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Research Paper

Estimating age using permanent molars and third cervical vertebrae shape with a novel semi-automated method

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ABSTRACT

Estimating chronological age accurately in young adults is difficult and additional methods are required to increase the accuracy. This study explored a new semi-automated method to assess shape change of third cervical vertebra (C3) with age in the living; comparing this as a method to determine whether individuals could be categorised into being less than 18 years of age (< 18), or at least 18 years of age (≥18) with tooth formation of the second and third mandibular molars (M2 and M3). The sample was panoramic and lateral skull radiographs of 174 dental patients (78 males, 96 females aged 15–22 years). Twelve variables were compared in two age categories: younger than 18 and at least 18 years of age in males and females separately using a *t*-test. Tooth formation of M2 and M3 was assessed. Mean values of eight variables of C3 in males and one variable in females were significantly different between the two age categories ($p < 0.05$). Results for males showed that the best age indicator for age ≥18 was the ratio between height and width of C3 and for females, the ratio between diagonals. Results for molars showed that M2 was mature in 69% of males and 83% of females, within the expected age range of 14–16 years. M3 was highly variable ranging from stages 6–14 for both; M3 was missing in 24% of males and 28% of females and mature in 14% of males and 15% of females. The conclusion was that shape change of C3 has potential as an additional method to group individuals < 18 and ≥ 18 years of age.

1. Introduction

Metric (e.g: body height) and non-metric (e.g: assessment of dental development) methods of age estimation are used in skeletal remains in order to estimate age-at-death and to form a biological profile.[1] In living individuals, the assessment of age is required in children and young adults with no documents for immigration control or asylum-seeking process[2]; and to determine whether the person concerned has reached the age of criminal responsibility or not.[3] It is claimed that the complexity of the study on human development is attenuated when different markers used for age estimation are combined. Variations in human development are better understood when the relationship between dental, skeletal and chronological age in children is analysed.[4] However, the difficulty of age assessment increases with age as individual teeth/bones reach maturity. After the second mandibular molar (M2) reaches maturity (on average around 14 years), the only remaining developing tooth available to estimate age is the third molar (M3). If M3 is mature, then the clavicle or other bones must be used to estimate age.

A range of techniques to assess human growth and development exist, but simple, non-invasive, and low-cost methods are preferable. Skull radiographs are frequently taken for orthodontic treatment and other medical purposes, such as for the diagnosis of pathological calcifications in the cervical region,[5] as well as for age estimation in living person.[6] For instance, lateral cephalogram (LC) of the skull assists with the visualization of lateral craniofacial skeleton, cervical vertebrae maturation (CVM) and dental development. Skeletal analysis compare linear and angular measurements from landmarks that change during growth.[7] Dental development is monitored through a sequence of events from initial mineralization, crown formation, root growth and root apex maturation.[8] The third cervical vertebrae have a trapezoidal shape and appear like a wedge of cheese where the posterior vertical height is longer than the anterior vertical height.[9] The shape changes from a wedge to a rectangle and then to a square during growth between ages 10–15 years. This anatomical change comes about by superior and inferior length increments being less than anterior and posterior height increments(10).

The aim of this study was to assess the potential of CVM growth changes during late adolescence and early adulthood. This was done by analysing maturation of different radiographic markers of a group of Southern Brazilian dental patients aged 15–22 years. The markers chosen were the third cervical vertebrae (C3) and the second (M2) and

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Table 1
Age and sex distribution of radiographic sample. Age in years. 15 includes age 15.00 to 15.99 etc.

Age (years)	Males	Females	Pooled
15	23	14	37
16	6	14	20
17	6	11	17
18	5	14	19
19	6	9	15
20	15	11	26
21	9	12	21
22	8	11	19
	TOTAL = 78	TOTAL = 96	
TOTAL = 174			

third molar (M3) on the left side of the mandible.

2. Materials and methods

The data from this cross-sectional study was obtained from anonymised archived lateral cephalogram (LC) and panoramic (OPG) radiographs. Those were taken with consent as part of routine orthodontic records of two Brazilian private radiographic clinics based in *Florianópolis* (capital city of Santa Catarina, South of Brazil). The sample included 174 Southern Brazilian adolescents and young adults of mixed ethnicity - 78 males and 96 females, aged 15–22 years - selected from 2013 to 2014 (Table 1). The inclusion criteria were: (a) subjects with no history of facial trauma and absence of congenital malformations, (b) both radiograph taken on the same day and (c) good visibility of C3 and M2/M3 lower left side in both radiographs.

2.1. Cervical vertebra maturation

The images were uploaded in an open access image processing program, *ImageJ*, 1.47v[11] and the following steps were used to generate a geometric outline of the C3 vertebra. Firstly, five points (dots) were equally placed along the border in each of the four corners of cervical vertebrae with the middle point on the apex; three points (rectangle dots) were placed on the lower border in equal distance from the inner black dots (1/4; ½; 3/4); and one point was placed at the middle (1/2) between the apex points on the other three borders (shown in Figs. 1 and 2). The outline of the C3 body was drawn using *ImageJ*, starting from top left in a clockwise direction. The corresponding Cartesian co-ordinates for each image were recorded for further investigation and analysis.

An in-house program called '*quadfit*' was used to align the cartesian co-ordinates to the vertebrae outline and enable the following automatic geometric measurements of the C3 (shown in Fig. 3): two diagonals K2 and K3[1 and 2] formed from two extreme points (d1, e1) and (d3, e3) for K2[3 and 4] and (d2, e2) and (d4, e4) for K3.[5 and 6] The length of K2 and K3 were divided in two, each one, by the centre of intersection and named K2.1 and K2.2[7 and 8] and K3.1 and K.3.2,[9 and 10] respectively. The width of C3 was the distance between the points (d1, e1) and (d2, e2) and the height of C3 were calculated from the perpendicular distance from the width. It was noted that the two centres of the cervical body: the intersection of the two diagonals (dot, 11) and the centre of the mass was defined as a mathematical centre for an irregular shape (cross, 12), were not always coincident and the distance between these two centres was calculated. Finally, the total area was calculated automatically and a parallelogram created by the connection of the four points (d1,e1/d2,e2/d3,e3/d4,e4) guided the calculation of the area of the lower border, which is concave and hence a negative value.

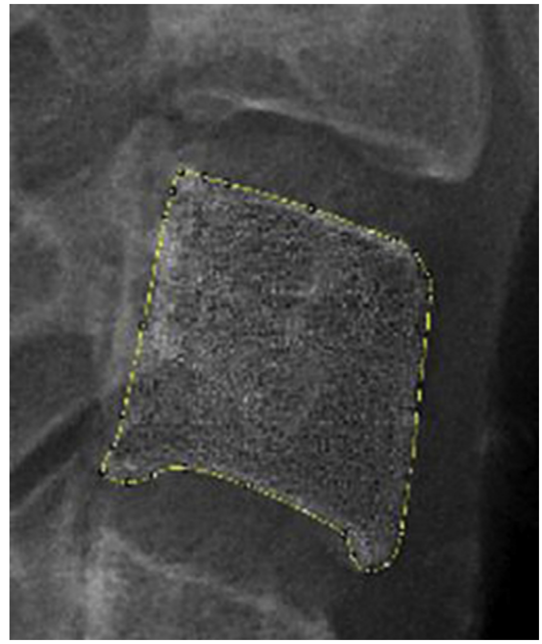

Fig. 1. Lateral cephalogram with C3 outline drawn using image J.

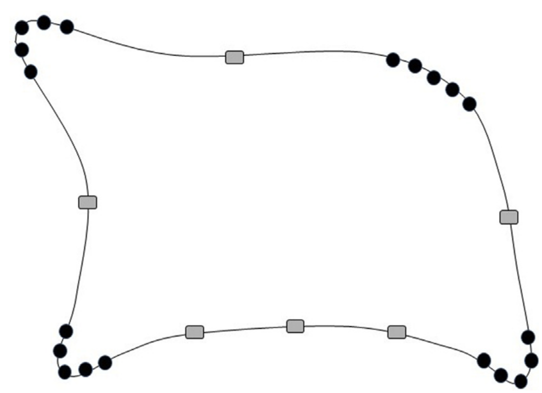

Fig. 2. Identification of landmarks on the corners and edges of the outline of the third cervical vertebra after standardising the inferior border on the horizontal.

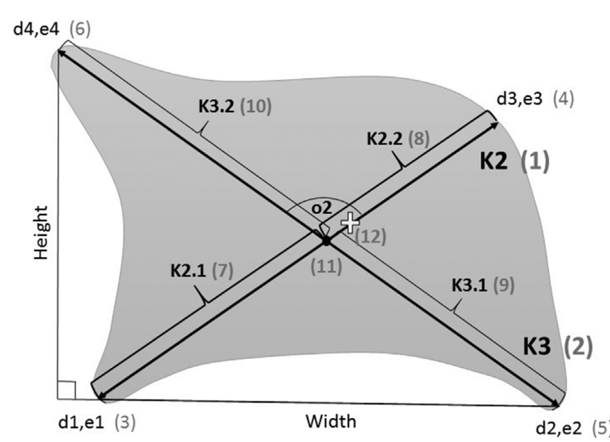

Fig. 3. Identification of dimensions assessing shape changes of the third cervical vertebra. See text for explanation of measurements.