

TRABAJO DE FIN DE GRADO

Grado en Odontología

**EVALUACIÓN DE LOS MÉTODOS DE ANÁLISIS
DE LA MADURACIÓN ÓSEA EN PACIENTES
ODONTOPEDIÁTRICOS**

Madrid, curso 2020/2021

Número identificativo

71

Resumen

Objetivos: Los objetivos de este trabajo fueron comparar la maduración ósea de vértebras cervicales y de muñeca, analizar los diferentes métodos diagnósticos utilizados así como las estructuras anatómicas recientemente estudiadas que puedan proporcionar información de maduración ósea y por último, determinar cuál de los métodos de maduración ósea a través de las radiografías de vértebras cervicales es el más utilizado.

Metodología: Búsqueda en bases de datos como Pubmed y Medline para conseguir artículos científicos, casos clínicos y estudios observacionales de los últimos 5 años.

Conclusiones: Se analizaron diferentes artículos, estudios e investigaciones actualizados, los cuales mostraron que el método de radiografía de vértebras cervicales tiene la misma similitud de resultados que el método de radiografía de muñeca, teniendo características más favorables el método de radiografía de vértebras cervicales; los métodos diagnósticos utilizados en la actualidad como la tomografía computarizada (TC) y la resonancia magnética (RM) siguen necesitando de investigación y un método específico para cada uno de ellos. Las estructuras anatómicas estudiadas como rodilla, clavícula, cresta ilíaca y cabeza del fémur tienen pocos estudios, pero estos han demostrado que, pese a la poca información, estas estructuras pueden llegar a ser un buen diagnóstico complementario a las radiografías de muñeca y de vértebras cervicales. Los métodos radiográficos de vértebras cervicales mostraron una diferencia entre ellos, siendo el método de Baccetti y cols. el más confiable.

Abstract

Objectives: The objectives of this work were to compare the bone maturation of cervical vertebrae and hand-wrist, analyze the different diagnostic methods used as well as the recently studied anatomical structures that can provide information on bone maturation and finally, determine which of the bone maturation methods through cervical vertebrae radiographs it is the most used.

Methodology: Search in databases as Pubmed and Medline to obtain scientific articles, clinical cases and observational studies from the last 5 years.

Conclusions: Different updated articles, studies and research were analyzed which showed that the cervical vertebrae method has the same similarity of results as the hand-wrist method, having the cervical vertebrae method more favorable characteristics; the diagnostic methods used such as computed tomography and magnetic resonance imaging continue to require research and specific method for each of them. The anatomical structures studied such as knee, clavicle, iliac crest and head of the femur have few studies, but these have shown that, despite the few information, these structures can become a good complementary diagnosis to hand-wrist and cervical vertebrae radiographs. The cervical vertebrae method showed a difference between them, concluding Baccetti et al method is the most reliable cervical vertebrae method.

Índice

1. Introducción	6
1.1 Radiografía de Muñeca	9
1.1.1 Roland ¹¹	9
1.1.2 Pryor ^{12,13}	10
1.1.3 Rotch y Crptom ¹²	10
1.1.4 Hellmann ¹⁴	10
1.1.5 Flory ¹⁵	10
1.1.6 Métodos para la Determinación de la Edad Ósea mediante Radiografía de Muñeca	11
1.1.6.1 Greulich y Pyle ^{16,17,18}	11
1.1.6.2 Fishman LS ¹⁹	12
1.1.6.3 Tanner y Whitehouse ²⁰	16
1.1.6.4 Gilsanz y Ratib ²¹	17
1.1.6.5 Métodos Actuales ¹⁷	22
1.2 Radiografía Vértebras Cervicales	22
1.2.1 Métodos para la Determinación de la Edad Ósea mediante Radiografía de Vértebras Cervicales	22
1.2.1.1 Lamparski ²²	22
1.2.1.2 Hassel y Farman ²⁴	25
1.2.1.3 Baccetti y cols. ^{25,26}	26
1.2.1.4 Chen y cols. ²⁷	32
1.3 Radiografía Falange Media del Tercer Dedo	33
1.3.1 Métodos para la Determinación de la Edad ósea mediante Radiografía de la Falange Media del Tercer Dedo	33
1.3.1.1 Hägg y Taranger ²⁸	33
1.3.1.2 Rajagopal y Kansal ^{9,29}	35
1.4 Otros Zonas Diagnósticas	37
1.4.1 Radiografía de Rodilla ^{30,31}	37
1.4.2 Radiografía de Clavícula ¹⁸	41
1.4.3 Radiografía de la Cresta Ilíaca ¹⁸	42
1.5 Otros Métodos Diagnósticos	43
1.5.1 Tomografía Computarizada Cone Beam (CBCT) ^{33,34}	43

1.5.2	<i>Resonancia Magnética (RM)</i> ^{17,34}	44
2.	Objetivos	46
3.	Metodología	47
4.	Discusión	48
5.	Conclusiones	56
	Responsabilidad Social	57
	Bibliografía	58

1. Introducción

En el individuo existen una serie de diferentes edades que pueden ser evaluadas, entre ellas la edad biológica, edad cronológica, edad ósea, edad dental, edad psicológica y edad sexual. Se asume que el crecimiento de un niño debería tener relación y equilibrio en cuanto a todos sus sistemas, incluyendo su edad biológica, su edad cronológica, su edad dental, desarrollo psicológico y crecimiento y desarrollo óseo. Un desarrollo normal en el crecimiento humano, si sale del patrón, se considera anormal o patológico. Su estimación se observa por rangos específicos de edad-crecimiento, basado en índices generales de signos de maduración y crecimiento de los distintos tipos de órganos¹. Es importante saber que el crecimiento es diferente en cada individuo y puede tener variaciones. De igual manera, si este periodo de diferencia de crecimiento varía en un tiempo menor a 1 año, no es considerado anormal, por lo que podría estar dentro del rango de crecimiento normal.²

“La edad es uno de los elementos fundamentales en la identificación del sujeto” (Correa Ramírez, 1990), por esa razón se pueden separar en 2 tipos de edades: Edad biológica y edad cronológica. Cuando hablamos de la edad biológica en un niño, nos referimos a aquella que se utiliza para determinar cómo es la maduración de todos los sistemas del cuerpo, también llamada edad fisiológica o de maduración. Se utiliza para estimar el desarrollo de los sistemas del cuerpo, de forma general para toda la población y no de manera individualizada. Por otro lado, la edad cronológica es aquella que empieza el día en el que un individuo nace y termina el día en el que este mismo individuo fallece, no tiene variaciones. Niños con la misma edad cronológica pueden mostrar diferentes etapas o tipos de maduración, ya que esto se ve afectado por

diferentes factores como la genética, desarrollo socioeconómico, hábitos o patologías.³

Uno de los factores para determinar el crecimiento y desarrollo es la relación que existe entre la edad cronológica y la maduración de los dientes. Algunos estudios describen que se puede estimar la edad de un niño viendo el desarrollo de los dientes a través de una radiografía panorámica, donde podríamos observar diferentes características como raíces, tamaño de la pulpa o gérmenes dentarios. De igual manera, se piensa que esta relación, entre todas las relaciones asociadas al crecimiento y desarrollo, es la más débil y la que más pudiera tener variaciones generales, pero su relación con la edad cronológica normalmente suele estar correlacionada.^{4,5,6}

Para la edad dentaria existen 2 maneras de estimación: Mediante la cronología de erupción y la calcificación de los tejidos dentales. Un cambio en la secuencia de erupción que pase los 2 años se considera anormal o patológico, viéndose principalmente en casos de maloclusiones, retenciones y agenesias. Este es el método más antiguo para identificar la edad cronológica de un paciente, dando una información estimada de esta posible edad, aunque a veces se ha puesto en duda porque la erupción dentaria puede verse afectada por diferentes factores como la anquilosis, retraso o adelanto de las erupciones dentarias, impactaciones y posición de los dientes permanentes. La estimación de la edad cronológica mediante la maduración o calcificación de los tejidos dentales, se da cuando los dientes alcanzan su formación, desde el momento en que aparecen los gérmenes dentales hasta su maduración completa.^{3,6}

Finalmente tenemos el crecimiento óseo, que se considera uno de los factores que tiene mayor cantidad de variaciones en cuanto a su desarrollo, porque está íntimamente unido a la maduración y mineralización de los huesos. Cada individuo tiene su propio grado de maduración, dependiendo de cómo esto evolucione se considera de crecimiento rápido, promedio o tardío.²

Se considera que cualquier hueso del cuerpo puede determinar una edad ósea, porque todos pasan por diferentes cambios, pero dentro de la práctica médica y odontológica los más estudiados para esta determinación son los huesos encontrados en la mano y la muñeca, ya que esta zona contiene varios huesos y epífisis que nos permitirán ver los cambios en el desarrollo y crecimiento de los huesos a través de los años.²

Las relaciones entre edad biológica y cronológica, edad dentaria, edad psicológica y crecimiento óseo, se estudian e investigan ya que tienen mucha importancia en distintas áreas de la odontología, como es el caso de la medicina legal y forense, la ortodoncia y la odontopediatría. En estas dos últimas especialidades antes mencionadas, tiene gran importancia ya que se logra estudiar qué puede o no puede pasar en el crecimiento óseo, para así poder decidir la mejor opción terapéutica para que un tratamiento sea más efectivo.

Se utilizan los métodos de estimación de crecimiento óseo para saber cuál es el mejor momento para tratar y cuáles son los factores que están a nuestro favor. Se determina observando las etapas de osificación y el patrón de crecimiento óseo.⁷

Existen diferentes maneras de saber cuál es el momento más favorable para tratar a un paciente. Esto se puede ver mediante una serie de rasgos

específicos en radiografías y siguiendo unas normales generales. La única desventaja de estos procedimientos es que no todos los profesionales están familiarizados con estos métodos, exponiendo al paciente más de una vez a la radiación.⁸

Gracias al descubrimiento de la radiografía en 1896 por Roentgen, se utilizó la radiografía para comenzar a detectar patrones o características en huesos en desarrollo en pacientes pediátricos para poder identificar su edad y etapa de crecimiento.^{9,10}

1.1 Radiografía de Muñeca

Se realiza principalmente en la mano izquierda. La razón principal de esto es porque la mayoría de personas suelen ser diestras, por ende pueden llegar a tener mayor cantidad de lesiones en su mano dominante, en caso que sean diestros tendrán más lesiones en la mano derecha que en la izquierda.^{9,10}

1.1.1 Roland¹¹

Tras el descubrimiento de la radiografía por Röntgen¹⁰, Roland en 1896, observó la relación entre una radiografía carpal con la maduración esquelética y el crecimiento, esto lo hacía mediante la observación de una radiografía en diferentes etapas y viendo los diferentes cambios en la forma de la estructura ósea que se apreciaban en la radiografía, pensando que los huesos de las manos podrían ser considerados indicadores de crecimiento.

1.1.2 Pryor^{12,13}

- 1) En 1904, Pryor estableció 3 principios: El primero consideraba que el desarrollo óseo de las mujeres se realizaba de manera más temprana que el de los hombres.
- 2) En un crecimiento considerado normal, indiferentemente de las variaciones del individuo, la osificación siempre sería asimétrica, es decir, todos los huesos crecían con la misma rapidez o tardanza alrededor de todo el cuerpo.
- 3) Finalmente, el último principio consistía en que pueden existir diferentes variaciones en los huesos, por lo que el patrón de crecimiento se consideraría de carácter hereditario.

1.1.3 Rotch y Crapton¹²

Años más tarde, Pryor en colaboración con Rotch y Crapton, en 1909, estudiaron todos los cambios en las radiografías de muñeca, concluyendo que estas podrían considerarse y aceptarse como indicadores fidedignos del desarrollo general.

1.1.4 Hellmann¹⁴

En 1928, Hellmann centró su investigación en la manera en la que se osificaban los cartílagos epifisarios de la mano. Correlacionó el momento en el cual aparece el sesamoideo, con el inicio de uno de los picos de crecimiento, relacionado con el máximo crecimiento en altura.

1.1.5 Flory¹⁵

Flory en 1936, confirmó la teoría registrada por Hellman¹⁴, donde la calcificación del sesamoideo del aductor podría considerarse una buena manera de determinar el momento en el que empieza el periodo

prepuberal. Ese pico de altura continúa activo por aproximadamente 1 año posterior a la aparición del sesamoideo.

1.1.6 Métodos para la Determinación de la Edad Ósea mediante Radiografía de Muñeca

1.1.6.1 *Greulich y Pyle* ^{16,17,18}

Para verificar los estudios realizados para la determinación de maduración ósea a través de la radiografía de muñeca, Greulich y Pyle (GP) realizaron un atlas donde estudiaron la edad ósea con la radiografía de la mano izquierda de un paciente (fig.1). Utilizaron pacientes pediátricos caucásicos de Cleveland, Ohio, Estados Unidos, entre los años 1931 y 1942. Este atlas contiene imágenes guía de ambos sexos, femenino y masculino, desde el nacimiento hasta los 18 años en mujeres y 19 años en hombres, aparte de sus respectivas explicaciones y cambios en cada una de las fotografías. Para analizar la edad ósea utilizando este atlas, se hace una radiografía de muñeca al paciente y posteriormente se busca la imagen que coincida en el atlas. Se consideró el método más sencillo en su época, utilizado en Pakistán y Australia.

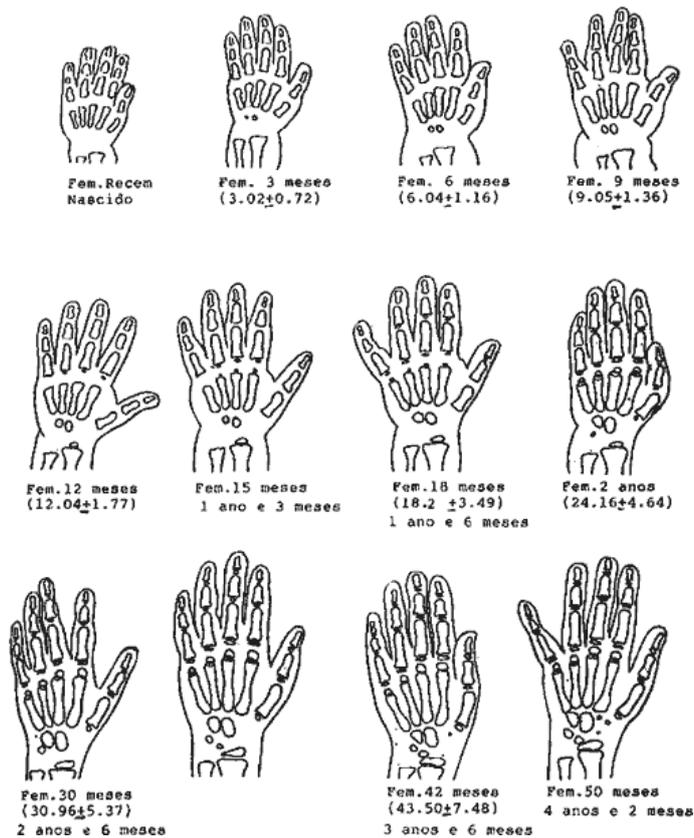


Fig. 1. Diferentes edades y sus cambios óseos con la radiografía de muñeca. Tomada del Atlas de Greulich y Pyle.¹⁶

1.1.6.2 Fishman LS¹⁹

En 1982, Fishman LS propuso utilizar la radiografía de muñeca para determinar el crecimiento óseo, clasificando la maduración ósea carpal en 11 estadios y así con esto, poder estudiar cuál sería el pico de crecimiento puberal.

Su método consistía en usar 4 etapas de maduración en 6 lugares anatómicos distribuidos en: El pulgar, tercer dedo, quinto dedo y el radio. Las 4 etapas de maduración consistían en:

La osificación a través del ensanchamiento epifisiario en las falanges, la osificación del sesamoideo del pulgar, el recubrimiento de epífisis sobre su diáfisis y fusión entre epífisis y diáfisis. Se

referencian 11 indicadores de maduración esquelética (SMI's) que se consideran estables (fig. 2). En el estudio de 2000 personas solo 3 se consideraron no estables, esto quiere decir que su crecimiento no era igual al de la media, pero este hecho no afectó en los resultados finales.

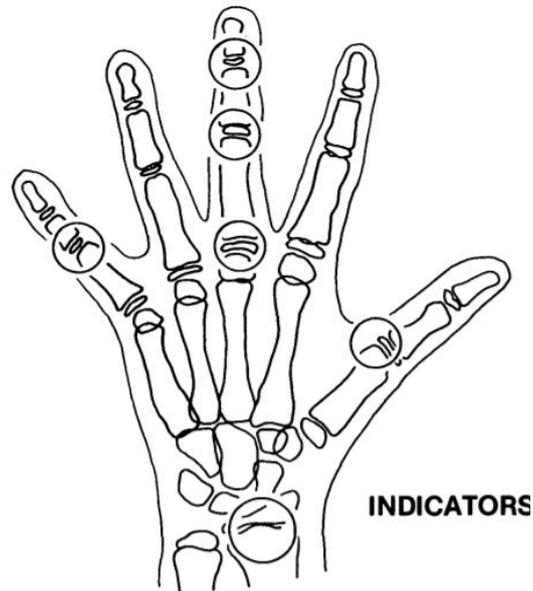


Fig. 2. Sitios donde se encuentran los Indicadores de Maduración Esquelética de Fishman (SMI). Tomada de Fishman L.¹⁹

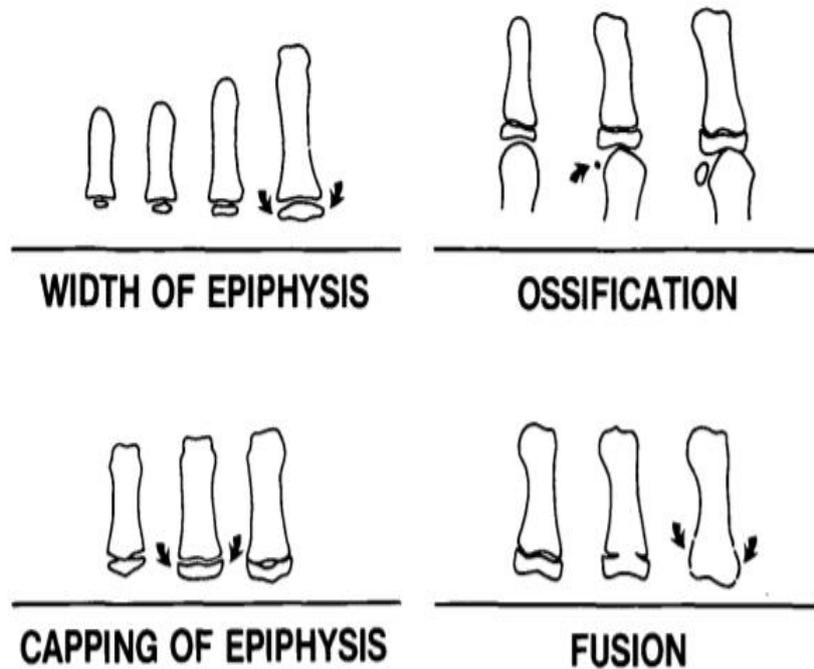


Fig. 3. Evolución de los Indicadores de Maduración Ósea: (A) Anchura de la epífisis con la anchura de la diáfisis. (B) Aparición del sesamoideo aductor del pulgar. (C) Encapsulamiento de la epífisis. (D) Fusión de la epífisis. Tomada de Fishman L.¹⁹

Indicadores de Maduración Esquelética (SMI) (fig. 3 y 4)

a) Anchura de la Epífisis con la Anchura de la Diáfisis:

SMI 1: Tercer dedo – Falange proximal.

SMI 2: Tercer dedo – Falange media.

SMI 3: Quinto dedo – Falange media.

b) Osificación

SMI 4: Se forma el sesamoideo aductor del pulgar.

c) Encapsulado de la Epífisis

SMI 5: Tercer dedo – Falange distal.

SMI 6: Tercer dedo – Falange media.

SMI 7: Quinto dedo – Falange media.

d) Fusión de la Epífisis con la Diáfisis

SMI 8: Tercer dedo – Falange distal.

SMI 9: Tercer dedo – Falange proximal.

SMI 10: Tercer dedo – Falange media.

SMI 11: Fusión del radio.

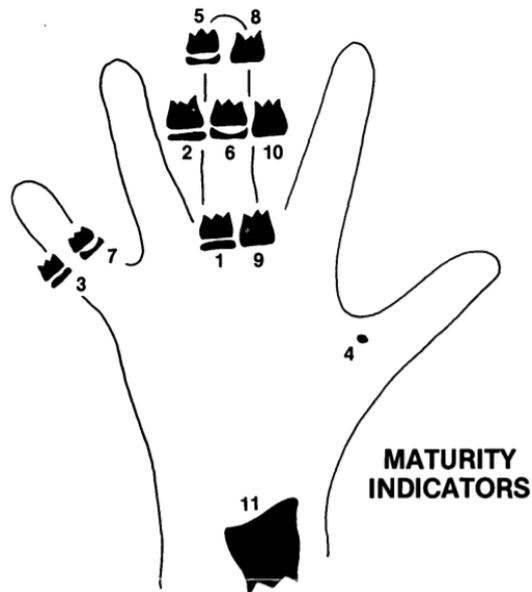


Fig. 4. Los 11 indicadores de maduración ósea (SMI). Tomada de Fishman L.¹⁹

La imagen que se observa en el estudio de Fishman se utilizó para visualizar de manera más sencilla los SMI's. En este mismo estudio, se comentó que un paso importante es determinar si el aductor sesamoideo del pulgar puede observarse o no. Si este indicador no se pudiese observar correctamente, el SMI 4 no sería útil para la estimación y se asociaría al ensanchamiento prematuro de la epífisis más que por su encapsulamiento. Por otro lado, si el sesamoideo es visible el indicador correspondiente será aplicado.

Los hallazgos mostraron que el pico de crecimiento mandibular se produce en la etapa de SMI 7, pese a que se demostró que el crecimiento en altura se produce entre el SMI 5 y

SMI 6. De igual manera, se demostró que el maxilar tiene su completa formación al final del periodo de crecimiento (SMI 4) mientras que la mandíbula es cuando ahí empieza a desarrollarse.

En el estudio de Fishman se concluyó que estos indicadores eran buenos para determinar la maduración ósea y su “pico de crecimiento”, pese a que esto sea individual de cada sujeto.

1.1.6.3 *Tanner y Whitehouse*²⁰

Tanner y Whitehouse (TW), en 1975 desarrollaron un método llamado TW2, este método no se basaba en la edad como otros sino que se basaba en la madurez de 20 regiones de interés de los huesos específicos de manos y muñecas, denominados ROI. Su función consistía en determinar los distintos niveles de la clasificación de ROI, estos distintos estadios se anotaban con letras (A, B, C....., I), se les daba un valor a cada estadio y a cada hueso individualmente. Estos resultados se sumaban y daba un resultado de maduración ósea que se relacionaba con la edad esquelética de los individuos de diferentes sexos. Al final de su trabajo, se demostró que el gran inconveniente es que esta técnica solo se aplicaba para la población donde se recogieron las muestras, aparte que se consideraba más complejo, que tomaba más tiempo y se comprobó que daba resultados muy similares al Atlas de GP.

1.1.6.4 *Gilsanz y Ratib*²¹

En el año 2005 se dio a conocer un nuevo método llamado el Atlas Digital de Gilsanz y Ratib (GR), realizado por Vicente Gilsanz y Osman Ratib. Su atlas era una versión digital de los atlas anteriores que contenía imágenes para cada edad y sexo, de manera estándar, según la maduración ósea. Este atlas analizaba el tamaño, forma, morfología y densidad ósea de los huesos de la mano. Para realizar este atlas se utilizaron niños sanos a los que consideraron que tenían las características típicas del desarrollo normal de la osificación. Estas imágenes, a diferencia de los atlas anteriores^{16,19}, son más específicas y con una mejor calidad. Las fotografías tienen una diferencia de 6 meses y dispone la información para las edades comprendidas entre 2 a 17 años. Este atlas fue utilizado por diferentes expertos, entre ellos radiólogos y endocrinos, y se llegó a la conclusión de que los resultados de este atlas eran idénticos a los del Atlas de GP, de igual manera en el atlas digital se encuentran más valores, pudiendo reemplazar el viejo atlas de GP.

Dividen la maduración ósea en 6 categorías, aunque algunas pueden sufrir algunas variaciones:

1. Infancia (se observan huesos carpales y epífisis radial): Edades comprendidas desde el nacimiento hasta los 10 meses en niñas y del nacimiento a los 14 meses en niños. (fig. 5)
2. Niños pequeños (se observa número de epífisis visibles en los huesos largos de la mano): Edades comprendidas entre 10

meses hasta 2 años en niñas y desde los 14 meses hasta los 3 años en niños. (fig. 6)

3. Prepuberal (se observan el tamaño de las epífisis de las falanges): Edades comprendidas entre los 2 años hasta los 7 años en niñas y desde los 3 años hasta los 9 años en niños. (fig. 7)
4. Pubertad temprana y media (se observan el tamaño de las epífisis de las falanges): Edades comprendidas entre los 7 años hasta los 13 años en niñas y desde los 9 años hasta los 14 años en niños. (fig. 8)
5. Pubertad tardía (se observa el grado de fusión de la epífisis): Edades comprendidas entre los 13 años hasta los 15 años en niñas y desde los 14 años hasta los 16 años en niños. (fig. 9)
6. Pospubertad (se observa el grado de fusión de la epífisis del radio y cúbito): Edades comprendidas entre los 15 años hasta los 17 años en niñas y desde los 17 años hasta los 19 años en niños. (fig. 10)



Fig. 5. Etapa de la infancia. Tomada del *"Hand Bone Age Atlas"* de Gilsanz y Ratib.²¹



Fig. 6. Etapa de niños pequeños. Tomada del *"Hand Bone Age Atlas"* de Gilsanz y Ratib.²¹



Fig. 7. Etapa prepuberal. Tomada del *"Hand Bone Age Atlas"* de Gilsanz y Ratib.²¹



Fig. 9. Pubertad temprana o media. Tomada del *"Hand Bone Age Atlas"* de Gilsanz y Ratib.²¹

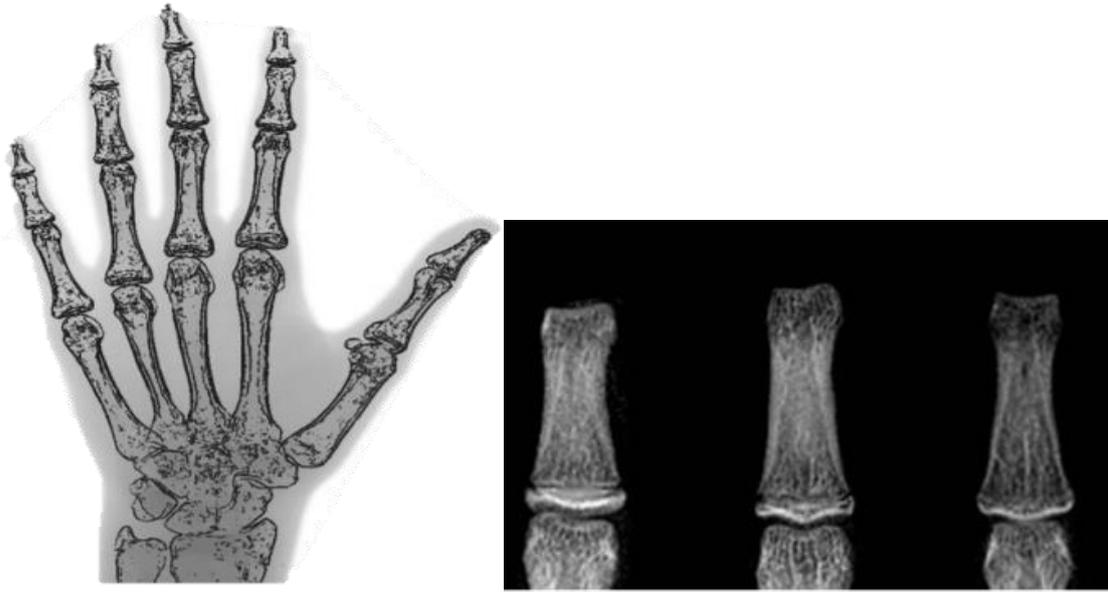


Fig. 10. Pubertad tardía. Tomada del *"Hand Bone Age Atlas"* de Gilsanz y Ratib.²¹

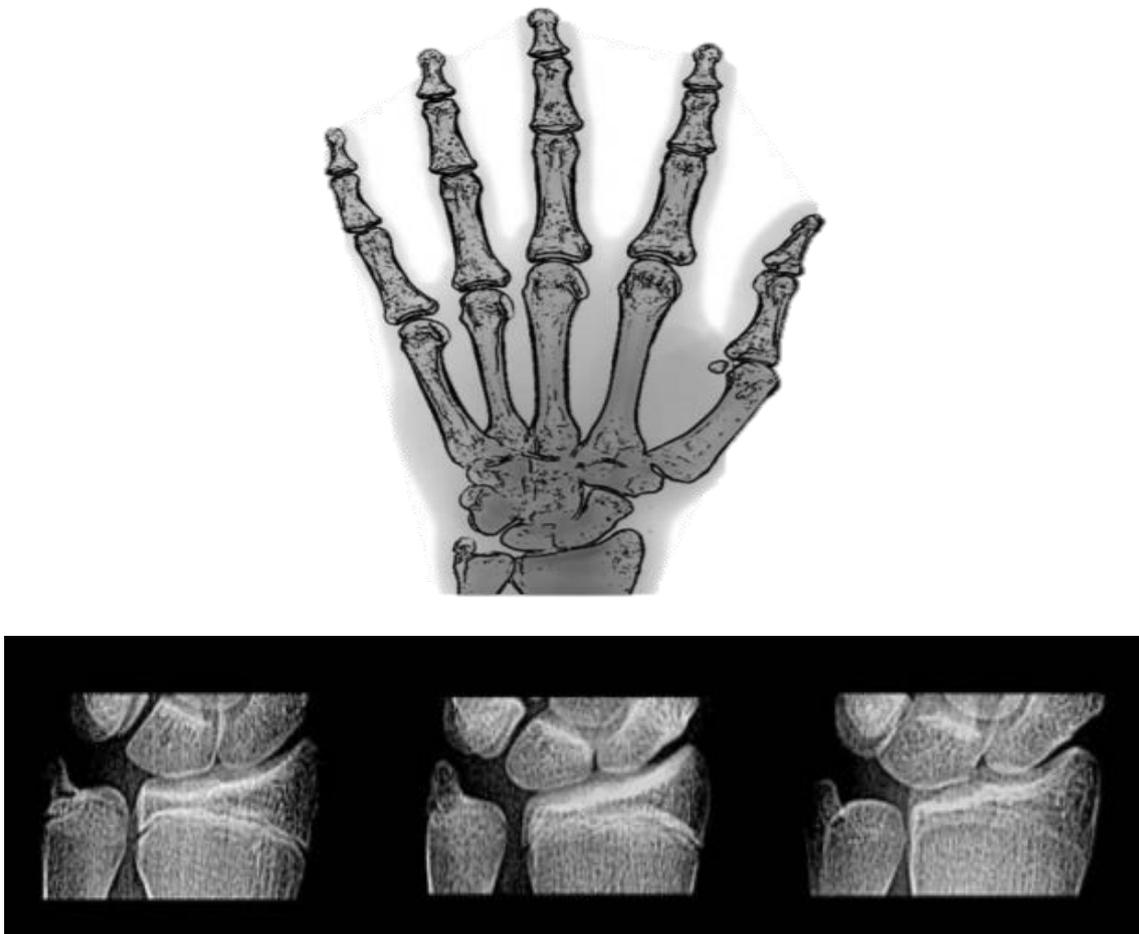


Fig. 10. Pospubertad. Tomada del *"Hand Bone Age Atlas"* de Gilsanz y Ratib.²¹

1.1.6.5 *Métodos Actuales*¹⁷

En la actualidad cabe destacar un método llamado BoneXpert, se trata de un método donde se determinan los bordes de 13 huesos, radio, cúbito y 11 huesos cortos de las falanges de forma automática. Consiste en dividir la imagen digital en 3 capas: La primera (A) observa bordes de huesos y los reconstruye. La segunda (B) determina la edad ósea de cada estructura estudiada. Finalmente la última (C) indica la edad ósea según clasificación de GP o el estadio según TW.

1.2 Radiografía Vértebras Cervicales

La RVC ha sido uno de los métodos más utilizados y aprobado dentro del área de la odontología para determinar la edad ósea. Para este método se realiza una radiografía lateral del cráneo, utilizado en ortodoncia para realizar los estudios cefalométricos, ventaja que se le atribuye ya que con una radiografía, necesaria en ortodoncia, se puede determinar la edad ósea del paciente pediátrico.⁹

1.2.1 Métodos para la Determinación de la Edad Ósea mediante Radiografía de Vértebras Cervicales

1.2.1.1 *Lamparski*²²

Uno de los métodos más conocidos es el propuesto por Lamparski en el año 1972, estudió las vértebras cervicales en su totalidad, desde su tamaño hasta su forma, para así crear diferentes etapas de maduración, las cuales comparó con los estudios de radiografía de muñeca, donde concluyó que los valores aparte de que se asemejaban estadísticamente,

clínicamente eran totalmente confiables. En este mismo estudio descubrió que el indicador de crecimiento, como cambios de forma, en los diferentes estadios no era diferente en sujetos femeninos y masculinos, pese a que las mujeres se desarrollaban antes que los hombres. Llegando a esta conclusión desarrolló lo que hoy se conoce como el MRVC. Este método consta de 6 etapas donde se pueden observar los cambios morfológicos de las vértebras cervicales. (fig. 11)

Etapa CVMI 1: Inicio

- a) Se observa que los bordes inferiores de las vértebras C2, C3 Y C4 son planos.
- b) Se observa que los bordes superiores de las vértebras se estrechan posteroanteriormente, formando una especie de “forma en cuña”.
- c) Buena capacidad de crecimiento en la adolescencia (80%-100%).

Etapa CVMI 2: Aceleración

- a) Desarrollo de concavidades en zona inferior de vértebras C2 y C3.
- b) Borde inferior de vertebra C4 se vuelve plano.
- c) Vertebra C3 y C4 adquieren una forma más rectangular.
- d) Capacidad de crecimiento en la adolescencia esperado (65%-85%).

Etapa CVMI 3: Transición

- a) Distintas concavidades en borde inferior de vértebras C2 y C3.
- b) Empieza el desarrollo de la concavidad en zona inferior de vértebra C4.
- c) Vértebras C3 y C4 son rectangulares.
- d) Capacidad de crecimiento moderado (de 25%-65%).

Etapa CVMI 4: Desaceleración

- a) Se encuentran diferentes concavidades en bordes inferiores de vértebras C2, C3 y C4.
- b) Vértebras C3 y C4 adquieren una forma más cuadrada.
- c) Poca capacidad de crecimiento en la adolescencia (10%-25%).

Etapa CVMI 5: Maduración

- a) Concavidades acentuadas en los bordes de las vértebras C2, C3 y C4.
- b) Vértebras C3 y C4 son cuadradas.
- c) Capacidad de crecimiento casi nula (5%-10%).

Etapa CVMI 6: Completación

- a) Las concavidades se ven profundas en los cuerpos vertebrales de C2, C3 y C4.
- b) C3 y C4 son más altos que anchos.
- c) Completación del crecimiento puberal (nulo o poco crecimiento).

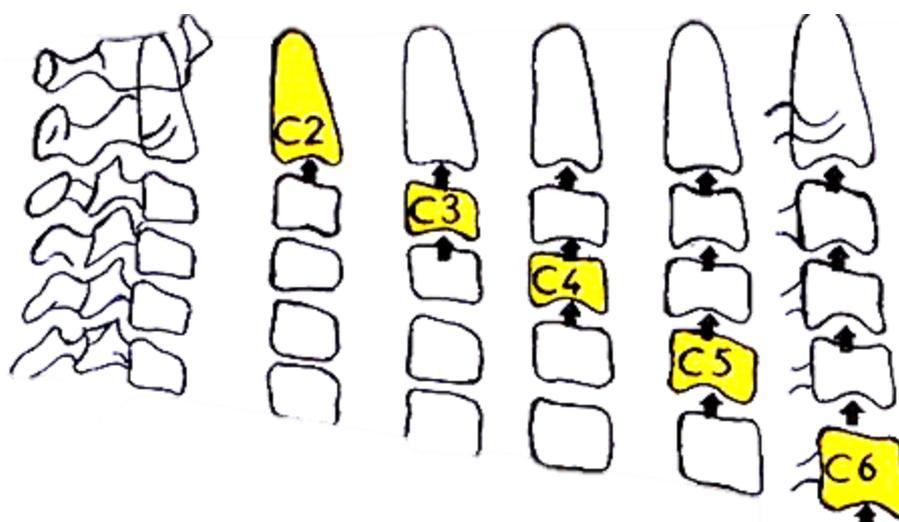


Fig. 11. Etapas de la maduración ósea de vértebras cervicales del Método Lamparski. Tomada de Ortiz M y cols.²³

1.2.1.2 Hassel y Farman²⁴

Años más tarde, en 1995, Hassel y Farman (HF) confirman y corroboran esta efectividad con el indicador de maduración de vértebras cervicales. Realizaron la comparación entre los indicadores de maduración ósea y edad cronológica en la radiografía de muñeca realizada por Fishman¹⁹ y los indicadores de radiografía de vértebras cervical realizados por Lamparski²².

Confirmaron que las etapas de SMI y de CVM concuerdan con los estudios ya realizados. (fig. 12)

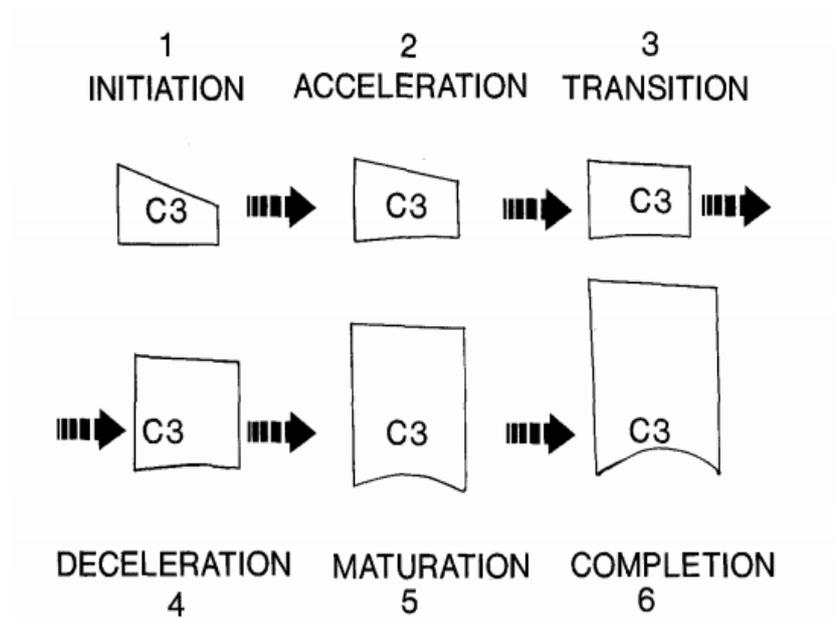


Fig. 12. Indicadores de las vértebras cervicales utilizando la C3 como guía. Tomada de Hassel y Farman.²⁴

1.2.1.3 Baccetti y cols.^{25,26}

Baccetti y cols. en el 2005 propuso una modificación actualizada del método para estudiar la maduración de vértebras cervicales, mientras se utilizaba un collar de protección de plomo. Se observó si existe ausencia o no de la concavidad del borde inferior en las vértebras C2, C3 y C4, así como la forma estructural del cuerpo del C3 y C4, pudiendo ser rectangulares, rectangulares pero horizontalmente, trapezoidales, cuadradas o bien rectangulares verticales. (fig. 13)

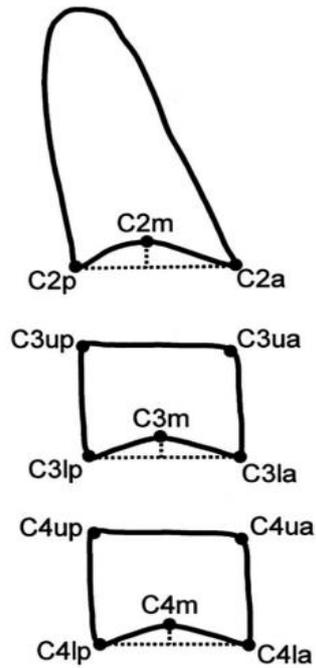


Figure 1 Cephalometric landmarks for the quantitative analysis of the morphologic characteristics of the vertebral bodies of C2, C3, and C4.

Fig. 6. Trazos del análisis cuantitativo de las características morfológicas de las vértebras cervicales C2, C3 y C4. Tomada de Baccetti y cols.²⁵

Análisis Visual

Se observa la morfología de las vértebras cervicales C2, C3 y C4 en 6 cefalometrías consecutivas (T1 a la T6). En estas se analizan 2 variables: (1) presencia de concavidad en la parte inferior del cuerpo de las vértebras C2, C3 y C4 y (2) la forma del cuerpo de C3 y C4:

- a) Trapezoidal: Borde superior cónico de zona posterior a anteriores.
- b) Rectangular Horizontal: La altura posterior y anterior con iguales; los bordes superiores e inferiores son más largos que los anteriores y posteriores.
- c) Cuadrado: Las 4 partes de la vértebra son iguales.

- d) Rectangular Vertical: Bordes anterior y posteriores son más largos que los superiores e inferiores.

Etapas de la Maduración de Vértebras Cervicales

- a) Etapa Cervical 1 (CS1): La parte inferior de las 3 vértebras (C2-C4) son planas. El cuerpo de la C3 y C4 son de forma trapezoidal (de posterior a anterior). El pico de crecimiento mandibular podría ocurrir años después de esta etapa. (fig. 14)



Fig. 14. Estado Cervical 1 (CS1), 2 ejemplos clínicos. Tomada de Baccetti y cols.²⁵

- b) Etapa Cervical 2 (CS2): La concavidad está presente en el borde inferior del C2 (en algunos casos algunos individuos puede seguir en la etapa 1 de la C2). Los cuerpos de C3 y C4 siguen siendo trapezoidales. El pico de crecimiento mandibular podría ocurrir 1 año después de esta etapa. (fig. 15)



Fig. 15. Estado Cervical 2 (CS2), 2 ejemplos clínicos. Tomada de Baccetti y cols.²⁵

- c) Etapa Cervical 3 (CS3): Se aprecia concavidades en borde inferior de C2 y C3. La forma del cuerpo de C3 y C4 puede mantenerse trapezoidales o bien pueden cambiar a una forma rectangular horizontal. El pico de crecimiento mandibular aparece durante el tiempo de esta etapa. (fig. 16)



Fig. 16. Estado Cervical 3 (CS3), 2 ejemplos clínicos. Tomada de Baccetti y cols.²⁵

d) Etapa Cervical 4 (CS4): Concavidades en C2 y C3 se mantienen y aparece concavidad en borde inferior del C4. La forma de C3 y C4 ahora es rectangulares horizontales. El pico de crecimiento mandibular ocurrió 1 o 2 años antes de esta etapa. (fig. 17)



Fig. 17. Estado Cervical 4 (CS4), 2 ejemplos clínicos. Tomada de Baccetti y cols.²⁵

d) Etapa Cervical 5 (CS5): La concavidades en el borde inferior de las vértebras antes mencionadas siguen presentes. Alguna de las vértebras (C3 o C4) es de forma cuadrada, si no lo es, el cuerpo de la otra sería un rectángulo horizontal. El pico de crecimiento mandibular habrá terminado por lo menos 1 año antes de que aparezca esta etapa. (fig. 18)



Fig. 18. Estado Cervical 5 (CS5), 2 ejemplos clínicos. Tomada de Baccetti y cols.²⁵

- e) Etapa Cervical 6 (CS6): Las concavidades siguen siendo evidentes en C2-C4. Por lo menos una de las vértebras (C3 o C4) tiene forma de rectángulo horizontal, si no, una de ellas tendrá forma cuadrada. El pico de crecimiento mandibular habrá terminado por lo menos 2 años antes de que aparezca esta etapa. (fig. 19)



Fig. 19. Estado Cervical 6 (CS6), 2 ejemplos clínicos. Tomada de Baccetti y cols.²⁵

1.2.1.4 Chen y cols.²⁷

En el 2008, Chen y cols. actualizaron el método MRVC y demostraron un sistema de maduración cervical cuantitativa mediante un software, el cual de manera automática realiza las medidas y determina la edad ósea, basada en los resultados de los estudios anteriores de vértebras cervicales y comparadas con las radiografía de muñeca de Fishman¹⁹. Se conoce como *Quantitative Cervical Vertebral Maturation* (QCVM) y la cual dividieron en 4 etapas que compararon con los indicadores de Fishman¹⁹: Periodo de aceleración (QCVM I; concuerda con SMI 1-3), periodo de alta velocidad (QCVM II; concuerda con 4-7), periodo de desaceleración (QCVM III; concuerda con SMI 8 y 9) y el periodo de culminación (QCVM IV; concuerda con SMI 10 y 11). (fig. 20)



Fig. 20. Radiografía lateral de cráneo y radiografía de mano-muñeca del mismo sujeto. CVM indica que está en la etapa 4. QCVM indica que está en la etapa 4, mientras que la mano-muñeca indica que está en la etapa 11 o en la etapa de crecimiento completo.

Tomada de Chen y cols.²⁷

El método de radiografía de vértebras cervicales tiene una fiabilidad compatible con las radiografía de muñeca (*Pichai y cols. 2014 y Flores y cols. 2006*).

1.3 Radiografía Falange Media del Tercer Dedo

1.3.1 Métodos para la Determinación de la Edad ósea mediante Radiografía de la Falange Media del Tercer Dedo

1.3.1.1 *Hägg y Taranger*²⁸

Hägg y Taranger (HT), en 1982, mediante un estudio longitudinal prospectivo del crecimiento y desarrollo, propusieron el método de osificación de la tercera falange, observando qué tipo de cambios hay en la región epifisiaria, la cual clasificarían dependiendo de la región en MP3F, MP3FG, MP3G, MP3H y MP3I. Este método tuvo aceptación positiva a comparación al método de Fishman¹⁹, ya que se utilizaban unos niveles de radiación inferiores, alta relación de las etapas de crecimiento de las falanges y las vértebras cervicales, no hay variaciones de postura y no se necesita un equipo especial para realizar esta radiografía. Encontraron que el sesamoideo estaba osificado al 40% de las mujeres y 25% del hombre durante su etapa de brote puberal.

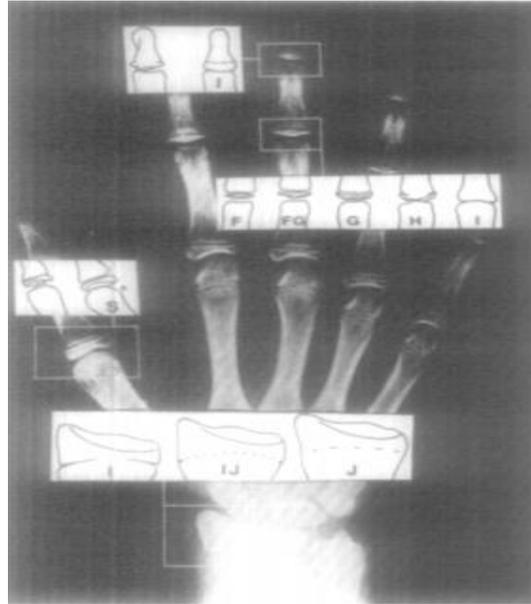


Fig. 21. Imagen de las diferentes etapas de clasificación de la osificación de la tercera falange (MP3F, MP3FG, MP3G, MP3H y MP3I). Tomada de Hägg y Taranger.²⁸

Clasificación de las Etapas

a) Etapa MP3-F: Empieza el crecimiento. La característica que observaron HT fue: Epífisis ancha como metáfisis.¹⁸

b) Etapa MP3-FG: Aceleración del crecimiento. Las características que observaron HT fueron:

b.1 Epífisis ancha como metáfisis.

b.2 Borde interno o lateral de metáfisis forma una línea de demarcación en forma de ángulo recto por el borde distal.

c) Etapa MP3-G: Máximo pico de crecimiento. La característica que observaron HT fue: Engrosamiento de bordes de la epífisis que pueden cubrir metáfisis, formando borde agudo en uno o en 2 lados.

d) Etapa MP3-H: Desaceleración del crecimiento. La característica que observaron HT fue: Fusión entre epífisis y metáfisis.

e) Etapa MP3-HI: Maduración del crecimiento.¹⁸

f) Etapa MP3-I: Fin del crecimiento. La característica que observaron HT fue: Fusión entre epífisis y metáfisis finalizada. (fig. 21)

1.3.1.2 *Rajagopal y Kansal*^{9,29}

En el 2002, Rajagopal y Kansal (RK) añadieron a la clasificación de HT, una etapa adicional, MP3-HI, una etapa intermedia entre MP3H y MP3I, que refleja cambios en la región epifisiaria del tercer dedo. Consideran que esta etapa que agregaron era el inicio del crecimiento puberal, que no estaba clasificada pero HT describen en sus estudios.

Características Añadidas al Trabajo de Hägg y Taranger

a) Etapa MP3-F: RK añadieron las siguientes características:

a.1 Extremos de epífisis se redondean y estrechan.

a.2 No hay ondulación de la metáfisis.

a.3 Línea radiotransparente ancha, que representa la placa cartilaginosa del crecimiento epifisiario, entre la epífisis y metáfisis.

b) Etapa MP3-FG: RK añadieron las siguientes características:

b.1 Metáfisis muestra ligera ondulación.

b.2 Línea radiotransparente ancha entre metáfisis y epífisis.

c) Etapa MP3-G: RK añadieron las siguientes características:

c.1 Ondulaciones marcadas en metáfisis, apariencia de “arco de cupido”.

c.2 Línea radiotransparente moderada entre metáfisis y epífisis.

d) Etapa MP3-H: RK añadieron las siguientes características:

d.1 Por lo menos un lado de la epífisis es un ángulo obtuso al borde distal.

d.2 Empieza a estrecharse la epífisis.

d.3 Pequeña zona convexa debajo de la zona central de la metáfisis.

d.4 “Arco de cupido” en metáfisis ausente, pero presenta leve ondulación.

d.5 Línea radiotransparente delgada entre epífisis y metáfisis.

e) Etapa MP3-HI: RK añadieron las siguientes características:

e.1 Superficie superior de epífisis lisa y cóncava.

e.2 Superficie de metáfisis lisa y convexa, pudiendo encajar con concavidad de epífisis.

e.3 Metáfisis sin ondulación.

e.4 Espacio radiotransparente entre metáfisis y epífisis casi nulo.

f) Etapa MP3-I: RK añadieron las siguientes características:

f.1 No existe espacio entre metáfisis y epífisis.

f.2 Línea epifisiaria radiopaca densa que forma parte de la zona proximal de la falange media.

1.4 Otros Zonas Diagnósticas

1.4.1 Radiografía de Rodilla^{30,31}

En el año 1988, Roche y cols.^{30,31} realizaron un apartado en un libro donde comentaron un nuevo método utilizando la rodilla como un indicador biológico del desarrollo óseo, visualizando la parte frontal de la misma (Método RTW). Comentaban en este apartado las ventajas que tiene la radiografía de rodilla para determinar la maduración ósea, pero que este método estaba más relacionado a la predicción del crecimiento en altura que lo que podía estar relacionada la radiografía de muñeca. Se resalta también que las lesiones en las rodillas tardan más en generarse, son más leves y menos constantes que en las manos y las muñecas; también consideran que hay cambios radiográficos más visibles que las que aparecen en las radiografía de muñeca, principalmente en las que se realizan en jóvenes varones de 11-15 años y mujeres de 9-13.5 años.

En el método RTW se utilizaban 34 indicadores: 12 femorales, 16 tibiales y 6 peroneos, aunque no todos se utilizaban en las mismas edades. La mayoría de estos indicadores se definen en base a la forma

del hueso y algunos según las medidas de la metáfisis del femoral hasta su epífisis. Para utilizar este método era necesario ver una radiografía de rodilla y colocar la información en un programa digital que determinaría la edad de maduración, así como el posible margen de error que pudiese haber.

Roche y cols.^{30,31} crearon diferentes grados que se podían observar en la rodilla:

- a. Grado 0: Área intracondilar proximal a la tibia es plana o solo hay una tuberosidad presente (en desarrollo).
- b. Grado 1: Proyección proximal ausente en la esquina lateral de la epífisis.
- c. Grado 2: Proyección presente en la esquina lateral de la epífisis.
- d. Grado 3: Epífisis fusionada lateralmente con la diáfisis.

Las desventajas del método RTW era que necesitaban artefactos muy específicos así como el tiempo de duración del método, aparte de necesitar 2 ordenadores cada uno con una memoria de al menos 40KB, tener el programa especial que ejecuta el análisis y finalmente y la más importante de todas, que el programa tenía que ser leído por un físico especializado que tuviera interés de ayudar o saber acerca de la maduración ósea.

El método más reciente para estudiar las radiografías de rodilla fue el realizado por O'Connor y cols.³² (2008) los cuales crearon una estadística para analizar y comprender el crecimiento óseo mediante observación de la unión de la epífisis de la rodilla en la radiografía.

O'Connor y cols.³² utilizaron como base para sus indicadores sus propios resultados obtenidos y los compararon con los de Roche y cols.^{30,31}, creando así los 7 indicadores de su estadística, que va de la A-G: (fig. 22-25)

- A. Proyección proximal de la esquina lateral de la epífisis distal del fémur.
- B. Encapsulamiento lateral de la metáfisis en la zona distal de la epífisis del fémur.
- C. Tubérculos intracondilares de la tibia.
- D. Proyección distal de la esquina lateral de la epífisis proximal de la tibia.
- E. Proyección distal de la esquina medial de la epífisis proximal de la tibia.
- F. Desarrollo de la tuberosidad tibial.
- G. Desarrollo de la apófisis estiloides del peroné.



Fig. 22. Radiografía anteroposterior de la rodilla. Las flechas blancas indican el lugar de los indicadores A-E y G y el grado en el que se encuentran, en este caso grado 0.

Tomada de O'Connor y cols.³²



Fig. 23. Radiografía anteroposterior de la rodilla. Se muestra el indicadores A-E y G en grado 1. Tomada de O'Connor y cols.³²



Fig. 24. Radiografía anteroposterior de la rodilla. Se muestra el indicador B grado 2. La flecha blanca que indica el asterisco señala una línea radiodensa horizontal que cruza la epífisis del peroné, que marca la línea articular. Tomada de O'Connor y cols.³²



Fig. 25. Radiografía anteroposterior de la rodilla. Se muestra el indicador A, D, E y G en grado 2. Indicador B en grado 3. Tomada de O'Connor y cols.³²

1.4.2 Radiografía de Clavícula¹⁸

La clavícula es uno de los huesos largos que primero empieza el proceso de osificación. La osificación de los extremos se hace a través de la osificación endocondrial mientras que el crecimiento de su eje lo realiza a través de la osificación membranosa. Durante el crecimiento la osificación aparece en la zona del extremo medio de la clavícula hasta su completa osificación que ocurre aproximadamente hasta los 22 años de edad. A los 18 años de edad el desarrollo óseo de la mano, la mineralización del tercer molar y la maduración sexual están completadas así que, en este caso, las radiografías tanto dentales como óseas carecen de importancia.

La radiografía de la clavícula se ve afectada por sombras que se superponen a su correcta visualización, entre ellas las de las vértebras

cervicales y las costillas; es por eso que una radiografía convencional se vería afectada para intentar determinar la maduración ósea a través de la clavícula. Se han utilizado otros métodos como TAC Multidireccional, pero no ha dado los resultados deseados. La opción que da un mejor resultado al momento de ver las estructuras de la clavícula es TAC Espiral, esta tiene varias ventajas como que hay menor tiempo de espera y de cantidad de artefactos, dándole más tranquilidad al paciente, pero por otro lado emite mayor cantidad de radiación a comparación al TAC convencional.¹¹

Otra opción para estudiar la relación entre la osificación de la clavícula y la edad ósea fue a través de la RM. Esta es una buena opción para eliminar el contacto con radiación que se produce en el TAC Espiral. La desventaja de este método es el protocolo que se necesita y que no hay muchos estudios que lo comprueben.

1.4.3 *Radiografía de la Cresta Ilíaca*¹⁸

Profesionales en el área de la odontología han querido investigar la evolución de la osificación de los huesos ilíacos para determinar la maduración ósea. Este método se conoce como el Signo de Risser, que se basa en observar la maduración de la cresta ilíaca. Los estudios sugieren que el problema de esta valoración es que la osificación de la cresta ilíaca carece de uniformidad y puede causar discrepancias al momento de querer determinar la edad ósea.

1.4.5 Radiografía de la Cabeza del Fémur¹⁸

Una de las alternativas más modernas es el estudio del cartílago de la cabeza del fémur que constantemente está osificándose, a diferencia de la parte final del fémur. Cuando todo el cartílago se ha terminado de desarrollar este se reemplaza por hueso y lo que queda se conoce como cartílago hialino.

En cuanto a este procedimiento solo existe un estudio, este mide el grosor de la cara anterior del fémur, en una población pequeña de una sola raza. Estas limitaciones causan que sea un método específico para un tipo de población.

1.5 Otros Métodos Diagnósticos

1.5.1 Tomografía Computarizada Cone Beam (CBCT)^{33,34}

Debido a la constante necesidad de reducir la exposición del paciente a los rayos X, se empezó a emplear la CBCT, un método de diagnóstico moderno. El CBCT es un método que se ha hecho muy popular en los últimos tiempos, ya que se pueden ver estructuras como la cabeza y el cuello en 3 planos distintos, entre ellas las vértebras cervicales y haciendo que los profesionales encontraran ligeras limitaciones en las radiografías convencionales.

Los estudios realizados por Chen y cols.²⁷ buscaban resolver las limitaciones de la radiografía lateral de cráneo, por ende crearon un método analítico para ver el crecimiento a través de las vértebras cervicales en una vista más sagital. Utilizar CBCT como método para

diagnosticar la maduración ósea en vértebras cervicales permite una visión global, lo cual aumenta la visión de los planos como en el plano coronal y plano transversal con una vista en 3D, no limitándose solamente al plano sagital a través de la imagen en 2D de las radiografías laterales de cráneo. Otra de las ventajas es que este método podría usarse no solamente para ver la maduración esquelética sino también podría ayudar a futuras operaciones ortognáticas, para cirugías de dientes retenidos, evitando así la exposición extra a las radiaciones.

1.5.2 *Resonancia Magnética (RM)* ^{17,34}

Los diagnósticos tradicionales utilizaban métodos como el de Greulich y Pyle¹⁶ o el de Tanner y Whitehouse²⁰ para diagnosticar el crecimiento óseo a través de una radiografía de muñeca en pacientes jóvenes, haciéndoles tener contacto con radiaciones ionizantes constantes que pueden, a largo plazo y con varias dosis, ser perjudiciales para ellos.

Se pensó en la posibilidad de suplantar las radiografías y utilizar la RM, ya que es libre de radiaciones y puede mostrar excelentes imágenes diagnósticas. Aparte proporciona información adicional como densidad ósea, peso y altura; datos que no pueden ser calculados con una radiografía convencional.

En el estudio de Tang y cols.³⁴ se realizaron resonancias magnéticas de mano-muñeca en jóvenes desde los 12 a los 17 años de edad (fig.26) y compararon estas imágenes con los valores indicados en

el método de TW. Cada RM mostraba las mismas estructuras anatómicas evaluadas en los estudios de TW.

La siguiente imagen muestra 2 RM realizadas al mismo individuo en diferentes etapas que concuerda con la etapa H y HI de TW:

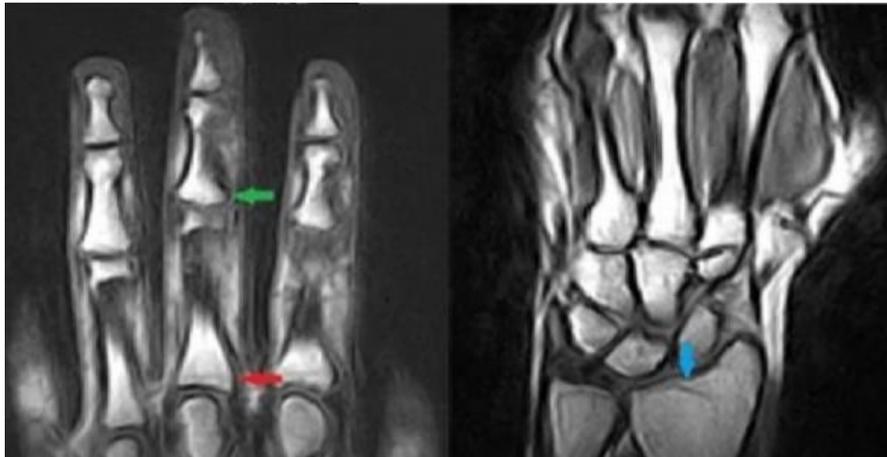


Fig. 26. Resonancia magnética del mismo sujeto en diferentes etapas H e I. La flecha roja indica falange proximal, con una línea hipodensa visible. La flecha verde indica la falange media, con ausencia de línea hipodensa visible. La flecha azul muestra la cara distal del radio con presencia de línea hipodensa. Tomada de Tang y cols.³⁴

El estudio de Tang y cols.³⁴ se aproxima a los resultados obtenidos con radiografías convencionales. Se pudo observar también que el crecimiento puede tener un rango de edad más amplio, haciendo que sea subjetivo y pueda causar discrepancias. Las imágenes radiográficas tenían algunos problemas de visualización como líneas borrosas en la zona de la muñeca, creando un falso diagnóstico por una posible fusión ósea que con RM no ocurre, ya que se puede ver de manera más clara las imágenes haciendo que se pueda dar un diagnóstico más preciso.

2. Objetivos

- 1) Comparar la eficacia entre los métodos de análisis de la maduración ósea mediante el estudio de vértebras cervicales y la radiografía de mano-muñeca.
- 2) Analizar otros métodos radiográficos y zonas anatómicas para la evaluación de la maduración ósea en pacientes en crecimiento.
- 3) Comparar qué método de análisis de radiografía de vértebras cervicales es el más fiable para determinar la maduración ósea en pacientes en crecimiento.

3. Metodología

Análisis de búsqueda de estudios

Estrategia de búsqueda

Se realizó una búsqueda bibliográfica en diferentes bases de datos como Pubmed y Medline para conseguir artículos científicos, casos clínicos y estudios observacionales que hubiesen sido publicados en los últimos 5 años.

Palabras claves

Las palabras claves empleadas fueron: *“Crecimiento óseo”, “maduración esquelética”, “métodos diagnósticos”, “relaciones óseas”, “maduración ósea”, “skeletal maturation”, “cervical vertebral maturation”, “hand-wrist method”, “maturity indicators”*.

Criterios de Inclusión

- Artículos publicados entre 2015 y 2020.
- Estudios realizados en pacientes pediátricos sin patologías que estuvieran en edades comprendidas desde los 6 años hasta los 18 años.

Criterios de Exclusión

- Revistas de bajo impacto científico.
- Artículos cuyos trabajos incluyeran pacientes con patologías sistémicas que afectarían a la maduración ósea.
- Trabajos que incluyeran adultos.

4. Discusión

A. Eficacia de los métodos de análisis de radiografía de vértebras cervicales frente a radiografía de muñeca

La edad cronológica y biológica son consideradas de importancia para estudiar el desarrollo de un paciente, pero la maduración ósea puede darnos información que la edad cronológica no puede, como para poder analizar el crecimiento. El correcto diagnóstico es un paso importante para el éxito de cualquier tratamiento, especialmente en el caso de los niños que están en constante cambio, principalmente en la edad puberal, y esta evolución se puede observar mediante el estudio del desarrollo óseo. En el área de la odontología, principalmente en la ortodoncia y la odontopediatría, se utilizan métodos radiográficos para saber en la etapa del desarrollo óseo que se encuentra el paciente y saber así el momento idóneo para realizar ciertos tipos de tratamientos. Existen diferentes métodos, pero los más conocidos son: Los métodos que emplean las radiografías de muñeca y otros métodos que lo hacen a través de la radiografía lateral de cráneo, analizando las vértebras cervicales. Se utilizan estas 2 estructuras ya que son las que han demostrado un cambio más notorio en sus formas óseas y han tenido valores similares en cuanto a la información del tiempo del pico de crecimiento.^{9,11}

El primer estudio que se realizó, fue a través de una serie de radiografías de la muñeca, que luego se analizaron, observando los cambios que realizaban a diferentes edades cronológicas, considerando también el sexo del paciente. En base a la radiografía de muñeca, autores como Greulich y Pyle¹⁶, Fishman¹⁹ y Tanner y Whitehouse²⁰ crearon diferentes métodos con los cuales los

profesionales del área de la odontología podrían utilizar como guía a la hora de determinar la maduración ósea en pacientes pediátricos.^{16,19,20}

Posteriormente, se pensó si existirían otras estructuras que pudiesen dar la misma información que se obtenían a través de la radiografía de muñeca. Las estructuras que más se estudiaron fueron las vértebras cervicales, las cuales se podían observar a través de una radiografía lateral de cráneo. Diferentes autores decidieron radiografiar las vértebras cervicales, pero fueron autores como Lamparski²², Hassel y Farman²⁴ y Baccetti y cols.²⁵ que decidieron estudiarlas más al detalle, creando diferentes métodos para determinar la maduración ósea. Los estudios de los autores anteriormente mencionados fueron comparados con los resultados dados por las radiografías de muñeca y sus métodos correspondientes, donde se concluyó que efectivamente las estructuras óseas de las vértebras cervicales podían dar la misma información que los huesos de la mano y la muñeca.^{22,24,25}

Autores como Babu y cols.³⁵, Hoseini y cols.³⁶, Kumar y cols.³⁷, Cunha y cols.³⁸ y Patil y cols.³⁹, concluyeron que la mejor manera de determinar la edad ósea de los pacientes pediátricos era a través de método de radiografía de vértebras cervicales, ya que es el método que más alta correlación y reproductibilidad tiene en relación a la maduración ósea. Además, este método ayuda a evitar la sobreexposición a la radiación, ya que únicamente se hace una sola radiografía lateral de cráneo y las vértebras cervicales tienen un tamaño adecuado para que los cambios que estas realizan durante el desarrollo óseo sean más notorio.

En el estudio de Babu y cols.³⁵ analizaron una muestra de 500 pacientes (250 niños y 250 niñas) con edades comprendidas entre los 9-16 años, rango de edad similar al resto de los estudios³⁶⁻⁴². El método más empleado para analizar la maduración ósea en las vértebra cervicales en las investigaciones^{38,39,42} que hemos incluido en nuestra revisión fue el propuesto por Baccetti y cols.²⁵. En cambio, para evaluar la radiografía de muñeca, observamos gran variabilidad en los métodos empleados, a pesar de esto, el método que más utilizado frecuentemente fue el de Fishman¹⁹.

Hoseini y cols.³⁶ agregaron que el método de radiografía de vértebras cervicales, además de tener una buena relación con la determinación de la maduración ósea, puede ser de gran ayuda para determinar el crecimiento mandibular.

Algunos autores^{35,36} concluyeron que los métodos que se emplean en la radiografía lateral de cráneo podrían suplantar a los que emplean la radiografía de muñeca ya que, además de dar la misma información que los segundos, minimizaban la radiación recibida por el paciente. Esta conclusión es cuestionada por autores como Szemraj y cols.⁴⁰ y Ye-Seul y cols.⁴¹, ya que en sus estudios se comenta que el método de radiografía de vértebras cervicales no tenía una correlación tan alta para determinar la maduración ósea por sí sólo, por lo que consideraban que la radiografía de muñeca era necesaria para confirmar la información dada por el MRVC. Patil y cols.⁴² agregan que de igual manera, ninguno de estos 2 métodos es fiable para determinar la edad cronológica, idea con la cual concuerdan Hoseini y cols.³⁶, ya que comentan que ambos métodos podrían variar por factores como el medioambiente, la etnia y el sexo.

B. Análisis de métodos diagnósticos y zonas anatómicas para evaluar la maduración ósea

Años más tarde, luego de observarse que las vértebras cervicales daban una información del desarrollo óseo muy parecido al de las estructuras de mano-muñeca, algunos investigadores decidieron buscar esta misma información en otras zonas ósea como lo son rodillas, clavículas y cabeza del fémur.

El estudio más reciente del método RTW fue en el 2018, realizado por Tang y cols.⁴³, quienes estudiaron una muestra de 279 niños y 224 niñas de edades comprendidas entre 6-16 años, a esta población se le realizó una radiografía de su mano-muñeca no dominante y una radiografía de cada una de las rodillas, utilizando los grados descritos por Roche y cols.^{30,31} junto con el método de O'Connor y cols.³² utilizada en la radiografía de rodilla. Concluyeron que el método de rodilla de O'Connor y cols.³² se encontraba más adelantado que los resultados dados por método de radiografía de muñeca en cuanto a la edad cronológica y edad ósea.

Por otro lado, de Tobel y cols.⁴⁴ estudiaron otro de los métodos más recientes, el cual se basa en estudiar la clavícula para determinar la maduración a través de la resonancia magnética de los 4 terceros molares, de la muñeca izquierda y de ambas clavículas. Utilizaron una población de ambos sexos, de niños y niñas y tomaron en consideración su edad de maduración sexual. Se concluyó que la combinación de las zonas anatómicas de terceros molares, muñeca y clavículas causaba una disminución en el error de los resultados dados, a diferencia de cuando se estudia cada zona anatómica individualmente. No hubo diferencias en los resultados al añadir la información de maduración

sexual. Se concluye que la estimación multifactorial de 2 o más estructuras anatómicas mejoran cuando los datos de resonancia magnética multifactorial se incorporan.⁴⁴ No se encontraron más estudios de alto impacto sobre esta zona anatómica para que sea nombrada.

La cresta ilíaca y la cabeza del fémur son estructuras recientemente estudiadas y por ende no se encontraron estudios de comprobación ni comparación para que sean nombrados en este trabajo.

Las radiografías de estructuras como rodillas y clavículas, no son consideradas como una alternativa que pudiera suplantar la radiografía de muñeca, pese a que han seguido los estudios para comprobar si usando programas digitales se podría mejorar la exactitud de este método¹⁷. Los estudios realizados en la cresta ilíaca y cabeza del fémur no tuvieron resultados concluyentes. Las investigaciones más actuales están orientadas a conocer si se puede utilizar con exactitud la evolución de la parte cartilaginosa de la cresta ilíaca, la apófisis ilíaca, dando buenos y prometedores resultados, aunque aún quede por investigar acerca del tema. De igual manera, los estudios realizados en otras zonas anatómicas tienen que seguir siendo estudiados, desarrollados y comparados para poder obtener más información.^{9,11}

Aparte de las radiografías se ha intentado visualizar las diferentes estructuras anatómicas a través de métodos más innovadores como la tomografía computarizada y la resonancia magnética. En el estudio de Bo-Ram y cols.⁴⁵ se realizó una comparación para saber la estimación de la maduración ósea mediante CBCT, resonancia magnética y radiografía de vértebras cervicales. En este estudio utilizaron a 47 niños y 57 niñas en edades

comprendidas entre 5 a 18 años que no tuvieran ninguna patología; basaron sus investigaciones principalmente en el método radiográfico de vértebras cervicales de Baccetti y cols.²⁵, aunque utilizaron el método de Fishman¹⁹ para la radiografía de muñeca y realizar la comparación de igual manera, y agregaron el método QCVM de Chen y cols.²⁷. El estudio de Bo-Ram y cols.⁴⁵ concluyó que el uso del CBCT era un método útil para poder observar con mayor claridad y detalle las estructuras óseas, como las vértebras cervicales y que el QCVM era un método que tenía una alta relación al compararlo con el método de radiografía de vértebras cervicales, principalmente en la segunda vértebra. Un estudio similar fue realizado en el 2020, por Tekin y cols.⁴⁶, quienes estudiaron la comparación para determinar la maduración ósea a través de radiografía de muñeca y de vértebras cervicales y CBCT de vértebras cervicales. En el estudio de Tekin y cols.⁴⁶ se utilizó una muestra de 105 pacientes de ambos sexos. Los métodos estudiados para la muñeca fue el de Greulich y Pyle¹⁶ y para las vértebras cervicales el de Hassel y Farman²⁴. En este estudio se concluye que los estadios de vértebras cervicales concuerdan en un porcentaje alto, menos el CVM 3 y CVM 4 que se encuentran por debajo del 45% de similitud, mientras que el CVM 1 tiene 100% de similitud con el método de la radiografía de muñeca y el CBCT de vértebras cervicales. Consideran que los métodos utilizados para evaluar las vértebras cervicales y las muñecas fueron adecuados y tenían gran similitud entre ellas, agregan que no se confirma que pueda dar los mismos resultados con métodos de otros autores para determinar maduración ósea.

C. Fiabilidad de los diferentes métodos de análisis de la maduración ósea mediante la observación de las vértebras cervicales

Varios autores como Lamparski²², Hassel y Farman²⁴, Baccetti y cols.²⁵ y Chen y cols.²⁷, realizaron diferentes estudios para analizar la asociación de vértebras cervicales con la maduración ósea en pacientes pediátricos, cada uno de acuerdo a su método. En el estudio realizado por Camacho-Basallo y cols.⁴⁷, en el 2016, compara 2 métodos distintos de radiografía de vértebras cervicales, el método de Hassel y Farman²⁴ y el método de Baccetti y cols.²⁵, inclinándose más a utilizar el método de Baccetti y cols.²⁵, el cual finalmente seleccionaron para su estudio, ya que comentan que, pese a que el método de Hassel y Farman²⁴ está perfectamente planteado, Baccetti y cols.²⁵ fusionan 2 de las etapas descritas por Hassel y Farman²⁴ transformándola en una sola etapa, haciendo que sean menos radiografías y etapas las cuales hay que observar. Por otro lado, Alvarado-Torres y cols.⁴⁸, quienes realizaron en el 2016 una comparación entre el método de Lamparski²² y Baccetti y cols.²⁵, utilizaron una muestra de 298 pacientes sanos de ambos sexos de 8 a 15 años, de los cuales ordenaron por edad y género, resultando grupos de 20 personas de cada género entre las edades de 10-15 años. El objetivo era saber qué método era el más fácil y fiable de utilizar para la determinación de maduración ósea mediante vértebras cervicales. Las radiografías de vértebras cervicales fueron utilizadas para ambos métodos^{22,25}. Para esta investigación el método de Lamparski²² es el método más fiable comparado al método de Baccetti y cols.²⁵

Los trabajos realizados por Vaida y cols.⁴⁹ y Constela⁵⁰ pese a que no realizaron una comparación exacta entre 2 métodos de vértebras cervicales sino con radiografía de muñeca o con la radiografía de la falange del tercer dedo,

describen que optaron por realizar la comparación de sus estudios con el método de Baccetti y cols.²⁵, ya que consideran que tiene una mayor comprobación de validez que otros MRVC. Así también se puede demostrar en otros estudios^{36-38,42}, los cuales tienen como común denominador que utilizaron el método de Baccetti y cols.²⁵ para realizar sus propias comparaciones.

5. Conclusiones

1. Al comprobar la radiografía de muñeca con la radiografía de vértebras cervicales se puede concluir que el método más eficaz para analizar la maduración ósea es mediante el método radiográfico de vértebras cervicales, pero el método de radiografía de muñeca puede ser un buen método de confirmación. Sin embargo, en este caso fue complicado conseguir estudios que hubiesen utilizado los mismos métodos tanto para radiografía de muñeca como para las vértebras cervicales.
2. Los métodos diagnósticos estudiados como tomografía computarizada, CBCT y resonancia magnética dan una mejor calidad de imagen, pero necesitan de más investigación y sus propios indicadores de crecimiento. Por otro lado, de todas las estructuras estudiadas en este trabajo, la radiografía de rodilla puede ser una buena opción como método complementario a la radiografía de muñeca o radiografía lateral de cráneo. Los resultados multifactoriales disminuyen el error de la estimación de maduración ósea. Ninguno de estos métodos podría suplantar los métodos de estimación de radiografía de muñeca y la radiografía lateral de cráneo.
3. El método más fiable para determinar la maduración ósea en pacientes en crecimiento mediante vértebras cervicales es el método de Baccetti y cols., ya se ha comprobado ampliamente su validez y eficacia.

Responsabilidad Social

- 1) Sostenibilidad económica: La sostenibilidad económica se ve influida ya que se realizan menos radiografías a los pacientes, porque con una sola radiografía se puede estudiar o analizar el desarrollo óseo y la cantidad de costo invertido en más radiografías disminuye o desaparece. El saber analizar y poder estudiar el desarrollo o maduración ósea influye de manera positiva a los tratamientos, ya que gracias a esto se podría disminuir la cantidad de citas porque podemos realizar correctos diagnósticos para hacer tratamientos en momentos idóneos y así disminuimos la cantidad de inversión monetaria de los pacientes en las citas.
- 2) Sostenibilidad medioambiental: El medioambiente ha sido una parte importante para los estudios de este trabajo, porque se está intentando una manera de reducir la cantidad de radiaciones emitidas por las radiografías, sustituyéndolas por métodos como la resonancia magnética.
- 3) Sostenibilidad social: Facilitaría la manera de conocer la edad de personas indocumentadas que llegan al país. Ayuda a mejorar la precisión de los tratamientos, ya que estos tendrían un resultado más exitoso que cuando no se analiza la maduración ósea y se trabaja de manera aleatoria sin tomar en consideración el desarrollo óseo de los pacientes pediátricos.

Bibliografía

1. Ashanin V, Druz V, Py S, Zhernovnikova Y, Aleksieieva I, Aleksenko Y, Yefremenko A, Pilipko O. Methods for determining the biological age of different children. JPES [Internet]. 2018 [citado 2 noviembre de 2020]; 18(4):1845-1849. Disponible en: <https://doi.org/10.7752/jpes.2018.s4270>
2. Bastardo R, Figuera A, Rueda Y, Ortiz M, Quirós O, Farías M, Alcedo C, Fuenmayor D, Godoy S, De Jusiric A, Mazza P. Correlación entre edad cronológica y edad ósea – edad dental en pacientes del Diplomado de Ortodoncia Interceptiva, UGMA – 2007. 2009 [citado 2 noviembre de 2020]. Disponible en: <https://www.ortodoncia.ws/publicaciones/2009/art-27/>
3. Kenny J. Aplicación del método de Moorrees, Fanning y Hunt modificado por Smith (1991) para predecir la edad cronológica en subadultos con fines antropológicos y forenses. 2019 [citado 2 noviembre 2020]; 2: 52-67. Disponible en: <https://sep.usac.edu.gt/revista>
4. Lamons F, Gray S. A study of the relationship between tooth eruption age, skeletal development age, and chronological age in sixty-one Atlanta children. Atlanta: Am J Orthod; 1956: 44(9): 687-691.
5. Cameron N. Can maturity indicators be used to estimate chronological age in children? Ann Hum Biol [Internet]. 2015 [citado 3 noviembre de 2020]; 1-6. Disponible en: <https://doi.org/10.3109/03014460.2015.1032349>
6. Ogodescu E, Ogodescu A, Tudor A. Estimation of child's biological age based on tooth development. Rom J Leg Med [Internet]. 2011 [citado 3

noviembre de 2020]; 19: 115-124. Disponible en:
<https://doi.org/10.4323/rjlm.2011.115>

7. Macha M, Lamba B, Sankar JS, Muthineni S, Shankar PGJ, Chitoori P. Estimation of correlation between chronological age, skeletal Age and dental age in children: A cross-sectional study. J CI Diag Research [Internet]. 2017 [citado 3 noviembre de 2020]; 11(9): ZC01-ZC04. Disponible en:
<https://doi.org/10.7860/JCRD/2017/.25175.10537>

8. Palanisamy V, Rao A, Shenoy R, Srikrishna S. Correlation of dental age, skeletal age, and chronological age among children aged 9-14 years: A retrospective study. JISPPD [Internet]. 2016 [citado 3 noviembre de 2020]; 34(4): 310-314. Disponible en: <https://doi.org/10.4103/0970-4388.191408>

9. Rodríguez V. Determinadores del crecimiento craneofacial: El IGF-I. Oviedo: Univ Oviedo; 2015 [Tesis]. Disponible en: <https://digibuo.uniovi.es>

10. Roentgen W. Roentgen's Discovery. Estados Unidos: Am J Dent Sci; 1896: 30(1): 33-96.

11. Ávila MA. Determinación del pico máximo de crecimiento puberal mandibular mediante la maduración ósea cérvico vertebral y la edad cronológica en pacientes adolescentes que acuden a la Clínica Dental Docente UPC: marzo 2011 – 2013. Lima, Perú: UPC; 2015 [Tesis]. Disponible en:
<http://hdl.handle.net/10757/609514>

12. Pryor JW. The hereditary nature of variation in the ossification of bones. Anat Rec. 1907; 1: 84-8.

13. Bernal N, Arias MI. Indicadores de maduración esquelética y dental. CES Odonto [Internet]. 2007 [citado 5 noviembre de 2020]; 20(1): 59-68. Disponible en: <https://doi.org/10.21615/139>
14. Hellman M. Ossification of epiphyseal cartilages in the hand. Estados Unidos: Am J Phys Anthropol. 1928; 11: 221-43.
15. Flory C. Osseous development in the hand as an index of skeletal development (monograph). Committee on Child Development. Chicago: University of Chicago Press, 1936.
16. Greulich WW, Pyle SI. Radiographic atlas of skeletal development of the hand and wrist. Estados Unidos: Am J Med Sci. 1959; 1(91): 53.
17. Pose G, Villacrés F, Silva C, Guiloff S. Correlation in radiological bone age determination using the Greulich and Pyle method versus automated evaluation using BoneXpert software. Rev Chil Pediatr [Internet]. 2018 [citado 11 noviembre de 2020]; 89(5): 606-611. Disponible en: <https://doi.org/10.4067/S0370-41062018005000705>
18. Manzoor A, Hassan N, Ahmed A. Bone age assessment methods: A critical review. Pak J med Sci [Internet]. 2014 [citado 11 noviembre de 2020]; 30(1):211-215. Disponible en: <http://doi.org/10.12669/pjms.301.4295>
19. Fishman L. Radiographic evaluation of skeletal maturation: A clinically oriented method based on hand-wrist films. Estados Unidos: Angle Ortho: 1982; 52(2): 88-111.

20. Tanner JM, Whitehouse RH, Marshall WA, Healy MJR, Goldstein H. Assessment of skeletal maturity and prediction of adult height. TW 2 method. Londres: Academic Press, 1975.
21. Gilsanz V, Ratib O. Hand bone age atlas: A digital atlas of Skeletal Maturity. *Pediatr Radiol* [Internet]. 2005 [citado 12 noviembre de 2020]; 35(10): 1035–1035. Disponible en: <https://doi.org/10.1007/s00247-005-1527-2>
22. Lamparski D. Skeletal age assessment utilizing cervical vertebrae. Pittsburgh: University of Pittsburgh, 1972.
23. Ortiz M, Godoy S, Fuenmayor D, Farias M, Quirós O, Rondón S, Lerner H. Método de la maduración ósea de las vértebras cervicales, en pacientes del Diplomado de Ortodoncia Interceptiva, UGAMA-2006. 2007 [citado 12 noviembre de 2020]. Disponible en: <https://www.ortodoncia.ws/publicaciones/2007/art-4/>
24. Hassel B, Farman A. Skeletal Maturation Evaluation using Cervical Vertebrae. *Am J Orthod Dentofac Orthop* [Internet]. 1995 [citado 19 noviembre de 2020]; 107(1): 58-66. Disponible en: [https://doi.org/10.1016/s0889-5406\(95\)70157-5](https://doi.org/10.1016/s0889-5406(95)70157-5)
25. Baccetti T, Franchi L, Mcnamara J Jr. The Cervical Vertebral Maturation (CVM) Method for the Assessment of Optimal Treatment Timing in Dentofacial Orthopedics. *Semin Orthod* [Internet]. 2005 [citado 19 noviembre de 2020]; 11: 119-129. Disponible en: <https://doi.org/10.1053/j.sodo.2005.04.005>
26. Hsiang-Hua LE, Liu JP, Chang JZ, Tsai SJ, Jane CC, Chen MH, Chen YJ, Lin CP. Radiographic Assessment of Skeletal Maturation Stages for Orthodontic Patients: Hand-wrist Bones or Cervical Vertebrae? *J Formos Med Assoc*

[Internet]. 2008 [citado 19 noviembre de 2020]; 107(4): 316-325. Disponible en: [https://doi.org/10.1016/S0929-6646\(08\)60093-5](https://doi.org/10.1016/S0929-6646(08)60093-5)

27. Chen LL, Xu TM, Jiang JH, Zhang ZZ, Lin JX. Quantitative Cervical Vertebral Maturation Assessment in Adolescents with Normal Occlusion: A Mixed Longitudinal Study. *Am J Orthod Dentofac Orthop* [Internet]: 2008; [citado 19 noviembre de 2020] 134: 720.e1-720.e7. Disponible en: <http://doi.org/10.1016/j.ajodo.2008.03.014>.

28. Hägg U, Taranger J. Maturation Indicators and the Pubertal Growth Spurt. *Am. J Orthod* [Internet]. 1982 [citado 19 noviembre de 2020]; 82(4): 299-309. Disponible en: [https://doi.org/10.1016/0002-9416\(82\)90464-X](https://doi.org/10.1016/0002-9416(82)90464-X)

29. Rajagopal R, Kansal S. A comparison of modified MP3 stages and the cervical vertebrae as growth indicators. 2002 [citado 20 noviembre de 2020]. Disponible en: <https://europepmc.org/article/med/12165981>

30. Roche AF, Wainer H, Thissen D. *Skeletal Maturity: The Knee Joint as a Biological Indicator*. Nueva York: Plenum; 1976.

31. Roche AF, Chumlea WMC, Thissen D. *Assessing the skeletal maturity of the hand-wrist. FELS method*. 1988: Springfield: CC Thomas.

32. O'Connor JE, Coyle J, Spence LD, Last J. Epiphyseal maturity indicators at the knee and their relationship to chronological age: results of an Irish population study. *Clin Anat* [Internet]. 2013 [citado 4 abril de 2021]; 26(6):755-767. Disponible en: <https://doi.org/10.1002/ca.22122>

33. Shim J, Heo G, Lagravère M. Assessment of Skeletal Maturation Based on Cervical Vertebrae in CBCT. *Inter Orthod* [Internet]; 2012 [citado 4 abril de 2021]; 10: 351-362. Disponible en: <https://doi.org/10.1016/j.ortho.2012.09.005>
34. Tang FH, Chan JLC, Chan BKL. Accurate Age Determination for Adolescents Using Magnetic Resonance Imaging of the Hand and Wrist with an Artificial Neural Network-Based Approach. *J Digital Imag* [Internet]; 2019 [citado 17 marzo de 2021]; 32: 283-289. Disponible en: <https://doi.org/10.1007/s10278-018-0135-2>
35. Babu D, Baskaranarayanan B, Karunanidhi, Arumugam M. Correlation between chronological age, cervical vertebral maturation and Fishman's skeletal maturity indicators in Chennai population. *RGUHS Med Sci*. 2015 [citado 17 marzo de 2021]. Disponible en: <https://rjms.in>
36. Hoseini M, Zamaheni S, Bashizadeh H, Akbari F, Chalipa J, Rahmati A. Comparative Evaluation of the Efficacy of Hand-Wrist and Cervical Vertebrae Radiography for the Determination of Skeletal Age. *Iran J Radiol* [Internet]; 2016 [citado 5 abril de 2021]; 13(3): 2-9. Disponible en: <https://doi.org/10.5812/iranjradiol.21695>
37. Kumar S, Agarwal N, Mehrotra A. Evaluation of skeletal maturity in North Indian subject using an objective method based on cervical vertebral bone age and assessment of its reliability as compared to hand wrist radiographic method. *J Indian Orthod Socie* [Internet]. 2016 [citado 7 abril de 2021]; 50(1): 3-7. Disponible en: <https://doi.org/10.4103/0301-5742.175704>
38. Cunha A, Cevidanes L, Sant'Anna E, Guedes F, Luiz R, McNamara J, Franchi L, Ruellas A. Staging Hand-Wrist and Cervical Vertebrae Images: A

Comparison of Reproducibility. Dentomaxi Radio [Internet]; 2018 [citado 10 abril de 2021]; 47: 1-7. Disponible en: <https://doi.org/10.1259/dmfr.20170301>

39. Cangialosi TJ, Vives VJ. Another look at skeletal maturation using hand wrist and cervical vertebrae evaluation. Open J Orthop [Internet]. 2018 [citado 10 abril de 2021]; 8: 1-10. Disponible en: <https://doi.org/10.4236/ojo.2018.81001>

40. Szemraj A, Wojtaszek-Slominska A, Racka-Pilszak B. Is the Cervical Vertebral Maturation (CVM) Method Effective Enough to Replace the Hand-Wrist Maturation (HWM) Method in Determining Skeletal Maturation? A Systematic Review. Euro J Radio [Internet]; 2018 [citado 10 abril de 2021]; 102: 125-128. Disponible en: <https://doi.org/10.1016/j.ejrad.2018.03.012>

41. Ye-Seul L, Sung-Hwan C, Kyung-Ho K, Chung-Ju H. Evaluation of skeletal maturity in the cervical vertebrae and hand-wrist in relation to vertical facial types. Korean J Orthod [Internet]. 2019 [citado 8 abril de 2021]; 49(5): 319-325. Disponible en: <https://doi.org/10.4041/kjod.2019.49.5.319>

42. Patil N, Maheshwari N, Sharma R, Soni S, Kushwah A. Correlation between chronological age, cervical vertebral maturation and Fishman's skeletal maturity indicators in Central India population. Orthod J Nepal [Internet]. 2016 [citado 10 abril de 2021]; 9(2): 52-56. Disponible en: <https://doi.org/10.3126/ojn.v9i2.28415>

43. Tang X, Yubo L, Mingfan P, Nhan D, Klyce W, Fritz J, Lee J. An Abbreviated Scale for the Assessment of Skeletal Bone Age Using Radiographs of the Knee. JHMI [Internet]; 2018 [citado 10 abril de 2021]; 41(5): e676-e680. Disponible en: <https://doi.org/10.3928/01477447-20180724-03>

44. De Tobel J, Fieuws S, Hillewig E, Phlypo I, van Wijk M, Bart de Haas M, Politis C, Verestraete KL, Werner P. Multi-factorial Age Estimation: A Bayesian Approach Combining Dental and Skeletal Magnetic Resonancia Imaging. *Foren Sci Inter* [Internet]; 2020 [citado 11 abril de 2021]; 306: 1-9. <http://doi.org/10.1016/j.forsciint.2019.110054>
45. Bo-Ram B, Yong-Il K, Tetsutaro Y, Koutaro M, Ching-Chang K, Dea-Seok H, Soo-Byung P, Woo-Sung S. Quantitative Skeletal Maturation Estimation Using Cone-Beam Computed Tomography-Generated Cervical Vertebral Images: A Pilot Study in 5-to 18-year-old Japanese Children. *Clin Oral Invest* [Internet]. 2015 [citado 11 abril de 2021]; 19: 2133-2140. Disponible en: <https://doi.org/10.1007/s00784-015-1415-6>
46. Tekin A, Aydin KC. Comparative determination of skeletal maturity by hand-wrist radiograph, cephalometric radiograph and cone beam computed tomography. *Oral Radiol* [Internet]. 2020 [citado 11 abril de 2021]; 36(4): 327-336. Disponible en: <https://doi.org/10.1007/s11282-019-00408-y>
47. Camacho-Basallo P, Yáñez-Vico RM, Solano-Reina E, Iglesias-Linares A. Five Radiographic Methods for Assessing Skeletal Maturity in a Spanish Population: Is There a Correlation? *Act Odonto Scandinava* [Internet]; 2016 [citado 8 abril de 2021]; 1-7. Disponible en: <http://doi.org/10.1080/00016357.2016.1265145>
48. Alvarado-Torres E, Gutierrez-Rojo JF, Rojas-García AR. Comparación de la Maduración Ósea de Vértebras Cervicales Utilizando el Método de Baccetti y Lamparski en Pacientes de 8 a 15 años de edad. *Int J Odontostomat* [Internet];

2016 [citado 8 abril de 2021]: 10(1): 63-67. Disponible en: <https://dx.doi.org/10.4067/S0718-381X2016000100011>

49. Vaida L, Moca AE, Todos L, Tent A, Todos B, Negrutiu BM, Moraru AI. Correlations between morphology of cervical vertebrae and dental eruption. Rom J Morphol Embryol. 2019 [citado 5 abril de 2021]. Disponible en: <https://rjme.ro/RJME/resources/files/600119175180.pdf>

50. Constela BV. Comparación del método de maduración ósea vertebral cervical CVMS con dos métodos de maduración ósea carpal en pacientes chilenos del postgrado de ortodoncia y ortopedia dentomaxilofacial de la UNAB, sede Santiago, año 2015. [Tesis]. Santiago de Chile: 2015.

ARTÍCULOS

Journal of Physical Education and Sport® (JPES), 18(Supplement issue 4), Art 270, pp. 1845 - 1849, 2018
online ISSN: 2247 - 806X; p-ISSN: 2247 - 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Methods for determining the biological age of different children

VOLODYMYR ASHANIN¹, VALERY DRUZ², SVETLANA PYATISOTSKAYA³, YANA ZHERNOVNIKOVA⁴, IRINA ALEKSIEIEVA⁵, YANA ALEKSENKO⁶, ANDRII YEFREMENKO⁷, OLGA PILIPKO⁸

^{1,3,4,5,6}Department of Computer Science and Biomechanics, Kharkov State Academy of Physical Culture, UKRAINE

⁷Department of Athletics, Kharkov State Academy of Physical Culture, UKRAINE

⁸Department of Water Sports, Kharkov State Academy of Physical Culture, UKRAINE

Published online: October 31, 2018

(Accepted for publication September 05, 2018)

DOI:10.7752/jpes.2018.s4270

Abstract. The aim is to examine the existing methods of determine biological age of the children and choose the most affordable for the population. *Research materials and methods:* theoretical analysis and generalization of literary sources. *Results:* The article presents a comparative analysis variety methods for determining the biological age. The qualitative component ratio of the body structure without its total volume and weight of body weight is the most effective method of determining the quality indicators of biological age. *Conclusions:* The main indicator of the biological age should be considered as a function of weight formation (weight) of the body that is associated in meaning with average population values.

Keywords: physical education, physical development, biological age, chronological age, types of constitution.

Introduction. The problem of individualization of physical education presumes first of all an account of age-specific habits of the developing organism. The traditional approach of an account of age-specific rates of physical growth and development is based on the average screening survey indexes of basic signs of differentiation and maturation of the certain systems of the organism. Such criteria are: skeletal age, dental age, the age reached by the shape of the body, secondary sexual characteristics chronological age and some others.

A significant drawback of this approach in the determination of the biological age is chronological inconsistency of these indicators for a single person. The choice of statistical indexes on the marked signs of biological age enables to create a model of an coincident chronological and biological age of the personal growth that satisfy the requirements. However in real terms in the criteria of biological development there is no coincidence with a chronological model of normal physical development. Taking into account an importance of problem solving, there were conducted an analysis of the scientific literature on this issue, an analysis of the statistical data of the examined contingent, the development of theory for building indicative semantic spaces with an introduced measure of their elements closeness, on the basis of what was installed a unified model that reflects the structure relations of the signs which characterize the biological age.

The aim is to examine the existing methods of determine biological age of the children and choose the most affordable for the population.

Research materials and methods:

The following methods of the researches were defined for the solution of objectives: analysis of scientific literature; method of analogies; method of natural experiment; method of the ordered submission of empirical data in semantic sign spaces with the entered uniform measure of their comparison; method of mathematical modeling in tolerant spaces.

Results.

In construction of the healthy lifestyle system the national system of physical education is one of the main components, which should be based on the results of a permanent monitoring of physical population development, it's physical readiness and physical state [5].

Current stage of construction of the physical education system implies obligatory systematic monitoring of physical development and the features of its individual manifestations, which determine the necessary and sufficient level of the physical readiness. This requires for one's turn the development of tools and methods to ensure the physical load for each physical development age level, which arsenal should meet the necessary requirements that are determined by the individual physical development characteristics [10; 16; 19].

-----1845

Corresponding Author: VOLODYMYR ASHANIN, E-mail: skharchenko@rambler.ru



Inicio > Publicaciones > Año 2009

Correlación entre edad cronológica y edad ósea - edad dental en pacientes del Diplomado de Ortodoncia Interceptiva, UGMA - 2007

Bastardo Ruby; Figuera Adriana; Rueda Yulmaira; Ortiz Mónica; Quirós Oscar; Farías Margarita ;Alcedo Carolina; Bastardo Ruby; Dorathys Fuenmayor; Godoy Sol; De Jurisic Aura; Mazza Patricia

Para efectos de referencia bibliográfica este trabajo debe ser citado de la siguiente manera:

Bastardo R; Figuera A; Rueda Y; Ortiz M; Quirós O; Farías M ;Alcedo C; Bastardo R; Dorathys F; Godoy S; De Jurisic A; Mazza P.

"CORRELACIÓN ENTRE EDAD CRONOLÓGICA Y EDAD ÓSEA - EDAD DENTAL EN PACIENTES DEL DIPLOMADO DE ORTODONCIA INTERCEPTIVA, UGMA - 2.007"

Revista Latinoamericana de Ortodoncia y Odontopediatría "Ortodoncia.ws edición electrónica noviembre 2009. Obtenible en: www.ortodoncia.ws. Consultada, D/D/D

Resumen

La evaluación y la determinación de los períodos de intenso crecimiento que ocurren durante la maduración de un individuo, proveen información clínica muy importante para la planificación de los tratamientos ortodóncicos, ortopédicos, y los procedimientos de retención.

La Edad Cronológica que rutinariamente se ha utilizado para evaluar el nivel de desarrollo y maduración del paciente, no siempre es un indicador muy confiable, y es por eso que en casos de duda, se realizan estudios comparativos con radiografías carpales y panorámicas como herramientas para determinar la Edad Ósea y la Edad Dental. Estos análisis son aplicados, principalmente en niños que se encuentran en período de dentición mixta, con la finalidad de realizar un buen diagnóstico y aprovechar los picos de crecimiento para garantizar la efectividad del tratamiento.

El **Objetivo** de este estudio es determinar la Correlación que existe entre la Edad Cronológica, la Edad Ósea y la Edad Dental en los pacientes del Diplomado de Ortodoncia Interceptiva UGMA 2007.

Materiales y Métodos: Se utilizaron 45 radiografías carpales de la mano izquierda y panorámicas de pacientes en edades comprendidas entre 5 y 10 años, consecuentemente, se analizaron las radiografías carpales para obtener la Edad Ósea, utilizando el Atlas de Maduración Ósea del Venezolano y el Atlas de Greulich y Pyle (Edad Ósea Universal), por otra parte, se analizaron las radiografías panorámicas para determinar la Edad Dental, a través del método de Demirjian. Posteriormente, se correlacionaron todas las variables (Edad Cronológica, Edad Ósea Venezolana, Edad Ósea Universal y Edad Dental) entre ellas. La Edad Cronológica, Ósea y Dental fueron suministradas por los alumnos del Diplomado en Ortodoncia Interceptiva de la Universidad Gran Mariscal de Ayacucho del año 2.007.

Conclusiones: A través del estudio de la radiografía carpal de la mano izquierda y radiografía panorámica de pacientes que experimentan cambios de crecimiento importantes, se observa el indicador de maduración de cada individuo para así diagnosticar y planificar el tratamiento ortodóncico adecuado.

Palabras Claves: Edad ósea, Edad dental, Edad cronológica, Análisis carpal, Maduración, Crecimiento, Desarrollo.

Abstract

The evaluation and the determination of intense growing periods that occurs during the maturity of a human been provides important clinical information for planning orthodontics, orthopedics and the retention procedures treatments.

Aplicación del método de Moorrees, Fanning y Hunt modificado por Smith (1991) para predecir la edad cronológica en subadultos con fines antropológicos y forenses

Jimmy Kenny Alvarado Cardona

Odontólogo

Universidad de San Carlos de Guatemala

Facultad de Odontología

Departamento de Postgrado

1. INTRODUCCIÓN

La identificación humana con fines forenses conlleva varios parámetros como lo son talla, edad, sexo y etnia. Los dientes son las estructuras del cuerpo más resistentes a cambios extrínsecos como golpes, cambios bruscos de temperatura, descomposición, ataque de agentes químicos entre otros, lo cual los hace una fuente de información valiosa para la investigación odontológica y forense.

El presente artículo tomó la edad como objeto de estudio, utilizando el método Moorrees, Fanning y Hunt (MFH) modificado por Smith (1991), para predecir la edad cronológica (EC) en base a la edad dental (ED), utilizando para ello datos preestablecidos por el autor y clasificado en tablas de estadios de maduración dental para las 8 piezas dentales inferiores permanentes del lado izquierdo, utilizando para este estudio 139 radiografías panorámicas de personas que asistieron al Centro Radiológico y Maxilofacial de la cabecera departamental de Huehuetenango - Guatemala, de ambos sexos (48 hombres y 91 mujeres) en edades comprendidas entre 5 a 20.9 años.

2. JUSTIFICACIÓN

En Guatemala aun no existen estudios para predecir la edad cronológica a partir de la edad dental, por lo que es necesario establecer un método efectivo, fácil de aplicar, reproducible, económico y sobre todo que brinde datos confiables y con un margen de error mínimo para la predicción de la edad en subadultos con fines forenses.

El método MFH, modificación Smith (1991) se considera altamente efectivo debido a que es más específico que otros, ya que cuenta para su estudio con 14 estadios de desarrollo dental, los cuales deben ser observados en radiografía panorámica o periapical, comparado con los 8 estadios del Demirjian y los 11 de Nolla.

3. OBJETIVOS

- Determinar la efectividad del método MFH modificación Smith para la predicción de la edad cronológica con fines antropológicos y forenses en población guatemalteca de la cabecera departamental de Huehuetenango que asisten al Centro Radiológico y Maxilofacial.
- Establecer las edades por rangos en las cuales es más efectivo la aplicación del método MFH, modificación Smith para la población objeto de estudio por género.
- Establecer la cantidad de piezas dentales necesarias para que sea más eficiente la presente metodología por género.
- Establecer el género en el cual es más efectivo la aplicación del método MFH modificación Smith para la población objeto de estudio.
- Establecer la variabilidad y margen de error que podemos encontrar al aplicar esta metodología a la población objeto de estudio.

4. PLANTEAMIENTO DEL PROBLEMA

Guatemala en la actualidad no cuenta con estudios sobre odontología forense con fines de identificación. La predicción de la edad cronológica es uno de los factores más importantes de la cuarteta básica de identificación humana (edad, sexo, etnia y talla) por lo que es necesario establecer parámetros y valores ciertos que permitan aplicarlos a la población guatemalteca.

La ausencia de dichos estudios ha hecho que utilizemos parámetros extranjeros lo cual es muy variable ya que, dependiendo del clima, cultura, hábitos alimenticios, evolución, nivel y desarrollo sociocultural y socioeconómico

A STUDY OF THE RELATIONSHIP BETWEEN TOOTH ERUPTION
AGE, SKELETAL DEVELOPMENT AGE, AND CHRONOLOGICAL
AGE IN SIXTY-ONE ATLANTA CHILDREN

FRANK F. LAMONS, D.D.S. AND STEPHEN W. GRAY, PH.D., ATLANTA, GA.

WATCHING a child grow has always been a source of interest to human beings. To each watcher, at some time, has come the question: "Is this child growing normally?" Gross defects, of course, are readily apparent, although their earliest onset may be far from obvious. It is the smaller deviations from normal growth patterns, however, that are by far the more usual and it is among these that the problems of the orthodontist lie.

It is a natural assumption that skeletal growth has an underlying symmetry and that skeletal development in one part of the body should bear some relationship to development in another part. That this is the case for segments of the appendicular skeleton is strongly suggested by the effective application of Huxley's relative growth equation to many vertebrates, including man.¹ We know also that this proportionality may be changed in some pathologic states, such as acromegaly, and even congenitally, as in anencephaly.

Howard,^{2, 3} working also with Atlanta children, was among the first to call attention to the importance of knowledge of a child's general growth pattern when evaluating abnormal jaw development.

We have described elsewhere⁴ the comparison between the growth of our Atlanta children and the two growth standards under discussion. Our girls agreed better with both standards than did our boys.

In this report we have correlated the hand and tooth development data of each child with a view to (1) investigating the agreement between the growth of two parts of the same body and (2) evaluating the predictive usefulness of the hand plate in orthodontic practice.

MATERIALS AND METHODS

We have concerned ourselves with two well-described indices of growth: development of dentition and hand and wrist bone development.

Schour and Massler's⁵ chart, "Development of the Human Dentition," distributed by the American Dental Association, was used to establish developmental age from full-mouth x-ray films of our subjects. Greulich and

From the Departments of Orthodontics and Anatomy, Emory University.

REVIEW

Can maturity indicators be used to estimate chronological age in children?

Noël Cameron

National Centre for Sport and Exercise Medicine, School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough, UK

Abstract

Context: There is widespread concern over the use of maturity indicators to estimate chronological age in children.

Objective: To review the definition of maturity indicators, the criteria governing their identification and use and the problems of their interpretation.

Methods: The development of maturity indicators, the criteria for their selection and the relationship of maturity to chronological age is critically reviewed.

Results and Conclusions: Maturity indicators are not related to the passage of chronological time, but to the progression of the individual from an immature to a mature state. They are discrete events in a continuous process or a series of processes (e.g. skeletal, sexual, dental, etc.) that highlight uneven maturation within the individual, the independence of maturational processes, sexual dimorphism and the relationship of maturity to size. The use of a *timescale* of development causes considerable problems in translating biological maturity into a developmental scale. One "year" of maturational time does not equate to 1 year of chronological time and, thus, the passage of time determined by developmental rather than temporal landmarks is both variable and inconsistent. Chronological age determination was not the aim of maturational assessment and, thus, its widespread use as an age determinant poses considerable interpretive challenges.

Keywords

Age estimation, children, dental maturity, skeletal maturity

History

Received 16 March 2015

Accepted 18 March 2015

Published online 15 June 2015

Introduction

Concern regarding the accurate determination of chronological age in children has its roots in the UK immigration policy of the 1970s. At that time South Asian single women were being subjected to virginity testing at Heathrow airport to verify their claims of entry to the UK for marriage. In addition, adults bringing children into the country were required to verify the ages of the children and if they could not then age assessment techniques were applied (Cameron, 1982). These practices were viewed as abhorrent by many and, in January 1979, the British Home Secretary announced that an inquiry, under the Chairmanship of Sir Henry Yellowlees, would be undertaken into the role of port medical officers and the use of "medical techniques" in relation to immigration control. Virginity testing and the X-raying of adults and pregnant women were terminated as a result of public pressure, but X-rays of children to determine their chronological age continued (White, 1981). Indeed it has continued to this day, despite further concerns raised in

debates in the House of Commons and the House of Lords (primarily by Erik Lubbock MP, the 5th Baron Avebury) and the setting up of committees of enquiry which appear to either not meet or to not arrive at conclusions and recommendations. Those with the authority to create legal guidelines for why, when and how chronological age might be estimated appear to be unaware of the biological relationships between maturity and chronological age, often treating the former as if it were equivalent to the latter.

The methods used to derive chronological age were based on maturity indicators that were assumed to be closely associated to chronological age. In the 1970s the British Government relied almost exclusively on the opinion of "medical advisors" who provided a chronological age based on data collected during a physical examination of the child. These data included height, weight, number of teeth, the appearance of ossification centres in certain bones and the normality or otherwise of gait, musculature, skin elasticity and tone amongst other supposed indicators (Cameron, 1982). Whilst some of these may be recognised as maturity indicators, e.g. number of erupted teeth, others are clearly far too subjective and variable to qualify as a maturity indicator, e.g. skin elasticity. To avoid completely inappropriate use of biological variables to indicate chronological age it is essential to be very clear about precisely what characteristics define and identify a maturity indicator and its relationship to age.

Correspondence: Professor Noël Cameron, National Centre for Sport and Exercise Medicine, School of Sport, Exercise and Health Sciences, Loughborough University, Epinal Way, Loughborough LE11 3TU, UK. Tel: +44 1509 223008. E-mail n.cameron@lboro.ac.uk

Estimation of child's biological age based on tooth development

Ana Emilia Ogorescu^{1*}, Elisabeta Bratu², Anca Tudor³, Alexandru Ogorescu⁴

Abstract: Dental development is relatively independent from other systems maturation. Recent studies have reported changes in the timing of tooth development for contemporary children comparing to children that lived more than 30 years ago (secular trend). Detectable variations in the tempo of tooth mineralization and duration of tooth maturation between children from different geographical regions were reported. Dental age is important not only for dental specialists, but also for pediatricians (in the evaluation of growth and development of healthy children, in pediatric endocrinology, in children with different diseases or syndromes) and forensic doctors (in order to estimate the age or to identify the child). The aim of our study was to investigate the regional characteristics of dental maturation in actual Romanian children. We conducted a cross-sectional study on a final sample of 441 radiographs of patients aged between 5.5 and 14.5 years (218 girls and 223 boys). The dental panoramic radiographs were scored by two examiners and intra- and inter-examiner calibration was made. We used a dedicated software for easy scoring, automatic dental age determination and as a database. On average, the Romanian girls showed an overestimation of 0.36 years, meaning 132 days, $p=0.129$, $\alpha = 0.05$ and boys an underestimation of 0.04 years, meaning 15 days, $p = 0.852$, $\alpha = 0.05$. New tables were developed in order to convert dental maturity calculated according to Demirjian method into dental age of contemporary Romanian children.

Key Words: stages of permanent tooth development, dental age, diagnostic tool, Romanian children sample, digital imaging technologies

The physiological age of a person is determined by the degree of maturation of the different tissue systems [1]. Physiological age can be used to define a child's progress towards completeness of development or maturity. Within a tissue system, the sequence of one or more irreversible events defines maturation. Dental Age is usually based on the maturation of the teeth [2]. This is observed when we look on a child's panoramic radiograph (Figure 1, 2).

Children with the same chronological age may show differences in the developmental stages of different biological systems. Several indices have been developed to determine the developmental stage of a child for a certain biological system, namely indices for sexual maturity, somatic maturity, skeletal age, and dental age [3].

1) * Corresponding author: DMD, PhD student, Department of Paedodontics-Orthodontics, School of Dentistry, University of Medicine and Pharmacy "Victor Babes" Timisoara, Romania, Bd-ul Revolutiei, nr. 9, Timisoara 300754, Phone: +40723330890, e-mail: eogorescu@gmail.com

2) Professor, Dr., DMD, PhD, Department of Paedodontics-Orthodontics, School of Dentistry, University of Medicine and Pharmacy "Victor Babes" Timisoara, Romania

3) Assistant professor, PhD, Department of Medical Informatics and Biostatistics, University of Medicine and Pharmacy "Victor Babes" Timisoara, Romania

4) Assistant professor, Dr., DMD, PhD, Department of Paedodontics-Orthodontics, School of Dentistry, University of Medicine and Pharmacy "Victor Babes" Timisoara, Romania

Estimation of Correlation between Chronological Age, Skeletal Age and Dental Age in Children: A Cross-sectional Study

MADHULIKA MACHA¹, BHARTI LAMBA², JOGENDRA SAI SANKAR AVULA³, SRIDHAR MUTHINENI⁴, PRATAP GOWD JAI SHANKAR MARGANA⁵, PRASAD CHITTOOR⁶

ABSTRACT

Introduction: In the modern era, identification and determination of age is imperative for diversity of reasons that include disputed birth records, premature delivery, legal issues and for validation of birth certificate for school admissions, adoption, marriage, job and immigration. Several growth assessment parameters like bone age, dental age and the combination of both have been applied for different population with variable outcomes. It has been well documented that the chronological age does not necessarily correlate with the maturational status of a child. Hence, efforts were made to determine a child's developmental age by using dental age (calcification of teeth) and skeletal age (skeletal maturation).

Aim: The present study was aimed to correlate the chronological age, dental age and skeletal age in children from Southeastern region of Andhra Pradesh, India.

Materials and Methods: Out of the total 900 screened children, only 100 subjects between age groups of 6-14 years

with a mean age of 11.3 ± 2.63 for males and 10.77 ± 2.24 for females were selected for the study. Dental age was calculated by Demirjian method and skeletal age by modified Middle Phalanx of left hand third finger (MP3) method. Pearson's and Spearman's correlation tests were done to estimate the correlation between chronological, dental and skeletal ages among study population.

Results: There was a significant positive correlation between chronological age, dental age and all stages of MP3 among males. Similar results were observed in females, except for a non-significant moderate correlation between chronological age and dental age in the H stage of the MP3 region.

Conclusion: The results of the present study revealed correlation with statistical significance ($p < 0.05$) between chronological, dental and skeletal ages among all the subjects (48 males and 52 females) and females attained maturity earlier than males in the present study population.

Keywords: Age estimation, Demirjian method, Modified MP3 method

INTRODUCTION

Development of every individual is influenced by various factors like genetic, racial, nutritional, hormonal, environmental and climatic conditions [1,2]. According to Stewart RE and Barber TK the age of an individual can be determined by various methods like chronological age, biological age, morphologic age, skeletal age, dental age, circumpubertal age, behavioural age, mental age and self-concept age [2]. Chronological age is the most apparent and easily determined developmental age which is simply figured from child's date of birth, but is not an accurate indicator of stage of development as it varies from individual to individual [2,3]. Hence, efforts were made to determine a child's developmental age by using dental age (calcification of teeth) and skeletal age (skeletal maturation). Dental age can be estimated by using two principles like tooth emergence and tooth calcification of which the tooth calcification stages are considered more reliable indicator than tooth emergence, since it is less influenced by local and systemic factors [3-7]. Estimation of dental age was done based on calcification stages using Demirjian's method. This method is most widely accepted because of its radiographic and schematic illustrations of tooth development and simplicity [4,8].

On the other hand, skeletal age is determined by recognizable stages of ossification and a characteristic pattern of progression of ossification of epiphyseal centres [9]. Fishman LS proposed the use of ossification centres seen in hand wrist radiographs and cervical vertebrae in lateral cephalogram [10]. However, its usage in pediatric patients is minimal due to various reasons like radiation exposure, high cost, huge equipment and the visibility of vertebra [10,11].

Hagg U and Taranger J proposed a method in which ossification of middle phalanx in the MP3 region was described as five stages of development namely MP3F, MP3FG, MP3G, MP3H, MP3I [11]. This method has many advantages over others such as low radiation exposure, high correlation with the six maturational stages of cervical vertebrae, no superimposition of bones or variations in posture and no need of special X-ray equipment. Abdel Khader HM first used intraoral periapical radiograph for assessing the reliability of the five stages of MP3 [12]. Later Rajagopal R and Kansal S modified MP3 method by adding MP3HI stage [13]. It has been well documented that the chronological age does not necessarily correlate with the maturational status of a child. However, high correlations exist between dental and skeletal age and these are more reliable and precise than chronological age in assessing the development of an individual [14]. Thus, the present study was aimed to correlate the chronological age, dental age and skeletal age in children between 6-14 years from Southeastern region of Andhra Pradesh, India.

MATERIALS AND METHODS

In this cross-sectional study, a total of 900 patients in the age ranging from 6 to 14 years without sex predilection and who visited as outpatients to the Department of Paedodontics and Preventive Dentistry, Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India, during December 2010 to June 2012 were screened. Well nourished children of Indian origin with pure ancestral background belonging to India and who require skeletal maturity assessment for orthodontic evaluation were selected for the study. The selected children presenting with all the seven permanent teeth

Correlation of dental age, skeletal age, and chronological age among children aged 9-14 years: A retrospective studyVignesh Palanisamy¹, Arathi Rao¹, Ramya Shenoy², Suprabha Srikrishna Baranya¹¹ Department of Paedodontics and Preventive Dentistry, Manipal College of Dental Sciences, Manipal University, Mangalore, Karnataka, India² Department of Public Health Dentistry, Manipal College of Dental Sciences, Manipal University, Mangalore, Karnataka, India

Date of Web Publication

29-Sep-2016

Correspondence Address:Arathi Rao
Department of Paedodontics and Preventive Dentistry, Manipal College of Dental Sciences, Manipal University, Mangalore, Karnataka, India [Login to access the email ID](#)

Source of Support: None, Conflict of Interest: None



DOI: 10.4103/0970-4388.191408

**Abstract**

Background: Growth can be one of the most uncertain variations, but understanding the same is very important for diagnosis and treatment planning. Skeletal age and dental age have been used to determine a child's developmental age. Several researchers have evaluated the association between dental and skeletal maturity with chronological age on different population. The purpose of the present study was to find out whether dental age estimation can be replaced for skeletal age estimation in the Dakshina Kannada population. **Methods:** A total of 104 samples equally distributed among both genders in the age group of 9-14 years were selected. Skeletal age was estimated using hand-wrist radiographs and Fishman's skeletal maturation index and dental age was measured using Demirjian's method. **Results:** Spearman's rank-order correlation coefficients were used to measure the association between the skeletal maturity and dental maturity. The mean ages of male and female samples were determined as 11.89 ± 1.867 years and 12.21 ± 1.473 years, respectively. Chronological age was found to be positively correlated to dental age and skeletal age and found to be statistically significant ($P < 0.01$). The correlation between dental age and skeletal age was also found to be statistically significant with $P < 0.001$ and correlation coefficient of 0.683 and 0.704 for males and females. **Conclusion:** The present study showed a strong relation between the developmental ages in mixed dentition population; hence, dental age can be considered as a replacement in the study population.

Keywords: Demirjian's method, dental age, hand-wrist radiograph, skeletal age**How to cite this article:**

Palanisamy V, Rao A, Shenoy R, Baranya SS. Correlation of dental age, skeletal age, and chronological age among children aged 9-14 years: A retrospective study. J Indian Soc Pedod Prev Dent 2016;34:310-4

How to cite this URL:Palanisamy V, Rao A, Shenoy R, Baranya SS. Correlation of dental age, skeletal age, and chronological age among children aged 9-14 years: A retrospective study. J Indian Soc Pedod Prev Dent [serial online] 2016 [cited 2021 May 4];34:310-4. Available from: <https://www.jisppd.com/text.asp?2016/34/4/310/191408>**Introduction**



Universidad de Oviedo



ASTURIAS
CAMPUS DE EXCELENCIA
INTERNACIONAL

UNIVERSIDAD DE OVIEDO
MÁSTER UNIVERSITARIO DE ORTODONCIA Y ORTOPEDIA DENTOFACIAL

**DETERMINADORES DEL CRECIMIENTO
CRANEOFACIAL: EL IGF-I**

Virginia Rodríguez Díaz

Trabajo Fin de Máster
MAYO 2015

usurp the office of the physician, but I do maintain that a thorough knowledge of the matter under deliberation is essential to our specialty, and may, at the most unforeseen time, be the means of saving a life.—*Western Dental Journal*.

ARTICLE X.

ROENTGEN'S DISCOVERY.

HOW IT CAN BE APPLIED TO MEDICINE AND SURGERY.

The New York Medical News prints the following article by Henry W. Cattell, M. D., demonstrator of morbid anatomy in the University of Pennsylvania, explaining the application of Roentgen's discovery to medical science:

"Roentgen's weird and wonderful discovery is destined to enrich medicine with possibly the most valuable diagnostic process which recent years have witnessed. Within a month from Roentgen's first announcement sufficient experiments have confirmed the value of his discovery and have pointed toward applications which, though yet unachieved, only await a development of details similar to that which converted Daguerre's slow, faint and uncertain methods into the instantaneous and brilliant photography of the present day.

"In brief, Roentgen has discovered that the electrical current passed through a Ruhmkorff coil and thence to a Crookes vacuum-tube, develops from the cathode an invisible form of energy having the double property of penetrating certain ordinarily opaque substances and of affecting an ordinary photographic plate. Flesh, for instance, is translucent to these rays, and bone and metal, glass and graphite are comparatively impervious. On this difference in penetrability depend the effects which are permanently

UNIVERSIDAD PERUANA DE CIENCIAS APLICADAS

FACULTAD DE CIENCIAS DE LA SALUD

ESCUELA DE ODONTOLOGÍA

**DETERMINACIÓN DEL PICO MÁXIMO DE
CRECIMIENTO PUBERAL MANDIBULAR
MEDIANTE LA MADURACIÓN ÓSEA CÉRVICO
VERTEBRAL Y LA EDAD CRONOLÓGICA EN
PACIENTES ADOLESCENTES QUE ACUDEN A
LA CLÍNICA DENTAL DOCENTE UPC MARZO
2011 - 2013**

TESIS PARA OPTAR EL TÍTULO PROFESIONAL CIRUJANO
DENTISTA

AUTOR

Marco Antonio Avila Villalobos

ASESOR DE TESIS:

Dra. Caridad Virginia Hidalgo Sifuentes

Lima, Perú

2015

**THE HEREDITARY NATURE OF VARIATION IN THE OSSIFICATION
OF BONES. By J. W. PUYOR. State College of Kentucky, Lexington,
Kentucky.**

While investigating the time of the appearance of centers of ossification in the bones of the human body, I have made the following observations:

First.—The process of ossification is inaugurated much sooner than hitherto supposed.

Second.—The bones of the female ossify in advance of the male. This is measured at first by days, then months, then years.

Third.—The chronological order in which the bones of the carpus are ossified is different from that formerly supposed.

Fourth.—The bones of the first child, as a rule, ossify sooner than those of subsequent children of the same parents.

Indicadores de maduración esquelética y dental

Natalia Bernal,¹ María Isabel Arias²

Resumen

A través de los años se han realizado diferentes estudios en donde evalúan los indicadores de maduración utilizados para determinar el pico de crecimiento esquelético como son: la osificación de la falange media del tercer dedo, de las vértebras cervicales y la formación del canino mandibular. Sin embargo se ha creado una gran controversia entre la existencia o no de una alta correlación entre estos tipos de indicadores de maduración esquelética y dental, y al mismo tiempo su relación con el pico de crecimiento mandibular. El propósito de este artículo es presentar una revisión crítica acerca de los diferentes indicadores de maduración presentados a través en la literatura. **Palabras Clave:** Crecimiento, indicadores de maduración, etapa puberal, P.V.E Pico de velocidad de estatura, pico de crecimiento mandibular.

Skeletal and dental maturation indicators

Abstract

Different methods such as ossification of mid-falange of the middle finger, ossification of cervical vertebrae and mandibular canine formation have been studied as skeletal maturation indicators. There is however controversy regarding the correlation between said indicators as well as with peak mandibular growth. The purpose of this article is therefore to present a critical review of the literature on the different type of maturation indicators. **Key words:** growth, maturation indicators, prepuberty, peak height velocity, peak mandibular growth.

Introducción

Los términos crecimiento y desarrollo en muchas ocasiones se utilizan como sinónimos, sin embargo cada uno de ellos tiene un significado diferente. Crecimiento se refiere a un incremento de las dimensiones de la masa corporal. Se da como resultado de hiperplasia (aumento de cantidad de células) e hipertrofia (aumento en el tamaño de la célula) de los tejidos del organismo; mientras que el desarrollo es un proceso en el que ocurren cambios en el tamaño y forma del cuerpo, en la complejidad de las funciones fisiológicas y en la maduración biológica.^{1,2}

Crecimiento puberal

Se entiende como pubertad aquel período del crecimiento y desarrollo del ser humano en donde este adquiere la capacidad de procrear y pasa de la etapa de la niñez para convertirse en adulto. Se dan por lo tanto grandes cambios en las características neuro-endocrinas, que se traducen en el desarrollo de los órganos sexuales y caracteres secundarios en conjunto con el incremento de la velocidad del crecimiento.¹

Es sabido que desde la fecundación hasta la madurez plena, el crecimiento se mantiene aunque variando sus relaciones, donde en las etapas pre o postnatales existen diferentes ritmos de crecimiento.¹

Al analizar la curva de velocidad del crecimiento total se observa que se manifiesta muy rápido en los primeros meses de vida y disminuye progresivamente, ya que los incrementos anuales de crecimiento se hacen cada vez menores. Existe un ligero incremento en la curva de velocidad, llamado "el brote medio de crecimiento"¹ el cual ocurren en algunos niños entre los 6 y 8 años de edad.

Posteriormente, de los 13 a 15 años en hombres y 11 a 14 en mujeres, hay una aceleración marcada de crecimiento, llamada "el brote de crecimiento de la pubertad", "empujón de la pubertad" ó "pico de velocidad de estatura (PVE.)", en el que se observa una etapa de máximo crecimiento denominada "pico de velocidad de crecimiento (PVC.)"^{1,2}

Se han encontrado diferencias en las edades del crecimiento puberal entre los dos sexos. Taranger y Hägg³ en 1982 reportaron un estudio longitudinal de la población sueca encontraron que en promedio el brote de crecimiento puberal comenzaba a los diez años y finalizaba a los 14.8 en mujeres, mientras que en los hombres comenzaba a los 12.1 y finalizaba a los 17.1 años. En ambos sexos el P.V.E. ocurrió dos años después del inicio, a los 12 años en las mujeres y a los 14.1 en hombres.

1. Ortodoncista CES.

2. Odontopediatra CES.

OSSIFICATION OF EPIPHYSIAL CARTILAGES IN THE HAND

MILO HELLMAN

Research Associate in Physical Anthropology, American Museum of Natural History, New York

SIX PLATES (TWELVE FIGURES)

INTRODUCTION

This study was originally undertaken with the object in view of gaining a more intimate knowledge of the time when the epiphysial cartilages in the bones of the hand ossify. The bones of the hand were chosen merely as a matter of convenience, because they are readily accessible and easier to observe than any of the other bones in the skeletal system of the living. It was thought that, by gaining a clear idea of the time of ossification of these bones, data would be available for comparative studies in the development of other bones. It soon became evident that the matter was not quite as simple as thought of at first. The difference in time of the onset of the process, the manifold ways in which ossification takes place, and the variability in growth of the bones themselves added to the complexity of the problem.

It was then realized that, in order to reach a definite goal, it was necessary, first, to sort out the various phases in which the process appeared; secondly, to arrange them in the order of their manifestation, and, lastly, to subject them to measurements on the time scale of age. By this procedure it was possible to gain a clearer understanding of the relationship between the beginning of ossification and the different phases in which it appears, as well as the bearing of that relationship on the phenomenon as a whole. The following pages, therefore, present just a record of the observed facts, with

223

AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY, VOL. XI, NO. 2
JANUARY-MARCH, 1928

Osseous Development in the Hand as an
Index of Skeletal Development

CHARLES D. FLORY

STUDY NUMBER 1

COMMITTEE ON CHILD DEVELOPMENT

University of Chicago

Published by arrangement with
UNIVERSITY OF CHICAGO PRESS

RADIOGRAPHIC ATLAS OF
SKELETAL DEVELOPMENT
OF THE HAND AND WRIST

SECOND EDITION

WILLIAM WALTER GREULICH

Professor of Anatomy, Stanford University School of Medicine

S. IDELL PYLE

*Research Associate, Departments of Anatomy,
Western Reserve University and Stanford University Schools of Medicine*



Correlación en la determinación de la edad ósea radiológica mediante el método de Greulich y Pyle versus la evaluación automatizada utilizando el software BoneXpert

Correlation in radiological bone age determination using the Greulich and Pyle method versus automated evaluation using BoneXpert software

Georgette Pose Lepe^a, Fabián Villacrés^b, Claudio Silva Fuente-Alba^a, Stefan Guiloff^b

^aMédico Radiólogo Departamento de Imágenes - Clínica Alemana de Santiago

^bResidente Programa de Especialidad en Radiología Facultad de Medicina, Clínica Alemana de Santiago-Universidad del Desarrollo

Recibido el 6 de marzo de 2018; aceptado el 4 de junio de 2018

Resumen

Objetivo: Determinar el grado de correlación en la valoración de la edad ósea radiológica mediante el método de Greulich y Pyle versus la evaluación automatizada por el programa computacional BoneXpert® entre los años 2013-2016. **Material y Método:** Estudio de correlación de técnicas diagnósticas de 1500 radiografías de carpo para evaluar la edad ósea, en pacientes menores de 16 años pertenecientes a Clínica Alemana de Santiago. Las radiografías con evaluación de la edad ósea por el Atlas de Greulich y Pyle (GP) por 1 de 7 radiólogos pediatras fueron sometidas al programa BoneXpert (BE) para la evaluación automatizada de la edad ósea. Se tomó 100 casos al azar para un análisis/re-análisis del método BE, para conocer su precisión. Se analizó el nivel de correlación de las mediciones por coeficiente de correlación (r de Pearson) y la variabilidad de las mediciones mediante análisis de Bland-Altman. **Resultados:** Se incluyeron 1.493 casos, se excluyeron 7 por falla en técnica de la radiografía, 922 de sexo femenino (61.8%), mediana de edad cronológica 9.96 años y 11.12 años para los varones ($p < 0,001$). La correlación entre la edad ósea manual GP y la edad ósea automatizada BE entre los lectores varió entre 0,91 y 0,93. El análisis de Bland-Altman indicó una diferencia promedio entre la edad ósea manual y la edad ósea BE de 0,19 años (IC 0,13 a 0,25). En el análisis/re-análisis de 100 casos al azar mediante BoneXpert, la correlación fue de 1,0. **Conclusión:** El análisis automatizado mediante BoneXpert permite una evaluación estandarizada, de baja variabilidad, y alta concordancia.

Palabras clave:
Edad ósea;
Greulich y Pyle;
BoneXpert

Abstract

Objective: To determine the degree of correlation in the radiological bone age assessment using the Greulich and Pyle method versus automated assessment through BoneXpert® software between 2013 and 2016. **Material and Method:** Correlation study of diagnostic techniques of 1500 carpal X-rays

Keywords:
Bone age measurement;
Greulich and Pyle;
BoneXpert

Correspondencia:
Fabián Villacrés
fabianvillacresdr@gmail.com

Bone age assessment methods: A critical review

Arsalan Manzoor Mughal¹, Nuzhat Hassan², Anwar Ahmed³

SUMMARY

The bone age of a child indicates his/her level of biological and structural maturity better than the chronological age calculated from the date of birth. Radiography of the hand & wrist is the commonest modality used to calculate bone age. Automated methods for evaluation of hand and wrist radiographs are also being developed which reduce inter rater variability compared to manual methods. Non radiation based techniques of visualizing hand & wrist bones such as ultrasonography for bone age calculation have been theorized but are not as accurate as radiographic methods. By the age of 18 years, bone age cannot be computed from hand & wrist radiographs, therefore the medial end of the clavicle is used for bone age calculation in individuals aged 18–22 years. CT visualization of the clavicle has been extensively studied but requires a high dose of radiation. MRI based methods are being developed but require more research. Dental age is an alternate form of bone age determination, which also gives an estimate of skeletal maturity. The iliac bone and femoral head have also been studied for computation of bone age but no standardized methods have yet been generated.

As different modalities of bone age estimation provide different results and their applicability differs in different ethnicities, we need to design studies in order to compare them and select the method best suited to Pakistani children.

Sources of Data/Study Selection: Recent articles published between years 2004-2013 obtained from online search engines Pubmed and Google Scholar were used in preparation of this review.

KEY WORDS: Bone Age Measurement, Diagnostic X-Ray Radiology, Ultrasonic Diagnosis, Panoramic Radiography, Clavicle, Ilium, Femur Head.

doi: <http://dx.doi.org/10.12669/pjms.301.4295>

How to cite this:

Mughal AM, Hassan N, Ahmed A. Bone age assessment methods: A critical review. *Pak J Med Sci* 2014;30(1):211-215.

doi: <http://dx.doi.org/10.12669/pjms.301.4295>

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. Dr. Arsalan Manzoor Mughal, MBBS, M. Phil Candidate, Senior Lecturer, Department of Anatomy, Ziauddin University, Karachi, Pakistan.
2. Dr. Nuzhat Hassan, MBBS, M.Phil (Anatomy), Professor & Head of Anatomy Department, Ziauddin University, Karachi, Pakistan.
3. Dr. Anwar Ahmed, MBBS, FMRD, MD, FCPS, Associate Professor of Diagnostic Imaging Dr Ziauddin Hospital, North Nazimabad, Karachi, Pakistan.

Correspondence:

Dr. Arsalan Manzoor Mughal, MBBS, M. Phil Candidate, Senior Lecturer, Department of Anatomy, Ziauddin University, Karachi, Pakistan.
E-mail: arsalanmanzoor@gmail.com

- * Received for Publication: August 30, 2013
- * Revision Received: November 13, 2013
- * Revision Accepted: November 20, 2013

INTRODUCTION

Bone age is an indicator of the skeletal and biological maturity of an individual. This is different from chronological age, which is calculated using the date of birth of an individual. Bone age is often requested by pediatricians and endocrinologists for comparison with chronological age for diagnosing diseases which result in tall or short stature in children. Serial measurements are also used to assess the effectiveness of treatments for these diseases.¹ Formulae have also been designed for computing the final adult height of children from bone age values in normal healthy children.²

Calculation of bone age is also employed for estimation of chronological age in conditions where accurate birth records are not available. Absent

Radiographic Evaluation of Skeletal Maturation

A Clinically Oriented Method Based on Hand-Wrist Films

LEONARD S. FISHMAN

Dr. Fishman is in the private practice of orthodontics in Syracuse, N.Y. He also serves as a Clinical Associate in the Graduate Department of Orthodontics, Eastman Dental Center, Rochester, New York, and as Director of the Dental Cleft Palate Program at the Upstate New York Medical Center. He holds a D.D.S. degree from Temple University School of Dentistry in Philadelphia, and a Certificate in Orthodontics from The Eastman Dental Center.

Address:

Dr. Leonard S. Fishman
550 East Genesee Street
Syracuse, NY 13202

This paper was presented at the annual meeting of the North Atlantic Component of the Edward H. Angle Society in Boston in March, 1981 and at the Biennial National meeting of the Angle Society at Durango, Colorado in September, 1981.

A system for the evaluation of skeletal maturity from hand-wrist radiographs is developed and presented with complete details for implementation in clinical practice.

The clinical importance of evaluating skeletal maturation has long been recognized by the health professions. Skeletal maturation is an integral part of individual patterns of growth and development. Genetic and acquired abnormalities often lead to deviations in maturation. Secular trends are also evident, with successive generations becoming taller and reaching puberty at earlier ages.

Maturation variations are closely associated with variations in the timing and magnitude of growth.^{1-8,10-18} This study deals with the evaluation of skeletal maturation, and presents a system for clinical implementation of such an assessment.

Hand-wrist radiographs have been used for this purpose in many ways by many different investigators. The underlying premise is that the osseous changes seen in the hand and wrist are indicators of more general skeletal changes.

The concept of skeletal or bone age based on the hand-wrist film has been developed so that it can be compared with the individual's chronologic age.

Assessment of Skeletal Maturity
and Prediction of Adult Height
(TW2 Method)



TANNER · WHITEHOUSE · CAMERON · MARSHALL
HEALY · GOLDSTEIN

SECOND EDITION

Vicente Gilsanz
Osman Ratib

Hand Bone Age

A Digital Atlas
of Skeletal Maturity

CD-ROM



INCLUDED

 Springer

Skeletal Age Assessment Utilizing Cervical Vertebrae

Don G. Lamparski

University of Pittsburgh School of Dental Medicine, Pittsburgh, Pa.

The purpose of the study was to determine whether maturational changes of the cervical vertebrae, as recorded on routine lateral cephalometric radiograms, could be used to assess the skeletal age of an individual.

The method of Todd, as followed by Greulich and Pyle, was the best method of determining standards and assessing skeletal ages: hence, this method was used as the basis for the study.

The sample (cross-sectional) was selected from the files of more than 500 patients at the Orthodontic Department in the School of Dental Medicine. A total of seventy-two girls and sixty-nine boys (considered separately) were used in the selection of the standards. The sample was limited to Caucasians, and all subjects with past or present pathoses which could affect the vertebrae were eliminated.

The ages 10 through 15 were selected, as most orthodontic patients are in this group and also since most maturational changes occur during this period.

To select the standards, a group of lateral cephalometric films of persons whose chronologic and skeletal ages were ± 6 months from the age under study were arranged in sequence from the last to the most mature as based on vertebral



Inicio > Publicaciones > Año 2007

Metodo de maduración ósea de las vertebrae cervicales, en pacientes del Diplomado de Ortodoncia Interceptiva, UGAMA - 2006

- **Ortiz Mónica.** Odontólogo, instructor de la Cátedra de Ortodoncia de la Universidad Gran Mariscal de Ayacucho,
- **Godoy Sol.** Odontólogo, instructor de la Cátedra de Ortodoncia de la Universidad Gran Mariscal de Ayacucho,
- **Fuenmayor Dorathys.** Odontólogo, instructor de la Cátedra de Ortodoncia de la Universidad Gran Mariscal de Ayacucho,
- **Fariás Margarita,** Ortodoncista Jefe de la Cátedra de Ortodoncia de la Universidad Gran Mariscal de Ayacucho,
- **Quirós Oscar.** Ortodoncista, Prof. Titular, Jefe de la Cátedra y coordinador del postgrado de Ortodoncia de la Universidad Central de Venezuela
- **Rondón Sandra.** Ortodoncista, Prof colaborador Cátedra de Ortodoncia UCV, Cátedra de Ortodoncia, UGMA
- **Lerner Harry.** Ortodoncista, Prof colaborador Cátedra de Ortodoncia UCV, Cátedra de Ortodoncia, UGMA, USM.

RESUMEN

Para aprovechar al máximo el tratamiento de ortodoncia interceptiva con aparatos de ortopedia funcional de los maxilares es necesario reconocer los periodos de aceleración y crecimiento óseo, para de esa manera corregir desbalances esqueléticos. El método de análisis de las vértebras cervicales es en la actualidad utilizado como herramienta para evaluar la maduración del paciente en crecimiento.

El **Objetivo** de este estudio fue describir el método de maduración ósea de las vértebras cervicales, dar una valoración numérica a la clasificación de la profundidad de la concavidad del borde inferior y aplicarla en pacientes del diplomado de ortodoncia interceptiva, UGMA-2006.

Materiales y métodos: Se utilizaron 47 radiografías cefálicas laterales, sobre las cuales se trazaron contornos de las vértebras cervicales C2, C3 y C4; se marcaron puntos en cada una de ellas, se procedió a medir la distancia entre los mismos, se determinó la forma, y la profundidad de la concavidad creando un método para clasificarlas, luego se les clasificó en un estadio CVMS de maduración esquelética.

Skeletal maturation evaluation using cervical vertebrae

Brent Hassel, BA, DDS, MS,* and Allan G. Farman, BDS, PhD(odont), Dip ABOMR, EdS, MBA^b
Monterey, Calif., and Louisville, Ky.

Lateral cephalometric and left hand-wrist radiographs from the Bolton-Brush Growth Center at Case Western Reserve University were reviewed a posteriori to develop a cervical vertebrae maturation index (CVMI). By using the lateral profiles of the second, third and fourth cervical vertebrae, it was possible to develop a reliable ranking of patients according to the potential for future adolescent growth potential. (AM J ORTHOD DENTOFAC ORTHOP 1995;107:58-66.)

Sexual maturation characteristics, chronologic age, dental development, height, weight, and skeletal development are some of the more common means that have been used to identify stages of growth. Determination of maturation and subsequent evaluation of growth potential during pre-adolescence or adolescence is extremely important. With many orthodontic patients, pubertal growth needs to be factored into the diagnostic equation.

One important diagnostic tool currently used in determining whether the pubertal growth has started, is occurring, or has finished is the hand-wrist radiographic evaluation. Biologic age, skeletal age, bone age, and skeletal maturation are nearly synonymous terms used to describe the stages of maturation of a person. Because of individual variations on timing, duration and velocity of growth, skeletal age assessment is essential in formulating viable orthodontic treatment plans.

The primary objective of this study was to create a method of evaluating the skeletal maturation of the orthodontic patient with the cephalometric radiograph that is routinely taken with pretreatment records. Correlations were made between cervical vertebrae maturation and the skeletal maturation of the hand-wrist.

BACKGROUND

Skeletal maturation refers to the degree of development of ossification in bone. Size and maturation can vary independently of each other. Skeletal maturation is more closely related to sexual maturity than to stature.¹⁻⁵

The views expressed herein by the authors are not necessarily those of the Department of Defense or the U.S. Government.

*Lieutenant Colonel, U.S. Army Dental Corp, Monterey, Calif.

^bProfessor of Radiology & Imaging Sciences, University of Louisville School of Dentistry.

8/1/47789

During growth, every bone goes through a series of changes that can be seen radiologically. The sequence of changes is relatively consistent for a given bone in every person. The timing of the changes varies because each person has his or her own biologic clock. There are some exceptions, but generally speaking, the events are reproducible enough to provide a basis for comparison between different persons.⁶⁻⁹

Many authors have shown that significant correlation exists between facial and statural growth. Statural growth acceleration generally precedes facial growth acceleration by 6 to 12 months.¹⁰⁻²⁰

Hand-wrist radiographic evaluation

After Roentgen demonstrated his new radiographic discovery in 1895, Roland, in 1896, introduced the idea of using the comparative size and shape of the radiographic shadows of growing bones as indicators of rate of growth and maturity.²¹

In the early 1900s, Pryor,²² Rotch,²³ and Crampton²⁴ began tabulating indicators of maturity on sequential radiographs of the growing hand and wrist. Hellman published his observations on the ossification of epiphysal cartilages of the hand in 1928.²⁵

Todd²⁶ compiled hand-wrist data that was further elaborated on by Greulich and Pyle in atlas form.⁶ Flory, in 1936, indicated that the beginning of calcification of the carpal sesamoid (adductor sesamoid) was a good guide to determining the period immediately before puberty.²⁷ The appearance of the adductor sesamoid has been highly correlated to peak height velocity and the start of the adolescent growth spurt.^{11-13,28-34} Most authors agree that peak height velocity follows adductor sesamoid appearance by approximately 1 year.

Fishman developed a system of hand-wrist skel-

The Cervical Vertebral Maturation (CVM) Method for the Assessment of Optimal Treatment Timing in Dentofacial Orthopedics

Tiziano Baccetti,^{*,†} Lorenzo Franchi,^{*,†} and James A. McNamara, Jr.^{†,‡,§}

The present study introduces a further modified version of the Cervical Vertebral Maturation (CVM) method for the detection of the peak in mandibular growth, based on the analysis of the second through fourth cervical vertebrae in a single cephalogram. The morphology of the bodies of the second (C2 –odontoid process), third (C3), and fourth (C4) cervical vertebrae were analyzed in 6 consecutive cephalometric observations (T₁ through T₆) of 30 orthodontically untreated subjects. Observations for each subject consisted of two consecutive cephalograms comprising the interval of maximum mandibular growth (as assessed by means of the maximum increment in total mandibular length, Condylion –Gnathion: Co-Gn), together with two earlier consecutive cephalograms and two later consecutive cephalograms. The analysis consisted of both visual and cephalometric appraisals of morphological characteristics of the three cervical vertebrae. The construction of this new modified version of the CVM method was based on the results of both ANOVA for repeated measures with post hoc Scheffé's test ($P < 0.05$) and discriminant analysis. The new clinically improved CVM method is comprised of six maturational stages (cervical stage 1 through cervical stage 6, ie, CS1 through CS6). CS1 and CS2 are prepeak stages; the peak in mandibular growth occurs between CS3 and CS4. CS6 is recorded at least 2 years after the peak. The use of the CVM method enables the clinician to identify optimal timing for the treatment of a series of dentoskeletal disharmonies in all three planes of space.

Semin Orthod 11:119–129 © 2005 Elsevier Inc. All rights reserved.

In the organization, differentiation, development, and growth of any somatic structure, time plays a crucial role in determining the final morphological and dimensional result. In orthodontics and dentofacial orthopedics, it is becoming increasingly evident that the timing of the treatment onset may be as critical as the selection of the specific treatment protocol, as will be discussed below. By beginning a protocol at the individual patient's optimal maturational stage, the most favorable response with the least potential morbidity can be anticipated.

The issue of optimal timing for dentofacial orthopedics is linked intimately to the identification of periods of accel-

erated growth that can contribute significantly to the correction of skeletal imbalances in the individual patient. Cephalometric investigations on longitudinal samples have identified a pubertal spurt in mandibular growth that is characterized by wide individual variations in onset, duration, and rate.¹⁻⁶ Individual skeletal maturity can be assessed by means of several biologic indicators: increase in body height¹⁻³; skeletal maturation of the hand and wrist⁷⁻¹⁰; dental development and eruption^{8,11,12}; menarche or voice changes^{9,13,14}; and cervical vertebral maturation.^{15,16} The biologic indicators of skeletal maturity refer mainly to somatic changes at puberty, thus emphasizing the strict interactions between the development of the craniofacial region and the modifications in other body regions.

The reliability and efficiency of a biologic indicator of skeletal maturity can be evaluated with respect to several fundamental requisites.¹⁷ An "ideal" biologic indicator of individual mandibular skeletal maturity should be characterized by at least five features.

1. Efficacy in detecting the peak in mandibular growth. The method should present with a definite stage or

*Department of Orthodontics, University of Florence, Florence, Italy.

†Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor, MI.

‡School of Medicine, University of Michigan, Ann Arbor, MI.

§Center for Human Growth and Development, University of Michigan, Ann Arbor, MI.

Address correspondence to Tiziano Baccetti, DDS, PhD, Università degli Studi di Firenze, Via del Ponte di Mezzo, 46-48, 50127, Firenze, Italy. E-mail: t.baccetti@odonto.unifi.it

Radiographic Assessment of Skeletal Maturation Stages for Orthodontic Patients: Hand-wrist Bones or Cervical Vertebrae?

Eddie Hsiang-Hua Lai,^{1,2,3} Jen-Pei Liu,⁴ Jenny Zwei-Chieng Chang,^{1,2,3} Shih-Jaw Tsai,^{1,2,3} Chung-Chen Jane Yao,^{1,2,3} Mu-Hsiung Chen,³ Yi-Jane Chen,^{1,2,3*} Chun-Pin Lin^{2,3}

Background/Purpose: The skeletal maturation status of a growing patient can influence the selection of orthodontic treatment procedures. Either lateral cephalometric or hand-wrist radiography can be used to assess skeletal development. In this study, we examined the correlation between the maturation stages of cervical vertebrae and hand-wrist bones in Taiwanese individuals.

Methods: The study group consisted of 330 male and 379 female subjects ranging in age from 8 to 18 years. A total of 709 hand-wrist and 709 lateral cephalometric radiographs were analyzed. Hand-wrist maturation stages were assessed using National Taiwan University Hospital Skeletal Maturation Index (NTUH-SMI). Cervical vertebral maturation stages were determined by the latest Cervical Vertebral Maturation Stage (CVMS) Index. Spearman's rank correlation was used to correlate the respective maturation stages assessed from the hand-wrist bones and the cervical vertebrae.

Results: The values of Spearman's rank correlation were 0.910 for males and 0.937 for females, respectively. These data confirmed a strong and significant correlation between CVMS and NTUH-SMI systems ($p < 0.001$). After comparison of the mean ages of subjects in different stages of CVMS and NTUH-SMI systems, we found that CVMS I corresponded to NTUH-SMI stages 1 and 2, CVMS II to NTUH-SMI stage 3, CVMS III to NTUH-SMI stage 4, CVMS IV to NTUH-SMI stage 5, CVMS V to NTUH-SMI stages 6, 7 and 8, and CVMS VI to NTUH-SMI stage 9.

Conclusion: Our results indicate that cervical vertebral maturation stages can be used to replace hand-wrist bone maturation stages for evaluation of skeletal maturity in Taiwanese individuals. [*J Formos Med Assoc* 2008;107(4):316-325]

Key Words: cervical vertebrae, hand-wrist radiography, lateral cephalometric radiography, skeletal maturation

In orthodontics and dentofacial orthopedics, the skeletal maturation status of a growing patient influences the selection and execution of treatment procedures. Favorable orthopedic effects for patients with mandibular retrognathism only occur when the treatment begins at his or her optimal maturation stage. Whereas, it is recommended

that the best time for correction of mandibular prognathism is after the completion of mandibular growth.

Considerable variations in the development among individuals of the same chronological age have led to the concept of assessing biological or physiological maturity. Several biological indicators

©2008 Elsevier & Formosan Medical Association



ELSEVIER

¹Department of Orthodontics, ²School of Dentistry, ³Dental Department, National Taiwan University Hospital and National Taiwan University College of Medicine, and ⁴Department of Agronomy, College of Bioresources and Agriculture, National Taiwan University, Taipei, Taiwan.

Received: November 13, 2007

Revised: December 7, 2007

Accepted: January 15, 2008

*Correspondence to: Dr Yi-Jane Chen, School of Dentistry, College of Medicine, National Taiwan University, 1 Chang-Te Street, Taipei 100, Taiwan.

E-mail: lcyj@ntu.edu.tw

Quantitative cervical vertebral maturation assessment in adolescents with normal occlusion: A mixed longitudinal study

Li-Li Chen,^a Tian-Min Xu,^b Jiu-Hui Jiang,^c Xing-Zhong Zhang,^c and Jiu-Xiang Lin^d
Wuhan and Beijing, China

Introduction: The purpose of this study was to establish a quantitative cervical vertebral maturation (CVM) system for adolescents with normal occlusion. **Methods:** Mixed longitudinal data were used. The subjects included 87 children and adolescents from 8 to 18 years old with normal occlusion (32 boys, 55 girls) selected from 901 candidates. Sequential lateral cephalograms and hand-wrist films were taken once a year for 6 years. The lateral cephalograms of all subjects were divided into 11 maturation groups according to the Fishman skeletal maturity indicators. The morphologic characteristics of the second, third, and fourth cervical vertebrae at 11 developmental stages were measured and analyzed. **Results:** Three characteristic parameters (H4/W4, AH3/PH3, @2) were selected to determine the classification of CVM. With 3 morphologic variables, the quantitative CVM system including 4 maturational stages was established. An equation that can accurately estimate the maturation of the cervical vertebrae was established: $CVM\ stage = -4.13 + 3.57 \times H4/W4 + 4.07 \times AH3/PH3 + 0.03 \times @2$. **Conclusions:** The quantitative CVM method is an efficient, objective, and relatively simple approach to assess the level of skeletal maturation during adolescence. (*Am J Orthod Dentofacial Orthop* 2008;134:720.e1-720.e7)

Bone age, as determined by hand-wrist radiographs and the Fishman skeletal maturity indicators (SMI), is a popular and reliable approach for evaluating skeletal maturation in orthodontic clinical practice.¹⁻³ However, this method requires a hand-wrist radiograph. Recently, the use of cervical vertebral maturation (CVM) has gained increasing interest as a valid replacement for hand-wrist evaluation.⁴⁻⁷ The main advantage of the CVM evaluation is that it can be done with a conventional lateral cephalogram (LCR); this avoids the extra radiation exposure of a hand-wrist radiograph.

Evaluation of the maturational stages in the cervical vertebrae was originally developed by Lamparski⁸ and

successively implemented by O'Reilly and Yanniello⁹ and Baccetti et al.¹⁰ Nevertheless, almost all previous classifications with cervical vertebrae either used or referred to the atlas of Lamparski.⁸ Compared with the hand-wrist evaluation, the cervical vertebrae have few indicators of skeletal maturity. The special signs of morphologic changes during growth are not as unique and identifiable as those of the hand and wrist, so that it is subjective and more difficult to evaluate the CVM by an atlas such as the hand-wrist radiograph. However, the shape and size of the vertebral bodies are relatively similar and regular, so it is feasible to evaluate skeletal maturation qualitatively and quantitatively by measuring parameters of the vertebral bodies.

To make the CVM analysis easier and more applicable to most patients, the following improvements will be needed: (1) use fewer vertebral bodies and more sensitive parameters to perform the staging, and the parameters should be only in the cervical vertebrae (C2-C4) that can be seen when the patient wears a protective radiation collar; and (2) avoid estimating the stages based on a comparative assessment of between-stage changes, and each stage should be identified easily in 1 cephalogram.

This study was conducted to accomplish these objectives. We established a quantitative CVM (QCVM) system. Every period of the QCVM has its definitive quantitative standard so that the skeletal maturation level can be evaluated both qualitatively and quantitatively.

^aClinical associate professor, Department of Stomatology, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan; formerly postgraduate student, Department of Orthodontics, Peking University School and Hospital of Stomatology, Beijing, China.

^bProfessor and chairman, Department of Orthodontics, Peking University School and Hospital of Stomatology, Beijing, China.

^cClinical associate professor, Department of Orthodontics, Peking University School and Hospital of Stomatology, Beijing, China.

^dProfessor, Department of Orthodontics; director, Research Center of Craniofacial Growth and Development, Peking University School and Hospital of Stomatology, Beijing, China.

Reprint requests to: Jiu-Xiang Lin, Department of Orthodontics, Peking University School and Hospital of Stomatology, #22 ZhongGuanCun South St, HaiDian District, Beijing 100081, China; e-mail, jxlin@pku.edu.cn.

Submitted, November 2007; revised and accepted, March 2008.

0889-5406/534.00

Copyright © 2008 by the American Association of Orthodontists.

doi:10.1016/j.ajodo.2008.03.014

Maturation indicators and the pubertal growth spurt



Dr. Hägg

Urban Hägg, D.D.S., Odont. Dr.,* and John Taranger, Dr. Med.**

Malmö and Göteborg, Sweden

The pubertal growth spurt and dental, skeletal, and pubertal development have been investigated in a prospective longitudinal study of 212 randomly selected Swedish children by means of maturation level indicators suitable for use in clinical orthodontics. The sample was examined from birth to adulthood and included a representative proportion of early-, average-, and late-maturing subjects. The number of dropouts and missing examinations was low and was allowed for in the statistical analysis. The results may therefore be considered representative for Swedish children. There was a 2-year sex difference in age at the beginning, peak, and end of the pubertal growth spurt in standing height. The individual variation was about 6 years at each event in both sexes. Dental development in relation to the pubertal growth spurt was more advanced in boys than in girls, but the individual variation was great in both sexes. Skeletal development at the beginning and peak was more advanced in girls than in boys, whereas at the end of the pubertal growth spurt the skeletal development was more advanced in boys. Dental development, determined by means of dental emergence stages (DES), was not useful as an indicator of the pubertal growth spurt. The peak and end—but not the beginning—of the pubertal growth spurt could be assessed by means of indicators taken from the skeletal development of the hand and wrist and the pubertal development (menarche and voice change).

Key words: Orthodontics, maturity indicator, pubertal growth spurt, dental development, skeletal development, pubertal development

Every skeletal and muscular dimension seems to be involved in the pubertal growth spurt.¹ The pubertal growth spurt is considered to be an advantageous period for certain types of orthodontic treatment and should be taken into account in connection with orthodontic treatment planning.²⁻⁵

Because of the wide individual variation in the timing of the pubertal growth spurt, chronologic age cannot be used in the evaluation of pubertal growth. Many studies have shown a strong correlation between the peak of facial growth and peak height velocity.^{3, 6-9} Longitudinal records of height can therefore be used for evaluation of the facial growth rate during puberty. In the clinical context, longitudinal growth records of height are seldom available. Even with adequate records, it may be difficult to locate the pubertal growth spurt before it is passed, since the increase in growth rate is often too small, especially in many girls, to be clinically discernible. Most of the time the clinician must base his judgment on a single examination and,

therefore, determine the status of the individual by cross-sectional evaluation alone.

Stature is not an indicator of maturity. Thus, additional information is necessary to estimate the maturation level of the individual. Such information can be obtained from the dental, skeletal, and pubertal development. By comparing with standards for age and sex, it is possible to assess whether the development of the individual is average, accelerated, or retarded. In orthodontics it is more relevant to evaluate the individual's maturation in relation to his or her own pubertal growth spurt. This presupposes knowledge of relationships in time between maturation indicators and pubertal growth events. Suitable maturation indicators for clinical orthodontics have been devised,¹⁰⁻¹² and the associations between these indicators and the peak of growth have been reported.^{3, 10, 12-19}

In samples that have not been followed during a sufficiently long period, especially early and/or late maturers are likely to be underrepresented. Furthermore, in any longitudinal study a substantial number of dropouts is inevitable. Since the dropout rate increases with time, the proportion of early, average, and late maturers in whom the growth events and maturation indicators are determined is very likely to be biased. As

*Department of Orthodontics, Faculty of Odontology, University of Lund, S-214 21 Malmö, Sweden.

**Department of Pediatrics I, University of Gothenburg, East Hospital, S-416 85 Göteborg, Sweden.

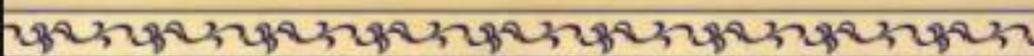
Comparative Study > J Clin Orthod. 2002 Jul;36(7):398-406.

A comparison of modified MP3 stages and the cervical vertebrae as growth indicators

R Rajagopal ¹, Sudhanshu Kansal

Affiliations + expand

PMID: 12165981



Skeletal Maturity:
The Knee Joint as a
Biological Indicator

Roche, Alex F.

ASSESSING THE SKELETAL MATURITY OF THE HAND-WRIST: FELS METHOD

By

ALEX F. ROCHE
M.D., PH.D., D.Sc., F.R.A.C.P.

*Fels Professor of Pediatrics and of Obstetrics
and Gynecology, Wright State University*

Wm. CAMERON CHUMLEA, Ph.D.

*Fels Association Professor of Pediatrics
Wright State University*

and

DAVID THISSEN, Ph.D.

*Professor of Psychology
University of Kansas*

This book presents an easy-to-learn and quick-to-apply method for assessing skeletal maturity of the hand-wrist. This thoroughly-tested method—the result of a 13-year research effort—will be of inestimable value to all professionals whose work involves the physical maturation of children. The authors open the text with a review of the literature and a general discussion of maturity and its assessment. Subsequent chapters examine materials and methods; hand-wrist maturity indicators; procedures for the application of the FELS method; findings with this method including levels and distribution, sex differences, replicability, comparisons with other methods, co-efficients of reliability, and prediction of adult stature. Rounding out the text are appendices containing information on the statistical basis of the FELS method, the recording form, and a computer program for skeletal maturity estimation.

CHARLES C THOMAS • PUBLISHER • SPRINGFIELD • ILLINOIS • U.S.A.

ORIGINAL COMMUNICATION

Epiphyseal Maturity Indicators at the Knee and Their Relationship to Chronological Age: Results of an Irish Population Study

JEAN E. O'CONNOR,^{1*} JOSEPH COYLE,² LIAM D. SPENCE,² AND JASON LAST¹

¹UCD School of Medicine and Medical Science, Dublin, Ireland

²Division of Radiology, Cork University Hospital, Cork, Ireland

Skeletal maturation is divisible to three main components; the time of appearance of an ossification center, its change in morphology and time of fusion to a primary ossification center. With regard to the knee, the intermediate period between appearance and fusion of the ossification centers extends over a period of greater than 10 years. This study aims to investigate radiographically the age at which morphological changes of the epiphyses at the knee occur in a modern Irish population. Radiographs of 221 subjects (137 males; 84 females) aged 9–19 years were examined. Seven nonmetric indicators of maturity were assessed using criteria modified from the Roche, Wainer, and Thissen method and Pyle and Hoerr's atlas of the knee. Reference charts are presented which display the timeline for each of the grades of development of the seven indicators. Mean age was found to increase significantly with successive grades of development of each of the seven indicators. A significant difference was noted between males and females at the same grade of development for six of the seven indicators. The narrowest age range reported for a single grade of development was 2.2 years for Grade 2 of development of the tibial tuberosity for males. The information on changing morphology of the epiphyses at the knee in the present study may provide an adjunct to methods used for evaluation of skeletal maturity before surgery for orthopedic disorders or to evaluate skeletal age in clinical scenarios where either delayed or precocious skeletal maturation is suspected. *Clin. Anat.* 00:000–000, 2012. © 2012 Wiley Periodicals, Inc.

Key words: skeletal maturation; epiphysis; knee; radiographs; age estimation; orthopedics

INTRODUCTION

There are three processes during the continuum of skeletal maturation from the immature state to the mature state, which are useful for age estimation. First, numerous studies record the time of appearance of ossification centers which in most cases follow a set schedule and sequence (Pryor, 1925; Francis, 1940; Buehl and Pyle, 1942; Lurie et al., 1943; Pyle and Sontag, 1943; Greulich and Pyle, 1959; Garn and Rohmann, 1960; Roche, 1970). Second, from the time of appearance of a secondary ossification center to the time at which it becomes fused to a primary center, to produce what we know as the adult form of

a bone, the center undergoes a number of morphological changes. Third, the time at which the epiphysis fuses to the diaphysis is also well documented (McKern and Stewart, 1957; Albert and Maples,

*Correspondence to: Jean E. O'Connor, UCD School of Medicine and Medical Sciences, C209 Health Sciences Centre, University College Dublin, Belfield, Dublin 4, Ireland.
E-mail: jean.oconnor@ucd.ie

Received 12 November 2010; Revised 30 June 2011; Accepted 25 May 2012

Published online in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/ca.22122

Assessment of skeletal maturation based on cervical vertebrae in CBCT

Évaluation de la maturation squelettique à l'aide des vertèbres cervicales et par CBCT

Jocelyne J. SHIM, Gisecon HEO, Manuel O. LAGRAVÈRE*

Room 5-524, Edmonton Clinic Health Academy, Department of Dentistry, University of Alberta, 11405 – 87, Avenue NW, Edmonton, AB T6G 1C9, Canada

Available online: 31 October 2012 / Disponible en ligne : 31 octobre 2012

Summary

Diagnosis of skeletal age in adolescents helps orthodontists select and time treatments. Currently this is done using lateral cephalometric radiographs. This study evaluates the application of the conventional method in cone-beam computer tomographic (CBCT) images to bring forth assessment of skeletal maturation in three-dimensions. Ninety-eight lateral cephalometric radiographs and CBCT scans were collected from orthodontic patients between 11 to 17 years of age over an 18-month period. CBCT scans were examined in seven sagittal slices based on cervical vertebral maturation staging (CVMS). Collected CVMS values were compared with those from corresponding lateral cephalometric radiograph. CVMS measured from CBCT and lateral cephalometric radiographs were the same on average. However, they were not consistent with each other and scored interclass correlation coefficient of 0.155 in validity test. Interoperator reliability was weak (0.581). Adaptation of cervical vertebrae maturation staging in CBCT requires further clarifications or modifications to become consistent with lateral cephalometric examinations and to become a reliable method. Alternatively, a completely new method may be developed consisting of maturational indicators or landmarks unique to CBCT imaging.

© 2012 CEO. Published by Elsevier Masson SAS. All rights reserved

Résumé

Le diagnostic de l'âge squelettique permet aux orthodontistes de mieux choisir et programmer leurs traitements. À l'heure actuelle, ce diagnostic est basé sur des radiographies céphalométriques latérales. Cette étude évalue l'utilisation de la méthode conventionnelle en tomographie volumique à faisceau conique (CBCT) pour produire des images permettant l'évaluation tridimensionnelle de la maturation squelettique. Quarante-deux radiographies céphalométriques et scanners CBCT ont été réalisés sur des patients orthodontiques âgés de 11 à 17 ans durant une période de 18 mois. Des scanners CBCT ont été analysés en sept coupes sagittales à l'aide du système de stadification de la maturation des vertèbres cervicales (CVMS). Les valeurs CVMS recueillies ont été comparées aux valeurs correspondantes obtenues par radiographie céphalométrique latérale. Les moyennes des stades CVMS mesurés par CBCT et par radiographie céphalométrique latérale étaient les mêmes. Cependant, il n'y avait pas de cohérence parfaite entre les deux systèmes et un test de validité a montré un coefficient de corrélation interclasses de 0,155. La fiabilité interopérateur était faible (0,581). L'adaptation du système de stadification de la maturation squelettique à partir des vertèbres cervicales a besoin d'être clarifiée ou modifiée afin de permettre une correspondance exacte avec les examens réalisés par céphalométrie latérale et de fournir une méthode fiable. Autrement, on pourrait envisager la mise au point d'une méthode totalement originale spécifique à l'imagerie CBCT basée sur des indicateurs ou repères de maturité.

© 2012 CEO. Édité par Elsevier Masson SAS. Tous droits réservés

* Correspondence and reprints / Correspondance et tirés à part.

e-mail address / Adresse e-mail : mlagravere@ualberta.ca (Manuel O. Lagravère)



Accurate Age Determination for Adolescents Using Magnetic Resonance Imaging of the Hand and Wrist with an Artificial Neural Network-Based Approach

Fuk Hay Tang^{1,2} · Jasmine L.C. Chan² · Bill K.L. Chan²

Published online: 15 October 2018
© Society for Imaging Informatics in Medicine 2018

Abstract

This study proposes an accurate method in assessing chronological age of the adolescents using a machine learning approach using MRI images. We also examined the value of MRI with Tanner-Whitehouse 3 (TW3) method in assessing skeletal maturity. Seventy-nine 12–17-year-old healthy Hong Kong Chinese adolescents were recruited. The left hand and wrist region were scanned by a dedicated skeletal MRI scanner. T1-weighted three-dimensional coronal view images for the left hand and wrist region were acquired. Independent maturity indicators such as subject body height, body weight, bone marrow composition intensity quantified by MRI, and TW3 skeletal age were included for artificial neural network (ANN) analysis. Our results indicated that the skeletal age was generally underestimated using TW3 method, and significant difference ($p < 0.05$) was noted for skeletal age with chronological age for female category and at later stage of adolescence (15 to 17 years old) in both genders. In our proposed machine learning approach, ages determined by ANN method agreed well with chronological age ($p > 0.05$). The machine learning approach using ANN method was about 10-fold more accurate than the TW3 method using MRI alone. It offers a more objective and accurate solution for prospective chronological maturity assessment for adolescents.

Keywords Skeletal maturity · Chronological age · Machine learning · Magnetic resonance imaging · Artificial neural networks

Introduction

Age determination of children is essential in clinical considerations in areas such as pediatrics, orthodontics, forensic sciences, and anthropology [1–3]. On the other hand, genetic, hormonal, racial, environmental, and nutritional differences may lead to an inconsistency between the chronological age of young individuals and their physiological maturity [4]. Furthermore, in age-related tournaments for young adults and adolescents, it is important to guarantee fair play for different age groups. However, in cases where there is no accurate birth registration record of the participating players, reliable age estimation is critical. Furthermore, growth rate changes of adolescents can be well monitored if a reliable

chronological age determination based on physiological parameters is guaranteed. Recent studies indicated that magnetic resonance imaging (MRI) of the skeletal maturity alone was not related to chronological age and was not recommended for age determination for young athletes [1, 2]. It seems that other parameters may need to be included for a more accurate age determination in addition to imaging of bony features.

The traditional studies of skeletal age determination by using either the Greulich and Pyle (GP) or the Tanner-Whitehouse (TW) method [5] where the left hand and wrist X-ray images of the subject were taken involved ionizing radiation. The MRI is radiation free, and it renders an excellent contrast of anatomical features with high reproducibility [6–9]. When radiation is a concern for children screening without clinical indications, it offers a good solution for prospective study of skeletal maturity [6]. On the other hand, the artificial neural network (ANN) method was one of the machine learning techniques and has been used for simulating the role of radiologists for assessing the bone maturity through extensive training. Wikipedia indicated that “Artificial neural networks (ANNs)....are systems inspired by the biological neural networks that constitute animal brains. Such systems learn (progressively improve performance on) tasks by

✉ Fuk Hay Tang
haytang@gmail.com

¹ School of Medical and Health Sciences, Tung Wah College, 31 Wylie Road, Homantin, Kowloon, Hong Kong

² Department of Health Technology and Informatics, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

Correlation between chronological age, cervical vertebral maturation and Fishman's skeletal maturity indicators in Chennai population

Dinesh Babu^{*}, Balashanmugam Baskaranarayanan^b, Karunanidhi^c, Manonmani Arumugam^d

^{*} Assistant Professor, ICH&HC, Chennai, ^b Professor, Department of Orthodontics and Dentofacial Orthopedics, Tamilnadu Government Dental College and Hospital, Chennai, India, ^c Dean, Madha Dental College and Hospital, Kundrathur, Chennai,

^d Private Practitioner, Bengaluru

Abstract

This was a study conducted in the Department of Orthodontics and Dentofacial Orthopaedics at Government Dental College & Hospital. The study was designed to determine the correlation between chronological age, cervical vertebrae maturation and Hand - Wrist maturation stages in Chennai population. The study included a total of 500 patients (250 males and 250 females) belonging to age group of 9 to 16 years.

The results indicated that there was a high correlation between chronological age and stage V in Hand -Wrist; and maturation stage in Cervical Vertebrae ($p=0.018$), whereas low correlation was seen between chronological age and other stages in both Hand-Wrist and cervical vertebrae stages. This led to the conclusion that chronological age, taken alone is a poor indicator of skeletal maturity, and should be supplemented with the analysis of hand wrist and cervical vertebral maturation.

Key words: Hand-wrist radiograph, cervical vertebrae maturation, chronological age, circumpubertal period

Introduction

Growth events and maturational status have a considerable influence on diagnosis, treatment planning and outcome of orthodontic treatment. Although growth events usually proceed in a fairly predictable sequence, their timing is quite variable among individual children. The developmental status of a child is best estimated relative to specific stages of physiologic maturity. These methods included sexual maturation characteristics^{1,2}, facial growth and peak height velocities, chronological age³, dental development⁴, body height^{5,6}, body weight⁶, and hand wrist maturity^{7,10}.

It has been clearly demonstrated that chronological age alone provides little insight or validity for identifying the stages of developmental progression through adolescence to adulthood^{11,12}. During growth, bone goes through a series of changes that can be seen radiologically. These events are generally reproducible to provide a basis for comparison between different persons. The use of skeletal age has been shown to be more reliable and precise than chronological age in assessing the progress towards maturity. The hand-wrist radiographs is one of the widely used method to assess skeletal age, more specifically to assess the peak of growth spurts in orthodontic clinics^{13,14}. The MP-3 method provides information similar to that of the hand-wrist to evaluate the developmental status of patients.

The cervical vertebral maturation (CVM) in the lateral cephalometric radiographs had been evaluated for its correlation to the skeletal maturity as an alternative to the hand-wrist radiograph¹⁵ as no extra radiograph is required. The lack of

association among maturity indices warrants a study for the evaluation of biologic systems and its relationship to the indices. This study aimed at formulating the correlation between chronological age, cervical vertebral maturation and hand wrist radiographs in the population of Chennai subjects within 9-16 years.

Materials and methods

The sample of the study consisted of the hand wrist radiographs and lateral cephalograms of 250 males and 250 females of age range 9-16 years obtained from the record files at Tamilnadu Government dental college and Hospital, Chennai.

The radiographs of the left hand were taken within the circumpubertal period. They did not have any history of previous orthodontic treatment and the bones were unaffected by any systemic disease. The bones appeared clearly in the radiograph and the interval between the hand wrist and the lateral cephalometric radiograph did not exceed 1 month.

Cervical vertebral maturation (CVM)

The CVM was located on the lateral cephalometric radiograph and its developments in the subjects were studied by the modifications suggested by Hassel and Farman¹⁶, which assessed the maturational stages on the second, third and fourth cervical vertebrae.

Initiation:

- ξ Inferior borders of C2, C3, and C4 are flat
- ξ Vertebrae are wedge shaped and superior vertebral borders are tapered from posterior to anterior.
- ξ Very significant amount of adolescent growth is expected

Acceleration:

- ξ Significant amount of adolescent growth is expected

Corresponding author

Dr. Balashanmugam Baskaranarayanan
8-B, Crescent Road, Shenoy Nagar
Chennai- 600 030,
Tamilnadu, India.
E-Mail: balasorthodontics@gmail.com

Comparative Evaluation of the Efficacy of Hand-Wrist and Cervical Vertebrae Radiography for the Determination of Skeletal Age

Mohammadhashem Hoseini,¹ Sara Zamaheni,² Hourieh Bashizadeh Fakhari,³ Fough Akbari,⁴ Javad Chalipa,¹ and Afsaneh Rahmati^{2,7}

¹Department of Orthodontic, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

²Department of Endodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

³Department of Radiology, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran

⁴Department of Pediatrics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

*Corresponding author: Afsaneh Rahmati, Department of Endodontics, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran. Tel: +98-2122403080, Fax: +98-2122403194, E-mail: drrahmati@gmail.com

Received 2014 September 10; Revised 2015 May 27; Accepted 2015 June 20.

Abstract

Background: Prediction of skeletal growth is necessary for growth modification and surgical orthodontic treatments and is usually done by assessing skeletal maturity indicators in hand-wrist radiographs. The use of growth stages of cervical vertebrae in lateral cephalograms has been suggested to avoid overexposure.

Objectives: This study seeks to assess the degree of agreement between hand-wrist and cervical vertebrae maturation stages for skeletal age determination and prediction of the peak growth spurt (PGS).

Patients and Methods: This cross-sectional study was conducted with 67 boys and 66 girls between 8 and 18 years of age, divided into 11 age groups; 266 hand-wrist radiographs and lateral cephalograms were obtained and analyzed. Hand-wrist maturation stages were evaluated according to the Grave and Brown, Bjork system (stages 1 - 9). The cervical vertebral maturation stage (CVMS) was determined on lateral cephalograms based on a system described by Baccetti et al. (CVMS1-5). To apply the Cohen's kappa index, the stages of growth were reduced to 5 intervals (A - E) to relate the 5 CVMS to the 9 stages of Bjork hand-wrist analysis.

Results: In all age groups, the skeletal maturity stages of the hand and wrist bones and the cervical vertebrae of the girls were ahead of the boys. Cohen's kappa test revealed a low level of agreement between the two methods [Kappa (95% CI) = 0.312 (0.290 - 0.377)]; concordance was slightly higher in males (K = 0.33 for males versus 0.27 for females). Evaluation of concordance coefficients between the stages determined by the two methods indicated the highest concordance in 8- and 9-year-olds and the lowest in 12- and 14-year-olds. The level of agreement between the two methods was only acceptable in 8- and 9-year-olds of both genders and 10-year-old boys. The level of agreement between the two methods in other age groups was not acceptable.

Conclusion: The level of agreement between the two methods was low; thus, they cannot be used alternatively to estimate patients' skeletal age or to predict the PGS. This may be due to the effect of different maturation levels (influenced by the environment, ethnicity, and gender) on the agreement between methods for skeletal age determination.

Keywords: Growth, Hand, Wrist, Cervical Vertebrae, Skeletal Age

1. Background

The prediction of facial growth may be the most critical aspect of clinical orthodontics for a large number of patients. Although the number of adult orthodontic patients has increased in recent years, most orthodontic treatments are provided to prepubertal and pubertal patients (1).

Growth modification appliances such as functional appliances and extra-oral devices (namely headgear, face masks, Herbst appliances, etc.) should be used during the peak velocity of growth. On the contrary, orthognathic surgery can be performed only after the pubertal growth

spurt because considerable post-surgical growth can cause relapse. Significant mandibular growth occurs during the peak growth spurt (PGS). PGS depends on gender and the chronological age of patients; it usually occurs between the ages of 10 - 12 years in girls and 12 - 14 years in boys. The growth periods mentioned are the most important for orthodontic treatments. Studies have shown that chronological age alone is not sufficient for the assessment and prediction of mandibular growth or the degree of skeletal maturation, which is the most important indicator of mandibular growth (2-8).

In orthodontics, skeletal age is used to determine the

Evaluation of skeletal maturity in North Indian subjects using an objective method based on cervical vertebral bone age and assessment of its reliability as compared to hand wrist radiographic method

Sandeep Kumar¹, Neeraj Agarwal², Anil Kumar Mehrotra³

Abstract

Aim: To evaluate the skeletal maturity objectively and assess the reliability and validity of this method in North Indian subjects. **Materials and Methods:** Sixty subjects (8–16 years) were taken and divided into two groups of 30 males and 30 females. For each subject, cervical vertebral bone age (VA) was evaluated by the objective method described by Mito *et al.*, and bone age (BA) was estimated by Grave and Brown method of hand wrist radiograph. Correlations and average differences between various ages were determined. An analysis of variance and Tukey's *post-hoc* tests were used to compare various ages at 5% significance level. **Results:** The correlations between cervical VAs and BAs were higher than other ages and also more in females than males. The analysis of female data showed no statistically significant difference ($P > 0.05$) whereas analysis of male data showed statistically significant difference ($P < 0.05$) between various ages. **Conclusion:** The findings of the present study suggest that this method of objectively evaluating skeletal maturation is reliable and can be applied to North Indian females only. The development of a new method to objectively evaluate cervical VA in males is needed.

Key words: Cervical vertebrae, growth, skeletal maturity

INTRODUCTION

Skeletal maturation is an integral part of individual patterns of growth and development.^[1] Skeletal maturation refers to the degree of development of ossification in bones (cervical vertebrae, hand wrist, frontal sinus, midpalatal suture). Biological age, skeletal age, bone age (BA), and skeletal maturation are nearly synonymous terms used to describe the stages of maturation of a person.^[2] Discrepancies in skeletal

maturation are closely associated with the variation in timing and magnitude of growth. The determination of skeletal age indicates how much further growth a child will attain and allows the prediction of final height. As far as orthodontics is concerned, by reliably determining maturation and growth stage, a correct diagnosis can be obtained, and appropriate treatment can be initiated.^[3] Maturation status can have considerable influence on the diagnosis, treatment goals, treatment planning, and eventual outcome of orthodontic treatment. Skeletal maturation assessed on hand-wrist radiographs is classically considered as the best indicator of maturity^[1,4-6] and has been found to be closely related to the growth spurt. Its main drawback is that an additional radiograph is required. Although minimal radiation is associated with a hand wrist radiograph, it would be ideal to assess the growth stage without additional radiography.^[3] Cervical vertebrae appear on cephalometric radiographs that orthodontists usually

Access this article online	
Website: www.jios.in	Quick Response Code 
DOI: 10.4103/0301-5742.175704	

¹Reader, ²Professor and Guide, ³Professor and HOD
¹Department of Orthodontics and Dentofacial Orthopedics, Uttarakhand Dental and Medical Research Institute, Dehradun, Uttarakhand, ^{2,3}Department of Orthodontics and Dentofacial Orthopedics, Hospital and Research Center, Rama Dental College, Kanpur, Uttar Pradesh, India

Address for correspondence: Dr. Sandeep Kumar,
 Department of Orthodontics and Dentofacial Orthopedics, Uttarakhand Dental and Medical Research Institute, Dehradun, Uttarakhand, India.
 E-mail: sharmasandeep009@gmail.com

Received: 06-06-2015, Accepted with Revisions: 29-10-2015

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Kumar S, Agarwal N, Mehrotra AK. Evaluation of skeletal maturity in North Indian subjects using an objective method based on cervical vertebral bone age and assessment of its reliability as compared to hand wrist radiographic method. *J Indian Orthod Soc* 2016;50:3-7.

RESEARCH ARTICLE

Staging hand-wrist and cervical vertebrae images: a comparison of reproducibility

¹Amanda C Cunha, ²Lucia HS Cevidanes, ¹Eduardo F Sant'Anna, ³Fabio R Guedes, ⁴Ronir R Luiz, ²James A McNamara, ^{2,5}Lorenzo Franchi and ¹Antonio Carlos O Ruellas

¹Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil; ²Department of Orthodontics and Pediatric Dentistry, School of Dentistry, University of Michigan, Ann Arbor, MI, USA; ³Department of Pathology and Oral Diagnosis, School of Dentistry, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil; ⁴Institute of Public Health Studies (IESC), Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil; ⁵Department of Surgery and Translational Medicine, University of Florence, Florence, Italy

Objectives: The aim of this study was to compare the reproducibility of skeletal maturation assessments by raters with similar orthodontic experience using hand-wrist (HW) and cervical vertebral maturation (CVM) methods.

Methods: HW and lateral cephalometric radiographs from 15 subjects (8 males and 7 females; ages, 9–16 years) were selected randomly. HW skeletal maturation was evaluated by the method of Greulich and Pyle, and CVM staging was evaluated by the method of Baccetti et al. Six orthodontic residents evaluated all images at three time periods: T_1 , initial evaluation; T_2 , re-evaluation after 7 days and T_3 , final evaluation after 5 weeks. Intra- and interexaminer reproducibility was evaluated with the intraclass correlation coefficient; the limits of agreement (LoA) were determined by using the Bland–Altman method.

Results: The intraexaminer reliability assessed by intraclass correlation coefficient was scored as good for both of methods (T_1 - T_2 - T_3 HW = 0.89 and CVM = 0.80; T_1 - T_2 HW = 0.87 and CVM = 0.77; T_2 - T_3 HW = 0.90 and CVM = 0.81), as well as the interexaminer evaluation, with the exception of HW- T_1 , which scored excellent (0.92). The width of LoA from Bland–Altman plot of cervical vertebra method was narrower (CVM T_1 - T_2 : -2.3 and +1.8; CVM T_2 - T_3 : -2.0 and +2.0) than the HW method (HW T_1 - T_2 : -3.9 and +4.8; HW T_2 - T_3 : -4.0 and +3.5).

Conclusions: Both HW and CVM methods presented good reproducibility for intra- and interexaminer correlation assessments. The small LoA indicated that the CVM is a reproducible method.

Dentomaxillofacial Radiology (2018) **47**, 20170301. doi: [10.1259/dmfr.20170301](https://doi.org/10.1259/dmfr.20170301)

Cite this article as: Cunha AC, Cevidanes LHS, Sant'Anna EF, Guedes FR, Luiz RR, McNamara JA, et al. Staging hand-wrist and cervical vertebrae images: a comparison of reproducibility. *Dentomaxillofac Radiol* 2018; **47**: 20170301.

Keywords: Growth and development; age determination by skeleton; hand-wrist radiographs; cervical vertebrae maturation; reproducibility of results

Introduction

The prediction of the pubertal growth spurt is a widely used tool for the orthodontic and dentofacial orthopedic therapy of growing individuals, in that such knowledge helps determine optimal treatment timing when growth

modification is considered.^{1,2} In this way, the identification of the maturational stage is indispensable for the diagnosis and treatment planning of patients with imbalances in their facial growth pattern as it determines the favorable intervention time and treatment approach.²

Although physiological parameters such as pubertal signs, chronological age and dental staging are classic

Correspondence to: Dr Amanda C Cunha, E-mail: ccunha.amanda@gmail.com
Received 02 August 2017; revised 15 February 2018; accepted 19 February 2018

Another Look at Skeletal Maturation Using Hand Wrist and Cervical Vertebrae Evaluation

Thomas J. Cangialosi^{1,2*}, V. Jason Vives³

¹School of Dental Medicine, Department of Orthodontics, Rutgers University, Newark, New Jersey, USA

²College of Dental Medicine, Division of Orthodontics, Columbia University, New York City, New York, USA

³Private Practice of Orthodontics, Old Bridge, New Jersey, USA

Email: *cangiatj@sdm.rutgers.edu

How to cite this paper: Cangialosi, T.J. and Vives, V.J. (2018) Another Look at Skeletal Maturation Using Hand Wrist and Cervical Vertebrae Evaluation. *Open Journal of Orthopedics*, 8, 1-10.
<https://doi.org/10.4236/ojo.2018.81001>

Received: November 7, 2017

Accepted: January 8, 2018

Published: January 11, 2018

Copyright © 2018 by authors and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Introduction and Aims—The Growth stage of a patient can have considerable influence on diagnosis, treatment goals, timing and planning and the eventual outcome of orthodontic/orthopedic treatment. The purpose of this study was to analyze associations between the cervical vertebrae maturation score (CVMS) and skeletal maturation index (SMI). The second objective was to determine the reproducibility of the measurements on lateral cephalograms and hand-wrist radiographs. **Materials and Methods**—Lateral cephalometric and left hand-wrist radiographs of 92 untreated subjects (44 females and 48 males) aged from 8 to 17 years were obtained from the files of the Columbia University, Division of Orthodontics and measured for growth stage using cervical vertebrae and hand-wrist methods. **Results**—A high correlation was revealed between the hand-wrist and cervical vertebrae measurements. The Spearman's rho correlation coefficient was 0.925 and significant at the 0.01 level. The correlation between hand-wrist and age (0.665, $p < 0.01$) was slightly greater than that of the CVMS (0.611, $p < 0.01$). Intra rater reliability was high. When the three categorically modified methods of the Fishman's 11 skeletal maturation stages in hand and wrist analysis were used to compare with CVMS, methods 2 and 3 were both statistically significantly different according to the Wilcoxon signed ranks test and the Sign test at a significance level of less than 0.05. However, for method 1, the tests showed probability scores of 0.028 and 0.151, respectively, showing no significant difference at the 0.01 level in the Wilcoxon Signed Ranks Test, and no significant difference in the 0.01 and 0.05 level in the Signed Test. **Conclusions**—The Fishman's hand and wrist skeletal maturation index and Bacetti's cervical vertebrae maturation stages are both useful tools in evaluating growth stages. Fishman's hand-wrist method is slightly more accurate.



Review

Is the cervical vertebral maturation (CVM) method effective enough to replace the hand-wrist maturation (HWM) method in determining skeletal maturation?—A systematic review



Agnieszka Szemraj^a, Anna Wojtaszek-Słomińska, Bogna Racka-Pilszak

^a Department of Orthodontics, Medical University of Gdańsk, al. Zwycięstwa 42c, 80-210 Gdańsk, Poland

ARTICLE INFO

Keywords:

Adolescent development/physiology
Age determination by skeleton/methods
Cervical vertebrae/diagnostic imaging
Cervical vertebrae/growth & development
Hand/diagnostic imaging
Wrist/diagnostic imaging

ABSTRACT

Introduction: Chronological age provides only general information on the development of a child/adolescent. However, the biological age of the patient is more significant. One of the methods is the determination of the bone age based on the development of the hand and wrist bones. In 1972 a method for assessing cervical vertebral maturation on the cephalometric radiographs was introduced (CVM method). As a result, additional patient radiation was eliminated. Currently, this type of radiograph is routinely applied in orthodontic treatment.

Aim: The aim of the study was to assess the usefulness of the CVM method and to verify the assumption, according to which the CVM method modified by Baccetti et al. may replace the method for the assessment of skeletal maturation based on a hand-wrist X-ray, which is known as the hand-wrist maturation (HWM) method.

Material and methods: The present study reviewed the literature between 2006 and 2016. In the first stage of selection 905 articles were obtained. Finally, 10 articles were enrolled for the review.

Results: All of the studies presented a high level of correlation between the examined methods. In eight articles the researchers admitted that the CVM classification could replace the HWM method, known as the "gold standard". In two studies the researchers suggested considering the CVM method an additional method despite its compatibility and usefulness. The lowest correlation coefficient was 0.616 and the highest 0.937.

Discussion: The assessment of the skeletal age with the CVM is done on a cephalometric radiograph, routinely used in orthodontic practice, which makes it easy to apply. The determination of features of only C2, C3 and C4 vertebrae is possible even if the patient wears an X-ray protective thyroid collar. Therefore, the radiation dose is minimized.

Conclusions: The CVM method shows a high level of correlation with the HWM method.

1. Introduction

Chronological age provides only general information on the development of a child/adolescent. However, the biological age of the patient is more significant when orthodontic treatment is planned. To evaluate the biological age, the level of psychosomatic development, dental and skeletal age should be assessed [1].

One of the methods is the determination of the bone age based on the development of the hand and wrist bones. It consists in the evaluation of secondary ossification nuclei, which undergo the process of mineralization during maturation, resulting in changes in bone shapes typical of different growth stages of the patient. The elements that are analyzed are also the characteristic features of the selected metaphyseal phalangeal cartilages and the radial bone i.e. the width, shape and

degree of the union of diaphyses and epiphyses [2].

The first atlas of human hand ossification was published by Poland in 1898. However, the first atlas considering sex differences and all the stages with X-ray radiographs was prepared by Siebert in 1935 [3].

In 1972, Lamparski introduced a method for assessing cervical vertebral maturation on the cephalometric radiographs. As a result, additional patient radiation was eliminated by Lamparski. Currently, this type of radiograph is routinely applied in orthodontic treatment. It was the first time the classification had been presented which included changes in the shape of the three cervical vertebrae (C2, C3 and C4) as the bone age index. Lamparski established the standards for the assessment of skeletal maturation separately for girls and boys. In the studies that researcher found a weaker correlation between his method and the method of determining bone age of the hand and wrist in male

^a Corresponding author.

E-mail addresses: agnieszkaszemraj@gumed.edu.pl (A. Szemraj), aslom@gumed.edu.pl (A. Wojtaszek-Słomińska), bracka@gumed.edu.pl (B. Racka-Pilszak).

<https://doi.org/10.1016/j.ejrad.2018.03.012>

Received 28 August 2017; Received in revised form 26 February 2018; Accepted 5 March 2018
0720-048X/ © 2018 Elsevier B.V. All rights reserved.

Evaluation of skeletal maturity in the cervical vertebrae and hand-wrist in relation to vertical facial types

Ye-Seul Lee^{a,b} 
Sung-Hwan Choi^{a,b}
Kyung-Ho Kim^{b,c}
Chung-Ju Hwang^{a,b} 

^aDepartment of Orthodontics, Yonsei University College of Dentistry, Seoul, Korea

^bInstitute of Craniofacial Deformity, Yonsei University College of Dentistry, Seoul, Korea

^cDepartment of Orthodontics, Gangnam Severance Dental Hospital, Yonsei University College of Dentistry, Seoul, Korea

Objective: To evaluate differences in skeletal maturity in relation to vertical facial types and to compare differences in the skeletal maturity of the cervical vertebrae and hand-wrist in females. **Methods:** This study included 59 females aged 7 to 9 years with skeletal Class I malocclusion. The participants were categorized into three groups (low, normal, and high) according to the mandibular plane angle. Skeletal maturity was measured using skeletal maturity indicators (SMIs) and the Tanner-Whitehouse III (TW3) method on hand-wrist radiographs and by using cervical vertebrae maturation indicators (CVMI) on lateral cephalometric radiographs. **Results:** The SMI was higher in the high-angle group than in the low-angle group ($p = 0.014$). The median TW3 bone age was 11.4 months higher in the high-angle group than in the low-angle group ($p = 0.032$). There was no significant difference in CVMI among the three groups. Skeletal maturity showed a weakly positive correlation with the mandibular plane angle (SMI, $r = 0.391$; TW3, $r = 0.333$; CVMI, $r = 0.259$). **Conclusions:** The skeletal maturity of the hand-wrist in females with a high mandibular plane angle was higher than that in females with a low mandibular plane angle. Obtaining additional hand-wrist radiographs may facilitate evaluation of skeletal maturity of females. In females with a high mandibular angle, the time to commence orthodontic treatment may be earlier than that in females with a low mandibular angle.

[Korean J Orthod 2019;49(5):319-325]

Key words: Skeletal maturity, Vertical facial type, Mandibular plane angle, Skeletal maturity indicators

Received February 18, 2019; Revised June 5, 2019; Accepted June 17, 2019.

Corresponding author: Chung-Ju Hwang.
Professor, Department of Orthodontics, Institute of Craniofacial Deformity, Yonsei University College of Dentistry, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea.
Tel +82-2-2228-3106 e-mail hwang@yuhs.ac

How to cite this article: Lee YS, Choi SH, Kim KH, Hwang CJ. Evaluation of skeletal maturity in the cervical vertebrae and hand-wrist in relation to vertical facial types. Korean J Orthod 2019;49:319-325.

© 2019 The Korean Association of Orthodontists.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Correlation between Chronological Age, Cervical Vertebral Maturation and Fishman's Skeletal Maturity Indicators in Central India Population

Dr Natasha Patil,¹ Dr Neha Maheshwari,² Dr Rohit Sharma,³ Dr Shashank Soni,⁴ Dr Ashish Kushwah⁵

¹Senior Lecturer, Department of Orthodontics, M.P.C.D & R.C. Gwalior, ²Private practitioner, Nanda Dental Care,

³Senior Lecturer, Department of Prosthodontics, ⁴Post Graduate Student, Department of Orthodontics, M.P.C.D & R.C. Gwalior,

⁵Post Graduate Student, Department of Orthodontics, Teerthankar Mahaveer University, India

Correspondence: Dr. Kushwah Ashish; Email: ashishkushwah98@gmail.com

ABSTRACT

Introduction: Skeletal maturity indicators are very important indicators when diagnosing and planning the treatment in growing population. Cervical Vertebrae Method (CVM) and Fishman's Skeletal Maturity Indicators are two commonly used methods for the diagnosis and treatment planning. The aim of the study was to investigate the correlation between cervical vertebral maturation (CVM) and Fishman's hand-wrist skeletal maturity indicator and chronological age by including subjects within the range of circumpubertal growth spurt in Central India.

Materials & Method: One Twenty Five contemporary hand-wrist and lateral cephalometric radiographs from population of Central India were randomly selected and analyzed. All subjects were within the circumpubertal period i.e. female subjects were between 10 and 15 years of age, and the male subjects were between 12 and 17 years of age. The hand-wrist bone analysis was evaluated using the method developed by Fishman whereas cervical vertebra bone analysis was evaluated using the method developed by Baccetti and coworkers. These two methods and chronological age were correlated using the Spearman rank correlation analysis.

Result: CVM was significantly correlated with hand-wrist maturation ($r=0.8868$). However low correlation was found between the CVM and chronological age ($r=0.7139$) and little correlation was found between the HWM and chronological age ($r=0.6892$).

Conclusion: CVM is a valid indicator of skeletal growth during the circumpubertal growth period and has a high correlation with the HWM for the Central India population. However chronological age is not suitable to measure skeletal maturity as shown by the low correlations found between the chronological age and both CVM and HWM.

Keywords: Cervical vertebra maturation, Chronological age, Hand-wrist maturation, Skeletal maturity.

INTRODUCTION

The issue of optimal timing in dentofacial orthopedics is intimately related to identification of periods of accelerated growth that contribute significantly in correction of skeletal imbalances in individual patient.

Several clinical studies have shown that the greatest response to functional jaw orthopedics tends to occur during circumpubertal growth period.¹ Before maximal pubertal growth the skeletal response were less in subjects as well as after maximal pubertal growth.^{2,3}

Therefore, to assess growth spurts for the determination of the optimal growth modification treatment timing

a biologic indicators series were used. These methods includes characteristics of sexual maturation, facial growth and peak height velocities, chronological age, dental development, body weight, body height and handwrist maturity.⁴

Successful growth modification in orthodontics is dependent on skeletal maturation.⁵ Hand wrist maturation (HWM) analysis is the most widely used and a classical method for evaluation of skeletal age. HWM is the highly reliable method done by radiograph. However, an addition exposure of ionizing radiation of the orthodontic patient required to the routine radiographic records for this analysis.⁴

An Abbreviated Scale for the Assessment of Skeletal Bone Age Using Radiographs of the Knee

XIN TANG, MD; YUBO LU, MD; MINGFAN PANG, MSPH; DEREK T. NHAN, BS; WALTER KLYCE, BA;
JAN FRITZ, MD; R. JAY LEE, MD

abstract

Hand and wrist radiographs are the most common means for estimating skeletal bone age. There is no widely used scale for estimating skeletal bone age using knee radiographs. Do skeletal bone age estimates from knee-maturity scales correlate sufficiently with both chronologic age and estimates from a hand-wrist scale to potentially substitute for estimates from the latter? The authors reviewed the records of 503 patients 6 to 19 years old who had hand and knee radiographs obtained within 30 days of each other. They analyzed radiographs using the O'Connor knee scale (based on 10 maturation markers) and a new, abbreviated version of the O'Connor scale (based on 7 markers). The authors also analyzed radiographs of the hands of boys 12.5 to 16 years old and girls 10 to 16 years old using the shorthand method. Multivariate linear regression was used for analysis. Inter- and intrarater reliabilities were assessed. Skeletal bone age derived from the O'Connor and abbreviated knee scales correlated with chronologic age (adjusted $R^2=0.88$ and 0.90 , respectively). Compared with estimates from the hand-wrist scale, estimates were lower by a mean of 0.91 years for boys and 0.38 years for girls when using the O'Connor scale and 0.96 years for boys and 0.52 years for girls when using the abbreviated scale. Inter- and intrarater reliabilities were very good ($\kappa=0.82$ and 0.90 , respectively) and were substantial at each bony landmark measured. Knee radiographs can be used to estimate skeletal bone age using an abbreviated knee scale. [*Orthopedics*. 2018; 41(5):e676-e680.]

Accurate estimates of remaining skeletal bone growth are helpful to guide surgical treatment around or involving the growth plates of skeletally immature patients. Chronologic age is not always an accurate predictor of

remaining growth; instead, skeletal bone age can be estimated by assessing the morphological characteristics of developing bone. Many areas of the skeletal system mature according to reproducible patterns. One of the most common meth-

ods for estimating skeletal bone age is the hand-wrist method described by Greulich and Pyle.¹ Although there is no commonly used method based on knee morphology, there are described patterns of maturation. The Pyle and Hoerr knee atlas shows standard knee morphology for different chronologic ages.² Roche et al³ first examined 34 individual markers around the knee to determine skeletal bone age, and O'Connor et al⁴⁻⁶ derived formulas from a refined set of markers around the knee. No method for estimating skeletal bone age using the knee has been widely accepted.

The authors are from the Department of Orthopaedic Surgery (XT, DTN, WK, RJJ), The Johns Hopkins Hospital; the Russell H. Morgan Department of Radiology and Radiological Science (YL, JF), The Johns Hopkins University School of Medicine; and The Johns Hopkins University (MP), Bloomberg School of Public Health, Baltimore, Maryland.

Dr Tang, Dr Lu, Mr Pang, Mr Nhan, Mr Klyce, and Dr Lee have no relevant financial relationships to disclose. Dr Fritz has received material support from DePuy and Zimmer, has received grants from Siemens AG and BTG International, is on the speaker's bureau of Siemens AG, and holds a patent with Siemens AG.

Correspondence should be addressed to: R. Jay Lee, MD, Department of Orthopaedic Surgery, The Johns Hopkins Hospital, 1800 Orleans St, Baltimore, MD 21287 (editorialservices@jhmi.edu).

Received: October 13, 2017; Accepted: April 23, 2018.

doi: 10.3928/01477447-20180724-03



Multi-factorial age estimation: A Bayesian approach combining dental and skeletal magnetic resonance imaging



Jannick De Tobel^{a,b,c,*}, Steffen Fieuws^d, Elke Hillewig^a, Inès Phlypo^e, Mayonne van Wijk^f, Michiel Bart de Haas^g, Constantinus Politis^c, Koenraad Luc Verstraete^a, Patrick Werner Thevissen^b

^a Department of Diagnostic Sciences – Radiology, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium

^b Department of Imaging and Pathology – Forensic Odontology, KU Leuven, Kapucijnenvoer 7 blok a bus 7001, 3000 Leuven, Belgium

^c Department of Oral and Maxillofacial Surgery, Leuven University Hospitals, Kapucijnenvoer 33, 3000 Leuven, Belgium

^d KU Leuven – Leuven University & Hasselt University, Department of Public Health and Primary Care, I-BioStat, Leuven, Kapucijnenvoer 35 blok d bus 7001, 3000 Leuven, Belgium

^e Department of Oral Health Sciences – Special Needs in Dentistry, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium

^f Division of Special Services and Expertise, Section of Forensic Anthropology, Netherlands Forensic Institute, Loen van Ypenburg 6, 2497 GB The Hague, the Netherlands

ARTICLE INFO

Article history:

Received 19 May 2019

Received in revised form 19 October 2019

Accepted 12 November 2019

Available online 15 November 2019

Keywords:

Age determination by skeleton

Age determination by teeth

Adolescent

Adult

Magnetic resonance imaging

ABSTRACT

Purpose: To study age estimation performance of combined magnetic resonance imaging (MRI) data of all four third molars, the left wrist and both clavicles in a reference population of females and males. To study the value of adding anthropometric and sexual maturation data.

Materials and methods: Three Tesla MRI of the three anatomical sites was prospectively conducted from March 2012 to May 2017 in 14- to 26-year-old healthy Caucasian volunteers (160 females, 138 males). Development was assessed by allocating stages, anthropometric measurements were taken, and self-reported sexual maturation data were collected. All data was incorporated in a continuation-ratio model to estimate age, applying Bayes' rule to calculate point and interval predictions. Two performance aspects were studied: (1) accuracy and uncertainty of the point prediction, and (2) diagnostic ability to discern minors from adults (≥ 18 years).

Results: Combining information from different anatomical sites decreased the mean absolute error (MAE) compared to incorporating only one site ($P < 0.0001$). By contrast, adding anthropometric and sexual maturation data did not further improve MAE ($P = 0.11$). In females, combining all three anatomical sites rendered a MAE equal to 1.41 years, a mean width of the 95% prediction intervals of 5.91 years, 93% correctly classified adults and 91% correctly classified minors. In males, the corresponding results were 1.36 years, 5.49 years, 94%, and 90%, respectively.

Conclusion: All aspects of age estimation improve when multi-factorial MRI data of the three anatomical sites are incorporated. Anthropometric and sexual maturation data do not seem to add relevant information.

© 2019 Elsevier B.V. All rights reserved.

Abbreviations: $P_{Pearson}$, Pearson correlation coefficient between the errors of two models; A, anthropometric and sexual maturation data; C, both clavicles' sternal ends; MAE, mean absolute error; MFA, multi-factorial age estimation; PI, prediction interval; RMSE, root mean squared error; SSA, single site age estimation; T, all four third molars; W, wrist-distal radius and ulna.

* Corresponding author at: Department of Diagnostic Sciences – Radiology, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium.

E-mail addresses: jannick.detobel@ugent.be (J. De Tobel), stefien.fieuws@kuleuven.be (S. Fieuws), elke.hillewig@gmail.com (E. Hillewig), ines.phlypo@ugent.be (I. Phlypo), m.van.wijk@nfi.mimvenj.nl (M. van Wijk), m.de.haas@nfi.mimvenj.nl (M.B. de Haas), constantinus.politis@uzleuven.be (C. Politis), koenraad.verstraete@ugent.be (K.L. Verstraete), patrick.thevissen@kuleuven.be (P.W. Thevissen).

<http://dx.doi.org/10.1016/j.foresint.2019.110054>
0379-0738/© 2019 Elsevier B.V. All rights reserved.

1. Introduction

Forensic age estimation based on the development at different anatomical sites is recommended by experts [1] and applied by most authorities [2,3]. In adolescents and young adults, combining the developmental information of different anatomical sites improves age estimation performance [1]. In the living, medical imaging can be used to obtain this developmental information. Currently, radiographs and computed tomography (CT) are the commonly applied imaging modalities. Numerous studies on single anatomical sites are available (single site age estimation – SSA), with large reference studies mostly based on retrospective data [4–7].

Quantitative skeletal maturation estimation using cone-beam computed tomography-generated cervical vertebral images: a pilot study in 5- to 18-year-old Japanese children

Bo-Ram Byun · Yong-Il Kim · Tetsutaro Yamaguchi · Koutaro Maki · Ching-Chang Ko · Dea-Seok Hwang · Soo-Byung Park · Woo-Sung Son

Received: 13 August 2014 / Accepted: 29 January 2015 / Published online: 12 February 2015
© Springer-Verlag Berlin Heidelberg 2015

Abstract

Objectives The purpose of this study was to establish multi-variable regression models for the estimation of skeletal maturation status in Japanese boys and girls using the cone-beam computed tomography (CBCT)-based cervical vertebral maturation (CVM) assessment method and hand-wrist radiography.

Materials and methods The analyzed sample consisted of hand-wrist radiographs and CBCT images from 47 boys and 57 girls. To quantitatively evaluate the correlation between the skeletal maturation status and measurement ratios, a CBCT-based CVM assessment method was applied to the second, third, and fourth cervical vertebrae. Pearson's correlation coefficient analysis and multivariable regression analysis were used to determine the ratios for each of the cervical vertebrae ($p < 0.05$).

Results Four characteristic parameters ($(OH_2+PH_2)/W_2$, $(OH_2+AH_2)/W_2$, D_2 , AH_3/W_3), as independent variables, were used to build the multivariable regression models: for the Japanese boys, the skeletal maturation status according to the CBCT-based quantitative cervical vertebral maturation (QCVM) assessment was $5.90 + 99.11 \times AH_3/W_3 - 14.88 \times (OH_2+AH_2)/W_2 + 13.24 \times D_2$; for the Japanese girls, it was $41.39 + 59.52 \times AH_3/W_3 - 15.88 \times (OH_2+PH_2)/W_2 + 10.93 \times D_2$.

Conclusions The CBCT-generated CVM images proved very useful to the definition of the cervical vertebral body and the odontoid process. The newly developed CBCT-based QCVM assessment method showed a high correlation between the derived ratios from the second cervical vertebral body and odontoid process.

Clinical relevance There are high correlations between the skeletal maturation status and the ratios of the second cervical vertebra based on the remnant of dentocentral synchondrosis.

B.-R. Byun · Y.-I. Kim · S.-B. Park · W.-S. Son
Department of Orthodontics, Dental Research Institute, Pusan National University Dental Hospital, Yangsan, South Korea

Y.-I. Kim (✉)
Department of Orthodontics, Biomedical Research Institute, Pusan National University Hospital, Gudeokro 137, Seogu Busan 626-739, South Korea
e-mail: kimyongil@pusan.ac.kr

T. Yamaguchi · K. Maki
Department of Orthodontics, School of Dentistry, Showa University, Tokyo, Japan

C.-C. Ko
Department of Orthodontics, School of Dentistry, University of North Carolina, Chapel Hill, USA

D.-S. Hwang
Dental clinic, Pusan National University Hospital, Busan, South Korea

Keywords Dentocentral synchondrosis · Cervical vertebra · Skeletal maturation · Regression model

Introduction

Craniofacial skeletal maturation is an important factor determining orthodontic growth modification treatment time. Research suggests several biological indicators of human development (chronologic age, dental development, sexual maturation, voice change, and others) [1–4]. Among the biological skeletal maturation indices, the skeletal maturation indicator (SMI), based on hand-wrist radiography, has been the most popular in the context of orthodontic practice [2]. More recently however, the cervical vertebral maturation (CVM)



Comparative determination of skeletal maturity by hand–wrist radiograph, cephalometric radiograph and cone beam computed tomography

Alperen Tekin¹ · Kader Cesur Aydın²

Received: 19 March 2019 / Accepted: 25 August 2019
© Japanese Society for Oral and Maxillofacial Radiology and Springer Nature Singapore Pte Ltd. 2019

Abstract

Objectives The purpose of this study is to assess the stages of skeletal maturity in cone beam computed tomography (CBCT), hand–wrist radiography (HWR) and cephalometric radiography (CR) techniques of orthodontic patients, and associate skeletal maturity stages with chronological age, in a Turkish subpopulation.

Methods Hand–wrist radiographs, cephalometric radiographs and CBCT of 105 patients were evaluated. For evaluation of HWR, the “Hand Bone Age A Digital Atlas of Skeletal Maturity” of Vicente Gilsanz and Osman Ratib (2005) was used. Skeletal maturation in the cephalometric radiographs and sagittal sections of cervical vertebrae obtained by CBCT were evaluated with Hassel and Farman’s method (1995). All results were re-evaluated 3 weeks later to assess intra-observer reliability.

Results Intra-observer reliability coefficients of the skeletal maturity stages in HWR, CR, and CBCT were 0.912, 0.595, 0.756 respectively ($p < 0.05$). Spearman’s correlation coefficient value between skeletal developmental stages in HWR, CR, and CBCT was found to be 0.785, 0.875, and 0.791, respectively ($p < 0.05$).

Conclusion Results of this study reveal that the determination of the skeletal development status with analysis of cervical vertebrae using cephalometric radiographs and CBCT is as reliable method as the evaluation of the hand–wrist radiographs and is compatible with chronological age in a subgroup of the Turkish population. When assessing the skeletal development stages of patients, both CBCT and CR can be used validly, so no extra hand–wrist radiography is required. This information is important for the prevention of increased radiation doses in patients.

Keywords Cephalometric radiograph · Chronological age · Cone beam computed tomography · Hand–wrist radiograph · Skeletal age · Skeletal maturation

Introduction

Skeletal maturity is an important factor for assessment, especially in diagnosis and treatment planning for orthodontic treatments. Stage of bone maturation as prepubertal, pubertal growth peak or completed skeletal development has a major impact on treatment goals, treatment planning and possible outcomes of treatment.

To assess skeletal maturity, chronological age, height increase rate, initialization of menstrual cycle, changes in physical appearance and changes in speech can be used, but these methods do not provide clear results; thus, several methods have been developed to evaluate the skeletal maturity stages [1–7].

The most common method used for the evaluation of skeletal maturity is based on the assessment of the morphological changes of the bones in the hand–wrist radiographies [8–10]. Studies reveal that skeletal development can also be evaluated by the morphological state of the cervical vertebral development [11–18].

Cone beam computerized tomography (CBCT), which is prominent due to the fact that the radiation dose given to the patient is very low compared to the computed tomography, has become increasingly popular in dentistry and orthodontics for treatment planning in 3D [19–22]. Skeletal

✉ Alperen Tekin
alperentekin37@gmail.com

¹ Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Istanbul Medipol University School of Dentistry, Istanbul, Turkey

² Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Turkey Beykent University, Istanbul, Turkey

ORIGINAL ARTICLE

Five radiographic methods for assessing skeletal maturity in a Spanish population: is there a correlation?

Paula Camacho-Basallo^{a,b}, Rosa-María Yáñez-Vico^{a,b}, Enrique Solano-Reina^{a,b} and Alejandro Iglesias-Linares^{a,b}

^aDepartment of Stomatology, Craniofacial Research Group CTS353, University of Seville, Seville, Spain; ^bDepartment of Stomatology IV, School of Dentistry, Complutense University of Madrid, Madrid, Spain

ABSTRACT

Objectives: The need for accurate techniques of estimating age has sharply increased in line with the rise in illegal migration and the political, economic and socio-demographic problems that this poses in developed countries today. The methods routinely employed for determining chronological age are mainly based on determining skeletal maturation using radiological techniques. The objective of this study was to correlate five different methods for assessing skeletal maturation.

Materials and methods: 606 radiographs of growing patients were analyzed, and each patient was classified according to two cervical vertebral-based methods, two hand-wrist-based methods and one tooth-based method. Spearman's rank-order correlation coefficient was applied to assess the relationship between chronological age and the five methods of assessing maturation, as well as correlations between the five methods ($p < 0.05$).

Results: Spearman's rank correlation coefficients for chronological age and cervical vertebral maturation stage using both methods were 0.656/0.693 ($p < 0.001$), respectively, for males. For females, the correlation was stronger for both methods. The correlation coefficients for chronological age against the two hand-wrist assessment methods were statistically significant only for Fishman's method, 0.722 ($p < 0.001$) and 0.839 ($p < 0.001$), respectively for males and females.

Conclusions: The cervical vertebral, hand-wrist and dental maturation methods of assessment were all found to correlate strongly with each other, irrespective of gender, except for Grave and Brown's method. The results found the strongest correlation between the second molars and females, and the second premolar and males.

Clinical relevance: This study sheds light on and correlates with the five radiographic methods most commonly used for assessing skeletal maturation in a Spanish population in southern Europe.

ARTICLE HISTORY

Received 19 June 2016
Revised 11 November 2016
Accepted 18 November 2016

KEYWORDS

Orthodontics; skeletal maturity; radiographic; age

Introduction

Age assessment is an important aspect of medicolegal, paediatric and forensic science. Estimating the age of a living individual who cannot prove his/her birth date poses a challenge, which results in a fairly common legal practice. The need for accurate techniques of estimating skeletal maturation has sharply increased in line with the increase in illegal migration, which is a growing political, economical and socio-demographical problem in developed countries today. In cases involving criminal proceedings, the evaluation of imputability or asylum is essential to be able to find out the age of someone who has no identification documents, since the chronological age limits defining full or legal responsibility vary considerably in different countries around the world.[1,2] In most European countries, the legal age limit falls between the 14 and 21 years of life; in the case of Spain, the age of criminal responsibility is 14 years.[3]

The methods routinely used to determine chronological age are mainly based on determining biological age.[2,4–7] Various indicators of maturity such as sexual maturation

characters,[8–10] dental development,[5,11–13] hand-wrist maturity [14,15] and cervical vertebral maturation [16–18] have been reported in the specialized literature for estimating the chronological age of children and adolescents. Voice change needs to be continuously monitored in order to detect changes, while the menarche has little predictive value if it has not occurred or if the patient cannot remember exactly when the first menstrual period was. To date, therefore, the use of radiographic growth parameters has been the most commonly used method of assessing biological age and so determining chronological age. Hand-wrist radiography has been one of the most commonly used methods of determining skeletal maturity, although cervical vertebral maturation and dental development have been proposed as valid alternatives to the hand-wrist method. Many authors have reported a significant correlation between the size and shape of the cervical vertebrae, weight and body height [19] and hand-wrist maturation.[17,20,21]

In Greulich and Pyle's [6] and Tanner et al.'s [22] methods, bone age is assessed by comparing the X-ray image of an unknown subject with a standard reference.[23] Among the

CONTACT Alejandro Iglesias-Linares  aleigl01@ucm.es, aiglesiaslinares@gmail.com  Department of Stomatology IV, School of Dentistry, Complutense University of Madrid, Plaza de Ramón y Cajal, 3 28040 – Madrid, Spain

© 2016 Acta Odontologica Scandinavica Society

Comparación de la Maduración Ósea de Vértebras Cervicales Utilizando los Métodos de Baccetti y Lamparski en Pacientes de 8 a 15 Años

Comparison of Bone Maturation of Cervical Vertebrae Using Baccetti and Lamparski Methods in Patients 8 to 15 Years of Age

Emerik Alvarado-Torres^{*}; Jaime Fabián Gutiérrez-Rojo^{**} & Alma Rosa Rojas-García^{***}

ALVARADO-TORRES, E.; GUTIÉRREZ-ROJO, J. F. & ROJAS-GARCÍA, A. R. Comparación de la maduración ósea de vértebras cervicales utilizando los métodos de Baccetti y Lamparski en pacientes de 8 a 15 años. *Int. J. Odontostomat.*, 10(1):63-67, 2016.

RESUMEN: La maduración se puede definir como un proceso gradual en el tiempo, presenta sucesivas modificaciones cualitativas en la organización anatómica y fisiológica durante la pubertad hasta el estado de madurez adulto. En el diagnóstico y tratamiento en ortodoncia es importante conocer los estadios de maduración ósea pues proporcionan información relevante que permite determinar ritmo y tiempo de maduración individual. El uso y la aplicación varían entre las técnicas y tienen un objetivo común, la clasificación de niños y adolescentes en estadios de maduración. El objetivo de este estudio fue comparar la maduración ósea de las vértebras cervicales utilizando los métodos de Baccetti y Lamparski en una población nayarita. La muestra fueron 298 radiografías laterales de cráneo de las edades de 8 a 15 años. Se compararon mediante t de Student los estadios de maduración de los grupos en el análisis CVM de Baccetti y el análisis de Lamparski; en hombres y mujeres. La población masculina de 8 y 10 años no presentaba diferencias significativas entre ambos análisis; la población femenina de 8 años y masculina de 9 años se encontraron diferencias, teniendo mayores valores el análisis CVM de Baccetti, en los demás grupos del estudio también se encontraron diferencias presentando mayores valores en el análisis Lamparski. Los estadios de maduración en los dos tipos de análisis mostraron una marcada diferencia en sus interpretaciones, siendo el análisis de Lamparski más confiable como método diagnóstico de la maduración ósea.

PALABRAS CLAVE: maduración ósea, vértebras, Lamparski, Baccetti.

INTRODUCCIÓN

La maduración biológica es un proceso de importantes cambios fisiológicos que se manifiestan de forma más intensa durante la adolescencia y el tiempo de su aparición depende del sexo y la etapa de maduración. La maduración se puede definir como un proceso gradual en el tiempo, en el que se presentan sucesivas modificaciones cualitativas en la organización anatómica y fisiológica, a través del cual se desencadena una gran movilización hormonal durante la pubertad hasta alcanzar el estado de madurez adulto (Gómez-Campos *et al.*, 2013).

En el diagnóstico y tratamiento en ortodoncia es importante conocer los estadios de maduración ósea (Mejía-Garduño *et al.*, 2014), ya que en las personas de la misma edad cronológica existen muchas diferencias fisiológicas en su desarrollo, por lo que es necesario evaluar mediante un indicador de maduración ósea su desarrollo (Echarri, 1998).

Dichos estadios proporcionan información relevante que permite determinar el ritmo o tiempo de maduración individual. El uso y la aplicación varía entre

^{*} Estudiante de la Especialidad en Ortodoncia, Universidad Autónoma de Nayarit, Nayarit, México.

^{**} Maestro en Salud Pública. Docente de la Especialidad en Ortodoncia y de la Unidad Académica de Odontología, Universidad Autónoma de Nayarit, Nayarit, México.

^{***} Maestra en Odontología. Docente de la Especialidad en Ortodoncia y de la Unidad Académica de Odontología, Universidad Autónoma de Nayarit, Nayarit, México.

Correlations between morphology of cervical vertebrae and dental eruption

LUMINIȚA LIGIA VAIDA¹⁾, ABEL-EMANUEL MOCA¹⁾, LIANA TODOR¹⁾, ADRIANA ȚENȚ¹⁾,
 BIANCA IOANA TODOR¹⁾, BIANCA-MARIA NEGRUȚIU¹⁾, ALINA IREN MORARU²⁾

¹⁾Department of Dental Medicine, Faculty of Medicine and Pharmacy, University of Oradea, Romania

²⁾Department of Odontology, Faculty of Dental Medicine, University of Medicine and Pharmacy of Craiova, Romania

Abstract

The process of dental eruption is submitted to physiological and pathological variables. A series of discrepancies may occur, one of these being a disturbance between dental age and bone age. The assessment of bone age is best made with the cervical vertebral maturation (CVM) method, simplified by Baccetti *et al.* (2005). The sample studied consisted of 215 orthodontic patients. The dental age was assessed on the orthopantomograph radiographies and the bone age on the lateral cephalograms. For determining the bone age, CVM method was used. Considering dental age, most of the patients (50.2%) have a premature dental age compared to bone age, while patients with normal dental age (27.9%) and patients with late dental age (21.9%) have a lower frequency. The correlation between the dental age and the bone age of the patients shows that patients who have higher values of dental age also have higher values of bone age ($p < 0.001$). The correlation between genders shows that female patients tend to have a higher average value of bone age in comparison to male patients ($p < 0.001$). The authors conclude that assessing bone age based on the morphology of cervical vertebrae and correlating it with the dental age could be of great use in opting for a certain orthodontic treatment plan.

Keywords: bone age, dental age, morphology of cervical vertebrae, orthodontic patients.

Introduction

Many studies investigating the physiological dental eruption mechanisms, as well as the pathological aspects of the eruption process have been carried out. Research has not always been conclusive, a unanimous opinion on the mechanisms of dental eruption needing yet to be formulated [1]. A number of studies support the need for further investigations and clarifications in cases with dental alveolar ankylosis, primary failure of eruption (PFE), dental impaction, secondary retention, local causes that produce disturbances of the dental eruption process, such as an imbalance between bone resorption and formation, the lack of space in the dental-alveolar arch, but especially the genetic causes of the dental eruption [2, 3]. Recent genetic research has highlighted that the gene involved in the dental eruption is located on the parathyroid hormone-1 receptor (*PTH-1R*), which is responsible for familial cases with PFE [2, 4, 5]. The genetic paradigm of dental eruption is also supported by the correlation between *PTH-1R* and parathyroid hormone-related protein (PTH-rP), a gene responsible for bone remodeling on the animal model [2, 6, 7]. Clinical differential diagnosis between dento-alveolar ankylosis and PFE is often impossible in the absence of any information about previous traumas, periodontal space obliteration, and medical history or *PTH-1R* gene mutations [8, 9]. Other studies indicate the fact that the circadian rhythm of the eruption is correlated with fluctuations of the hormonal levels, which influence bone and periodontal ligaments metabolic activity [10].

On the other hand, dental eruption discrepancies can be analyzed by reference to the chronological age or to the

bone age of the child or adolescent. Dental malpositions are most often the result of dental eruption discrepancies. Another category of eruption discrepancies is the occurrence of gaps between the dental eruption process and the degree of bone development of the patient. Dental eruption discrepancies, as well as malocclusions, may affect smile attractiveness and produce psychosocial disorders related to dento-facial aesthetics in terms of low self-esteem. Also, they may cause disorders of oral functions (such as chewing, swallowing or speech) [11, 12].

Franchi *et al.* (2000) propose an improved version for assessing bone development based on cervical skeletal maturation, bone age assessment being found on an analysis of the morphological maturity of cervical vertebrae using lateral cephalograms [13]. The respective authors evaluated the maxillary and mandibular growth stage in relation to the CVM, a useful tool for planning the orthodontic treatment [13, 14]. Baccetti *et al.* proposed in 2005 a simplified and improved version of the CVM method, in order to allow the optimal choice of momentum for orthodontic and dentofacial orthopedic treatment [15].

Aim

The aim of this research was to analyze a number of correlations between the dental age and the bone age of children and adolescents.

Materials and Methods

The sample consisted of 300 patients, aged between 8–14 years, in the North-West of Romania. From these, about 1/3 have been excluded. Exclusion criteria are



**Universidad
Andrés Bello®**

UNIVERSIDAD ANDRÉS BELLO

Facultad De Odontología

Departamento de Ortodoncia y Ortopedia Dentomaxilofacial

**COMPARACIÓN DEL MÉTODO DE MADURACIÓN ÓSEA VERTEBRAL
CERVICAL CVMS CON DOS MÉTODOS DE MADURACIÓN ÓSEA CARPAL
EN PACIENTES CHILENOS DEL POSTGRADO DE ORTODONCIA Y
ORTOPEDIA DENTOMAXILOFACIAL DE LA UNAB, SEDE SANTIAGO, AÑO
2015**

Tesis de para optar al título profesional de Cirujano Dentista

Autor:

Bárbara Valentina Constenla Villanueva

Profesor Responsable:

Dr. Hernán Palomino Montenegro

Tutor Guía:

Dra. Pamela Córdova Obreque

Santiago de Chile, 2015