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THE UNIVERSITY OF
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GROWTH
ANALYSIS

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GROWTH ANALYSIS

While planning orthodontic treatment on a growing patient, assessing their growth status can be very important. Clinicians need a reliable method of determining a patient's growth stage and predicting its optimum timing for the planned treatment.

When looking at growth status, we are usually trying to determine whether patients have yet commenced, are midway through, or past the peak of their pubertal growth spurt, and how much active growth remains. The timing of some orthodontic treatment may be best either before, during or after pubertal growth.

Maxillary expansion is generally better undertaken before peak pubertal growth is reached. Although simple expansion can be undertaken during the end of pubertal growth, it can be more difficult, less stable, and more prone to unwanted sequalae.

The treatment of Class III malocclusions is generally acknowledged to be challenging in orthodontics. Where the malocclusion is due to a retrognathic maxilla, the use of a maxillary protraction facemask – also known as reverse pull headgear - has been widely used. Clinicians will aim to undertake this maxillary protraction before pubertal growth as it is found to be more effective then rather than in later stages of development.[1] However, for patients whose Class III malocclusion is due to excess mandibular growth, their treatment is usually best undertaken after peak growth and often after all active pubertal growth has ceased as either orthognathic surgery or camouflage treatment may be required.[1, 2, 3]

The treatment of Class II malocclusions with functional appliances (fixed or removable) is generally acknowledged to be most effective and efficient if carried out during peak growth.[2] Although patients sometimes commence treatment based on their dental development and age, trauma risk or physical and psychological concerns, it is generally accepted that coinciding treatment with the puberal growth spurt will enhance treatment outcomes.

If treatment outcomes can be optimised by commencing orthodontic treatment at specific times in a patient's growth and development, then it is important to undertake growth analysis before planning their treatment.

But can we reliably predict the pubertal growth spurt?

There is a great degree of individual variability in the way children and adolescents grow, let alone when they grow, so accurate growth prediction can be very difficult. Various methods have been developed over the years, and although this can be a contentious subject, it is important to understand and consider.

Growth assessment can be broadly categorised into:

1. Minimally invasive analysis such as Chronological Age, Statural Height and Sexual Maturation Characteristics.

2. Radiographic assessment such as Cervical Vertebral Maturation, Hand Wrist Radiographs or Dental development as seen on an OPG.

Chronologic Age Assessment

Haag and Taranger suggested that on average, the pubertal growth spurt commenced at 10 years in females and ceased at 14.8 years, while in males it commenced at approximately 12.1 years and ended at 17.1 years. While growth continues after these ages, it is at a significantly slower rate. Although chronological age can be used to estimate cognitive development, physical capability, height and weight it tends to be a poorer predictor of the timing of the pubertal growth spurt.[4,5]

Statural Height Increase

Peak facial growth is generally accepted to coincide with peak height velocity growth.[1,2,3] However establishing an association between condylar and bodily growth has been more challenging.[4]

Using the correlation between rapidly increasing statural height and the beginning of the adolescent facial growth spurt holds some advantages, particularly in that recording height measurements is minimally invasive and relatively easily performed in the clinic and at home.[1] However, though generally a good guide, the range can vary from 25 months before actual peak pubertal growth to 3 months after, particular in females.[6] Thus statural height may be a useful guide but may not always be accurate.

Sexual Maturation Characteristics

The development of secondary sex characteristics as the body transitions both in form and function to its adult form have often been associated with active pubertal growth. Parents should look for such things as the presence of axillary/pubic hair. In males the presence of upper lip/facial hair and voice changes may be indicative while in females breast development and the onset of menarche may be helpful. It is generally accepted that menarche occurs about midway through a female's most active pubertal growth, which usually lasts about two to three years.

However, many of these signs are general indicators of the peak pubertal growth having already started some time ago, or perhaps even having passed completely and so cannot be used to predict the start of the adolescent growth spurt.[5,7] In addition their accuracy has been questioned as there can be considerable variation between individuals.

Given the relative unreliability of the above three methods, researchers and clinicians have sought more accurate and scientific methods of making such an assessment. The advent of radiography very quickly provided new methods of growth assessment.

Hand-wrist Maturation Assessment

Fishman developed a system of 11 skeletal maturation indicators covering adolescent development, using 4 stages of bone maturation at 6 anatomical sites located on the thumb, middle finger, smallest finger, and the radius.[8]

WIDTH OF EPIPHYSIS   OSSIFICATION

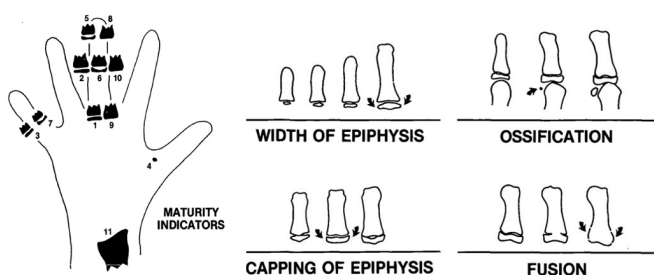MATURITY INDICATORS

CAPPING OF EPIPHYSIS   FUSION

Fig. 1 Eleven indicators of growth status and in Fig. 2 Radiographic identification of skeletal maturity indicators. A. Epiphysis equal in width to diaphysis. B Appearance of adductor sesamoid of the thumb. C. Capping of epiphysis. D. Fusion of epiphysis

Although the evidence suggests that there is a significant correlation between statural height increase and growth prediction, hand-wrist radiographs are now the least commonly utilised method of growth analysis.

Hand-wrist radiographs are now rarely taken for the purpose of pubertal growth spurt or mandibular growth prediction as they cannot be justified due to the possible deleterious effects of radiation on a growing individual.[9]

Cervical Vertebrae Maturation (CVM) Assessment

Lateral Cephalographs are routinely used in orthodontic treatment planning. Using them Hassel and Farman developed a method of assessing growth status. Using cervical vertebrae, which are always visible on these radiographs, they determined six cervical vertebral maturation stages of C2, 3 and 4 to assess growth status.[10] Bacetti further correlated the CVM stages to mandibular growth and revised the use of CVM stages.[13,14,15,20]

Schematic representation	CS 1	CS 2	CS 3	CS 4	CS 5	CS 6
Inferior borders of C2, C3, and C4[a]	F, F, F	C, F, F	C, C, F	C, C, C	C, C, C	C, C, C
C3 morphology[a]	T	T	T	RH	S/RH	RV/RH
C4 morphology[a]	T	T	T/RH	RH	S/RH	RV/RH
Clinical implication	Prepubertal stage	Prepubertal ("get-ready") stage	Circumpubertal stage	Circumpubertal stage	Postpubertal stage	Postpubertal stage

F+Flat   C = Concavity   T=Trapezoid   RH=Rectangular Horizontal   S=Square   RV=Rectangular Vertical

- CS 1: Inferior borders of all 3 are flat, or even slightly convex, except for C2 which may have concavity; C3, C4 bodies are trapezoid and tapered

  Peak mandibular growth will occur after at least 1 year

- CS 2: Concavities/Notching at inferior border of C2 while C3 and C4 remain flat; Bodies of C3, C4 remain trapezoidal

  Peak mandibular growth will occur within 1 year.

- CS 3: Concavities/notching at inferior borders of C2, C3 while C4 remains flat; Bodies of C3, C4 usually still trapezoidal but either C3 or C4 could have a rectangular horizontal shape.

  Maximum craniofacial growth velocity is expected.

- CS 4: Concavities/notching at inferior borders of C2, C3, C4; Both C3, C4 are rectangular horizontal.

  Peak mandibular growth occurred within the last year.

- CS 5: Concavities/notching at inferior borders of C2, C3, C4; At least one of the bodies of C3 or C4 is square.

  Peak mandibular growth occurred within the last two years.

- CS 6: Concavities/notching at inferior borders of C2, C3, C4. Either C3 or C4 or both bodies are rectangular vertical in shape

  Cessation of significant craniofacial growth

Fig.3 Bacetti's 6 Cervical Stages of maturation

In summary, CS 1 and CS 2 indicate Pre-pubertal growth, CS 3 and CS 4 indicate Circum-pubertal growth and CS 5 and CS 6 indicate Post-pubertal growth
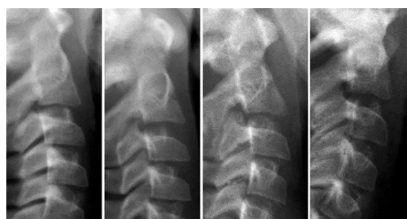

Fig. 4 Indicates CS 1/2

Fig. 5 Indicates CS 3

Numerous studies have been conducted, looking at the reliability of the CVM indices. Some, such as Hosni[11] and Szemraj[12] found there was a relationship between CVM and statural height velocity, while others such as Gray et. al. concluded that CVM assessment was better suited to determining whether peak mandibular growth had already happened, however that it was not a reliable predictor for peak growth.[13]

Although the CVM method is widely used because it can be easily read from a routine lateral cephalogram, it cannot be solely relied upon as its accuracy has been brought into question by recent studies.

Dental Development

Development of the dentition based upon radiographic stages of calcification has also been suggested as a potential method of predicting growth maturation, with the development of several indices of dental calcification.[14,15] Džemidžic et. al., correlated mandibular canine calcification to CVM and concluded that they are a dependable method in the assessment of pre-pubertal growth phases.[14] Of course, this is assuming CVM is a reliable method of growth analysis.

Though dental calcification indices hold the advantage of not requiring additional radiation exposure, it is generally recognised that there is often a discrepancy between development of the dentition and chronological age. There is some, though minimal, evidence to suggest associations between dental development and skeletal maturity assessed

from hand-wrist radiographs and CVM, however correlation to the pubertal growth spurt has not yet been established. [14,16]

Unfortunately this method also cannot be solely relied upon for accurate growth assessment.

So which method is good, better, or best?

Mellion et al 2013 looked at whether hand-wrist and cervical vertebrae radiography are superior to chronological age and height, when predicting maturation and the pubertal growth spurt. They found in terms of growth prediction, hand–wrist radiographs provided the better indication that maturation had reached the peak velocity stage, followed closely by chronological age. Meanwhile CVM was consistently the poorer indicator for growth.[17]

Conclusion

While it is imperative to understand the concepts of growth patterns and predictability in orthodontics, and to appreciate that successful orthodontic treatment will rely on a close prediction of growth, many of the growth analysis methods discussed have shortcomings. In clinical practice, it is much simpler to incorporate examination based, minimally invasive analysis methods, into diagnosis and growth prediction. Especially as chronological age, statural height and presence of secondary sex characteristics are generally documented throughout the course of treatment.

For growth analysis methods that require radiographs, both Dental Development and CVM can be readily utilized with the routine use of OPG, Lateral Cephalogram and sometimes, CBCT radiographic images. Hand-wrist radiographs, although suggested by Mellion et al to be the most reliable indicator of growth, involve additional radiography outside the scope of routine orthodontic/dental x-rays and as a result, are seldom used.[17]

Clearly, there is no single, reliable, and precise predictor of the onset of the adolescent growth spurt. Therefore, a combination of several growth analysis methods should be utilised to estimate growth status as best as possible to deliver timely treatment.

References available upon request

Past issues of Brighter Futures can be accessed at: www.aso.org.au/resources/brighter-futures-newsletters

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