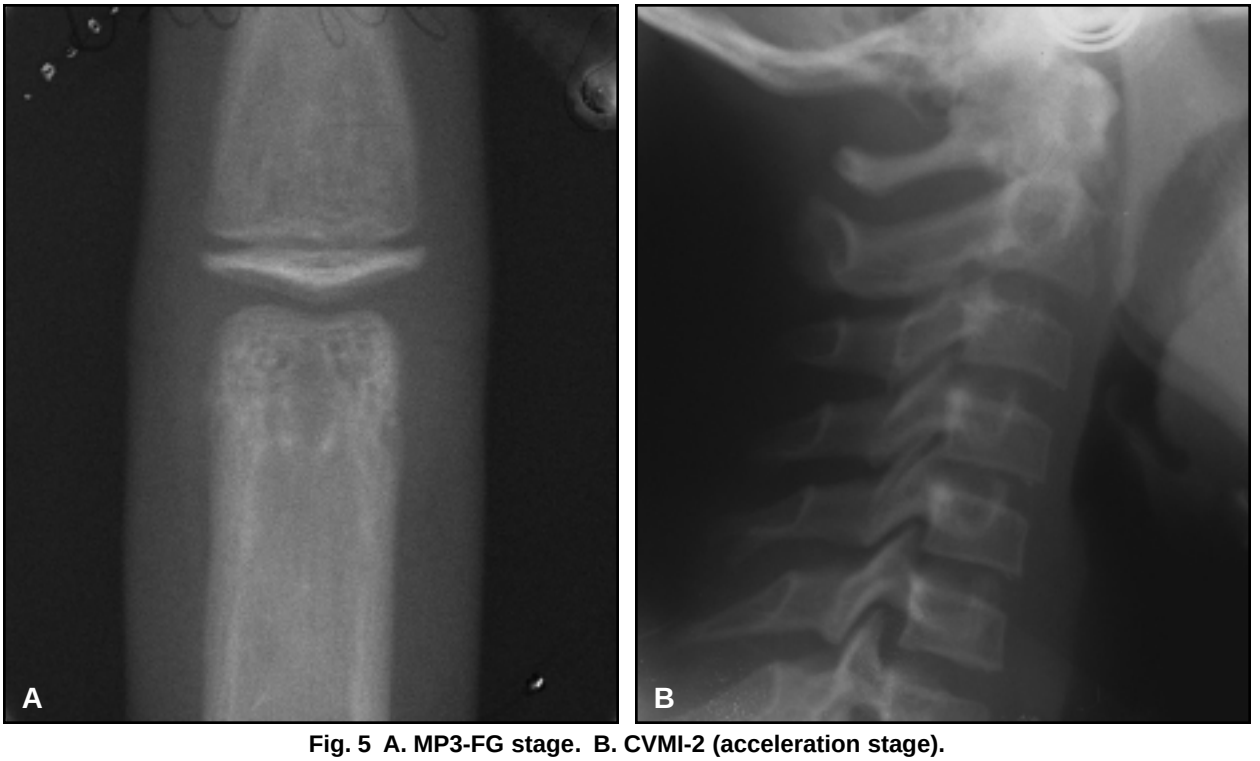

Fig. 5 A. MP3-FG stage. B. CVMI-2 (acceleration stage).

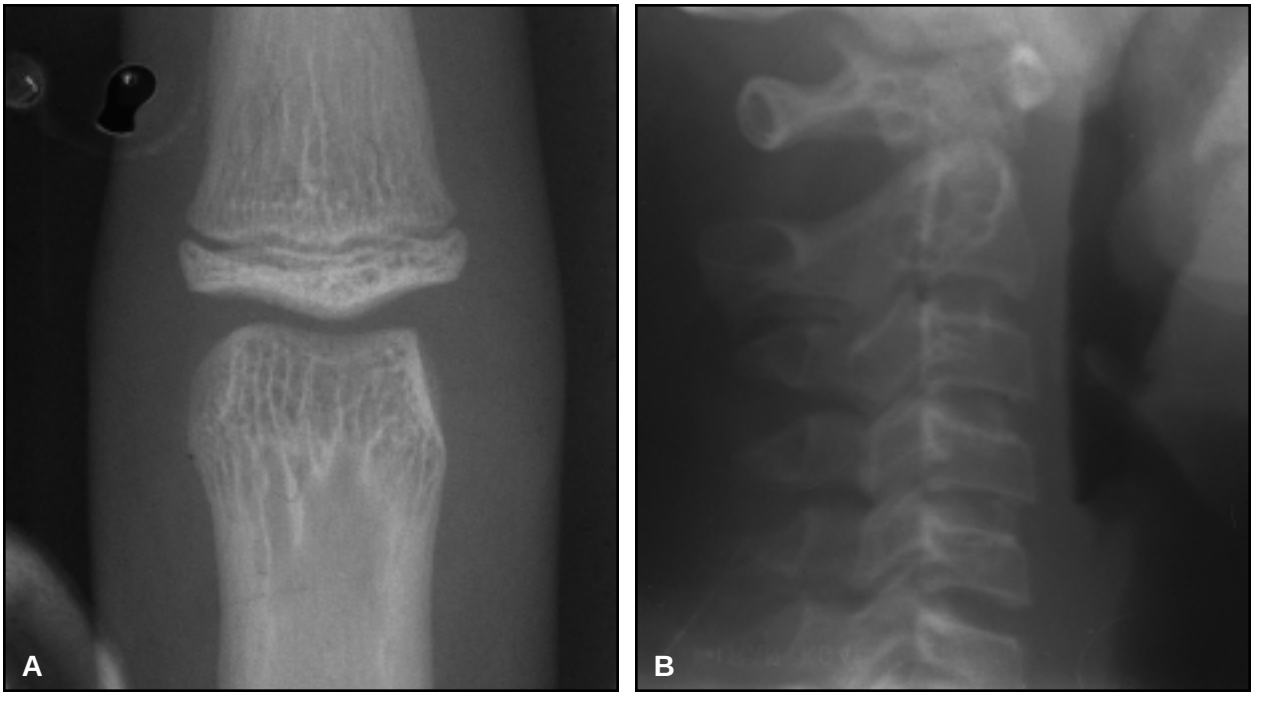

Fig. 6 A. MP3-G stage. B. CVMI-3 (transition stage).

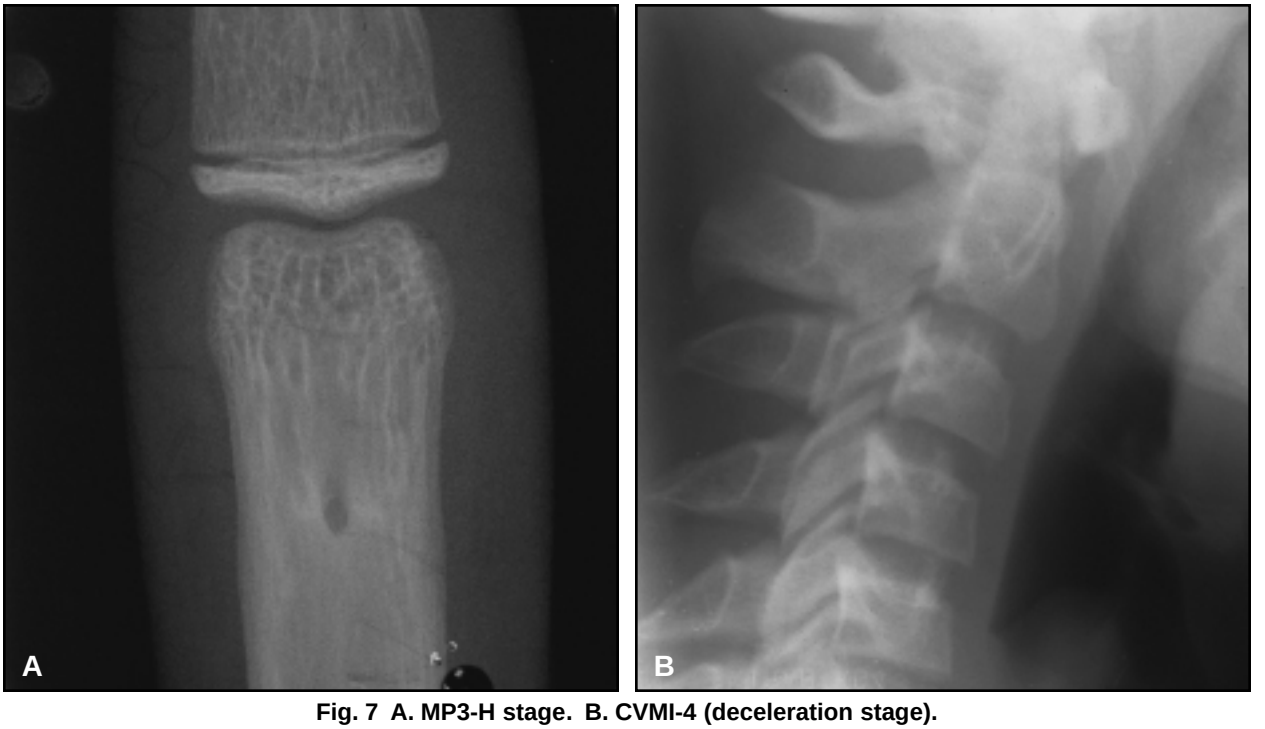

Fig. 7 A. MP3-H stage. B. CVMI-4 (deceleration stage).

MP3-H stage: Deceleration of the curve of pubertal growth spurt (Fig. 7A)
Features observed by Hagg and Taranger:
1. Fusion of epiphysis and metaphysis begins.
Additional features observed in this study:
2. One or both sides of epiphysis form obtuse angle to distal border.
3. Epiphysis is beginning to narrow.
4. Slight convexity is seen under central part of metaphysis.
5. Typical "Cupid's bow" appearance of metaphysis is *absent*, but slight undulation is distinctly present.
6. Radiolucent gap between epiphysis and metaphysis is narrower.

CVMI-4: Deceleration stage of cervical vertebrae (Fig. 7B)
1. Distinct concavities are seen in lower borders of C_2, C_3, and C_4.
2. C_3 and C_4 are nearly square in shape.
3. 10-25% of pubertal growth remains.

MP3-HI stage: Maturation of the curve of pubertal growth spurt (Fig. 8A)
Features of this "new" stage observed in this study:
1. Superior surface of epiphysis shows smooth concavity.
2. Metaphysis shows smooth, convex surface, almost fitting into reciprocal concavity of epiphysis.
3. No undulation is present in metaphysis.
4. Radiolucent gap between epiphysis and metaphysis is insignificant.

CVMI-5: Maturation stage of cervical vertebrae (Fig. 8B)
1. Accentuated concavities of C_2, C_3, and C_4 inferior vertebral body borders are observed.
2. C_3 and C_4 are square in shape.
3. 5-10% of pubertal growth remains.

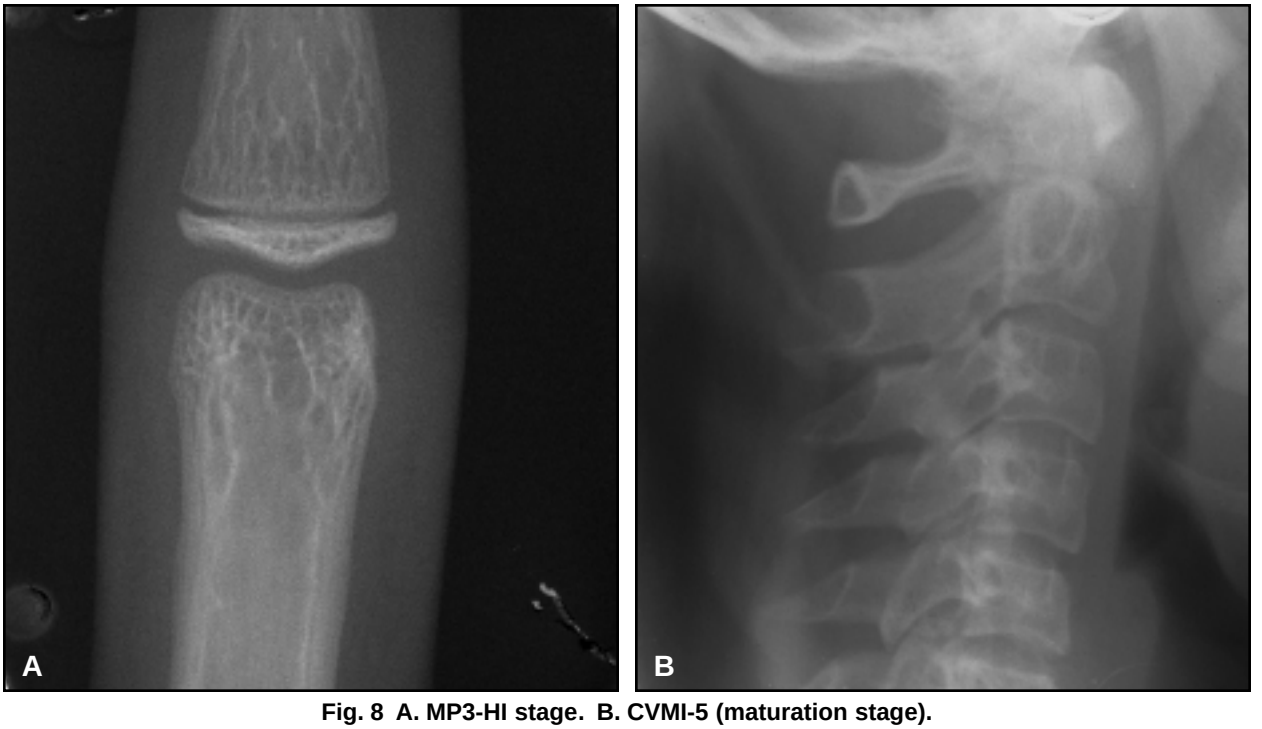

Fig. 8 A. MP3-HI stage. B. CVMI-5 (maturation stage).

MP3-I stage: End of pubertal growth spurt (Fig. 9A)
Features observed by Hagg and Taranger:
1. Fusion of epiphysis and metaphysis complete.
Additional features observed in this study:
2. No radiolucent gap exists between metaphysis and epiphysis.
3. Dense, radiopaque epiphyseal line forms integral part of proximal portion of middle phalanx.

CVMI-6: Completion stage of cervical vertebrae (Fig. 9B)
1. Deep concavities are present in C_2, C_3, and C_4 inferior vertebral body borders.
2. C_3 and C_4 are greater in height than in width.
3. Pubertal growth is complete.

In these 150 subjects, the six modified MP3 stages showed a high correlation with the six stages of cervical vertebrae, with an overall similarity of 94.7% (Table 1). Radiographs of only 5.3% of the subjects were dissimilar in at least one bone stage (Table 2, Fig. 10).

Discussion

Chronological age is an inaccurate indicator of the stages of dental development through adolescence to adulthood.[4-8] In fact, dental age has a significantly low correlation with biological age.[4,8,9] Growth prediction based on the appearance of secondary sexual characteristics requires a long observation period and frequent physical examinations. The skeletal maturity of the bones of the hand and wrist and the cervical vertebrae, on the other hand, is closely related to that of the craniofacial region, and skeletal maturity indices are reliable predictors of sexual and somatic maturity as well.[4-8,10-13]

Tanner and colleagues devised a method called TW2 to classify many of the ossification centers of the hand and wrist.[14] Development of the radius, metacarpals, phalanges, and trapezium were each divided into nine stages (A-I), and that of the ulna and the rest of the carpals into eight stages (A-H). Houston, Miller, and Tanner

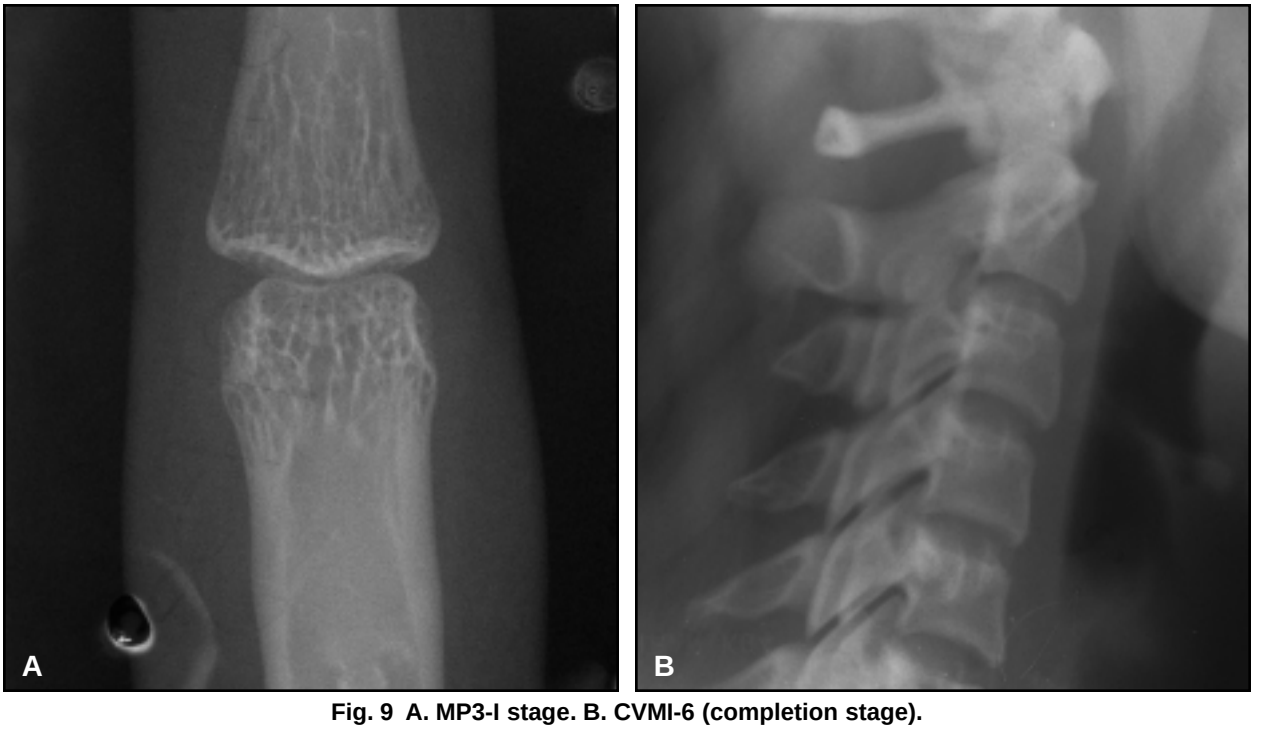

Fig. 9 A. MP3-I stage. B. CVMI-6 (completion stage).

identified the four stages of MP3 bone development (F-I) that occur within a few years of the onset of puberty.[15] Hagg and Taranger recommended using five distinct stages of MP3 development (adapted from Tanner's classification[14]) as a reliable biological indicator.[1]

Chapman was the first to use periapical x-ray film to evaluate ossification of the ulnar sesamoid bone as a skeletal maturity marker.[16] Abdel-Kader applied this idea to recording MP3 stages.[3] As the present study confirms, assessment of remaining pubertal growth can be reliably performed throughout treatment using the modified MP3 stages by taking simple periapical x-rays, without the need for extra lateral cephalograms or hand-wrist x-rays.[6,17]

Conclusion

This study has shown that recording modified MP3 stages using periapical x-ray film can be an accurate, simple, practical, and economical growth indicator for making decisions on treat-

TABLE 1
SIMILARITY BETWEEN MODIFIED MP3 STAGES AND CVMI (ALL SUBJECTS)

	No.	Pct.
Similar	142	94.7%
Dissimilar	8	5.3%

TABLE 2
SIMILARITY BETWEEN MODIFIED MP3 STAGES AND CVMI BY AGE AND SEX

Age	Male	Female	Overall
9	100%	100%	100%
10	100%	100%	100%
11	80%	90%	85%
12	90%	90%	90%
13	90%	100%	95%
14	90%	100%	95%
15	90%	100%	95%
16	100%	100%	100%
17	100%	100%	100%

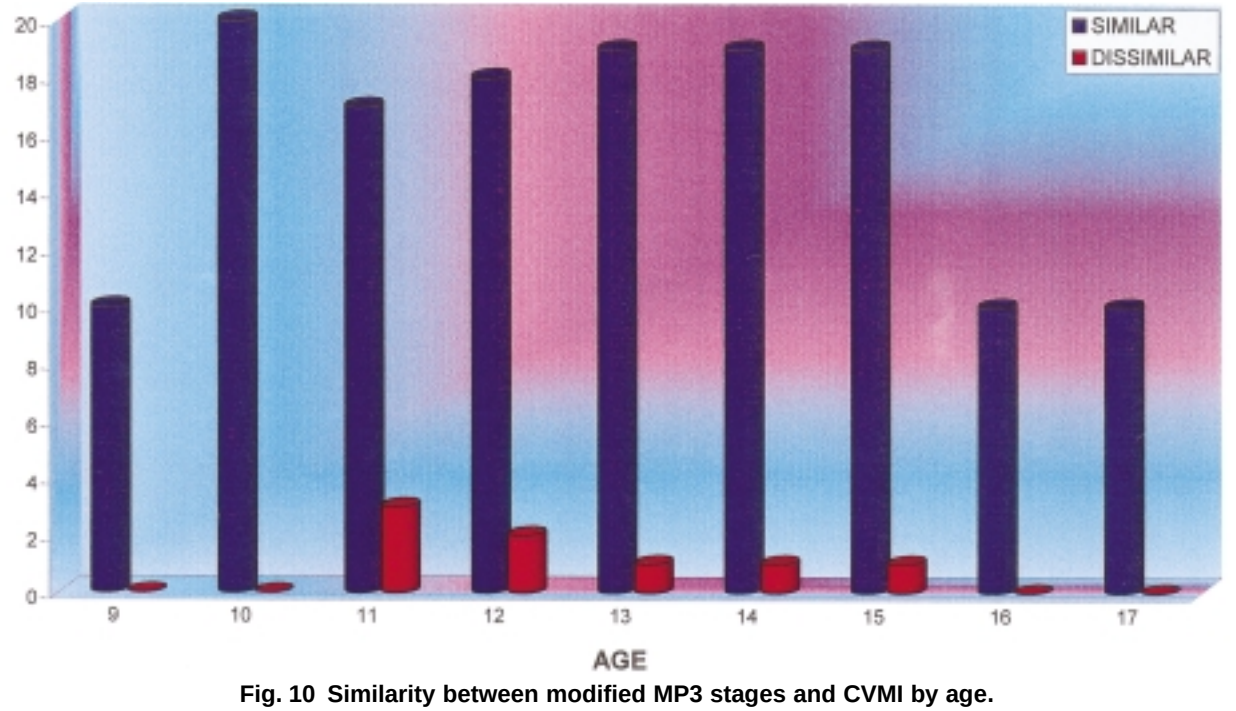

Fig. 10 Similarity between modified MP3 stages and CVMI by age.

ment timing. Advantages of the modified MP3 stages include:

1. Significantly lower radiation exposure compared to lateral cephalograms or hand-wrist x-rays.
2. High degree of clarity on the radiographs, with no superimposition of bones or variations in posture as in evaluation of the cervical vertebrae.
3. Discrete, easily identifiable stages of development, unlike the more subtle changes in CVMI stages.
4. Close correlation to the six stages of CVMI.
5. No need to obtain equipment beyond the standard periapical x-ray film and dental x-ray machine.

Further longitudinal studies are needed to establish the changes observed in the metaphysis in all stages of MP3 and to prove the validity of the new MP3-HI stage.

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