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*Valeria Santoro,[1] Ph.D.; Piercarlo Lozito,[1] D.D.S.; Nunzio Mastrorocco,[2] Ph.D.; and Francesco Introna,[1] Ph.D.*

# Morphometric Analysis of Third Molar Root Development by an Experimental Method Using Digital Orthopantomographs

**ABSTRACT:** The aim of the study was to conduct a morphometric analysis of the root development of the third molar, with the purpose of overcoming the limits of an exclusively morphological analysis. The study was divided in two phases. The first one was the verification of the existence of a constant crown-root (C/R) ratio on a sample of 100 third molars, characterized by a complete root development. The value obtained was used in the second phase to predict the final root's length, knowing the crown height. So we have calculated, on a sample of 322 third molars with developing roots, the final ratios between incomplete roots and complete roots. Statistical analysis was then made with 90%, 95%, and 99% confidence intervals. The results showed a significant difference according to the age of the subject and the limit values, lower and upper, for subjects aged 16 and 17 years versus those aged 18 and 19. For each analysis, the width of the class of tolerance and other statistical indicators were calculated. The results we obtained support the advantage of a morphometric study as opposed to an exclusively morphological study, but all the techniques used to determine the age of a living subject can provide only indications of the biological age, but no certainties as regards chronological age.

**KEYWORDS:** forensic science, age determination, third molar, forensic odontology

Assessment of the biological age of a subject around the age of majority has always been a challenging issue for an Italian forensic doctor because of the implications on criminal liability, and also for other purposes as regards young illegal immigrants and refugee children, such as school attendance, social benefits, adoption procedures, employment, and marriage, in the context of the international protection guaranteed by the United Nations High Commissioner for Refugees (1).

In fact, forensic age estimation is often requested by authorities to ascertain whether a person suspected of a crime has reached the age of imputability. In most European countries, the legally relevant age limit range is between the 14th and the 21st year of life (2).

In particular, in Italy, the limit above which a person has legal responsibility is 14 years and the age limit of 18 is decisive for establishing whether juvenile delinquency law, or general criminal law in force for adults, is to be applied.

For this reason, young foreign criminals sometimes have false passports with a late birth date inserted in the attempt to evade punishment (3), so forensic experts are asked to give their opinion as to whether a person is younger or older than 18 years.

To this end, recourse to orthopantomography, together with radiography of the left hand and wrist bones and the iliac crest, is a consolidated technique. In particular, late in adolescence (after 15–16 years) all of the hand-wrist bones have achieved the adult morphology and their epiphyses are fused; likewise all of the teeth have erupted and completed the root formation, with the exception of the roots of the third molars, that continue to develop (4).

Thus, many studies have carried out a morphological analysis of the late developmental stages of root formation of the wisdom teeth, as a means of determining adult age. The aim of our study was to test the possibilities of use of digital orthopantomographs (OPTs), on the basis of a morphometric analysis of the development of the third molar, carried out with the purpose of overcoming the limits of an exclusive morphological analysis. In fact, it is known that morphological analysis presents difficulty in the precise identification of the third molar in the various stages of development; moreover, in previous studies, we also observed the presence of an intermediate stage between the last two stages of Demirjian's classification (G and H) (3,5,6). The risk, therefore, is that of observer bias, because of the subjectivity of the evaluation criteria adopted by each individual; besides, this kind of analysis indicates the length of the roots, which is neither a known nor predictable part of the final length.

Therefore, it is necessary to conduct a morphometric analysis to search for constant dimensional crown-root (C/R) ratio and standard deviation values of the third molar, to enable objective analysis of the specimens. Our goal was to predict a final root length, having noted the crown dimension, and finally to obtain a ratio between the true root length in the growing third molars, and the estimated length.

## Materials and Methods

In the application of our method, OPTs were acquired by digital systematic analysis using specific dental software (Kodak Dental Software) on a Pentium processor.

The measurements were taken only on inferior molars because the apexes are more evident; in fact, in the upper arch, the wall of the maxillary sinus hides the apex of the third molars, making it more difficult to interpret intermediate stages of development.

In addition, teeth with malformations or evident defects in root development were excluded.

Our study was subdivided into two phases. In the first, the existence of a constant C/R ratio was verified on a sample of 100 third molars characterized by complete root development.

[1]Section of Legal Medicine, University of Bari, P.zza Giulio Cesare n.11, 70124 Bari, Italy.
[2]Section of Statistics Sciences, University of Bari, Via Camillo Rosalba n.53, 70124 Bari, Italy.
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When applying our method, we referred to the works by Holtta and Jepsen (7,8) who studied the C/R ratio of some dental elements, for orthodontic and prosthetic purposes, but not the third molars. We therefore adopted the same reference points in the latter elements, with some modifications.

First, two points of the cemento-enamel junction (AC) were established in order to trace a straight line joining those points; subsequently, parallels to the straight line were drawn, tangentially to the apex of the highest coronal cusp and the apex of the longest root, respectively (Fig. 1).

The measurements were made perpendicularly for the three straight lines and their parallels, in order to minimize the error in the calculation phase.

Both steps (drawing of the line and measurement), as well as the acquisition of the OPT, were carried out by digital systematic search using specific dental software.

Then the crown and root measurements were taken and the ratio calculated of the third molars with completely formed roots (Table 1).

After the measurements, we carried out a statistical analysis targeted at individualizing the arithmetic mean of the ratios, and standard deviation, which produced an average value of the C/R ratio equal to 0.518 and a standard deviation of 0.05.

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}}$$

$\bar{x}$ is the mean of the sample.

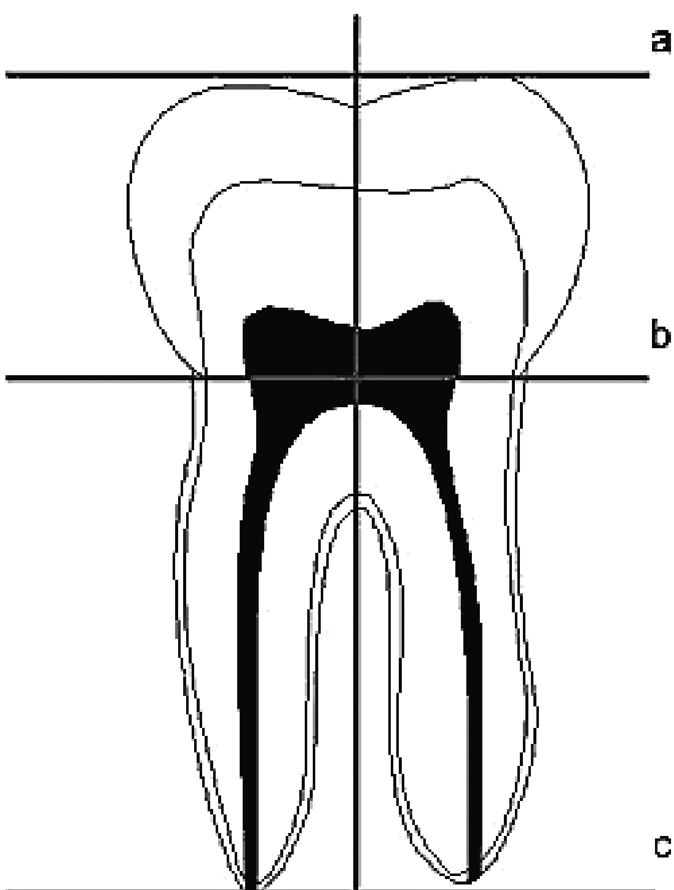


FIG. 1—*The parallel lines passing through the reference points considered in the measurements*: *(a) the summit of the highest coronal cusp, (b) cemento-enamel junction, and (c) the apex of the longest root.*

TABLE 1—*Measurement of 100 complete third molars.**

| No. | C | R | C/R | No. | C | R | C/R |
|---|---|---|---|---|---|---|---|
| 1 | 7.09 | 14.05 | **0.504** | 51 | 8.17 | 17.44 | **0.468** |
| 2 | 7.11 | 13.49 | **0.527** | 52 | 7.81 | 17.81 | **0.438** |
| 3 | 8.72 | 17.05 | **0.511** | 53 | 8.22 | 17.81 | **0.461** |
| 4 | 9.23 | 16.67 | **0.552** | 54 | 10.49 | 19.26 | **0.544** |
| 5 | 8.00 | 16.00 | **0.5** | 55 | 9.38 | 17.28 | **0.542** |
| 6 | 7.44 | 15.13 | **0.491** | 56 | 8.95 | 17.76 | **0.503** |
| 7 | 7.82 | 15.13 | **0.516** | 57 | 8.42 | 17.37 | **0.484** |
| 8 | 7.79 | 13.38 | **0.582** | 58 | 8.00 | 17.86 | **0.447** |
| 9 | 7.38 | 12.00 | **0.619** | 59 | 8.71 | 16.14 | **0.539** |
| 10 | 7.34 | 14.56 | **0.504** | 60 | 7.00 | 17.13 | **0.408** |
| 11 | 7.50 | 14.46 | **0.518** | 61 | 7.86 | 14.27 | **0.538** |
| 12 | 7.28 | 14.46 | **0.503** | 62 | 8.33 | 16.26 | **0.545** |
| 13 | 7.07 | 13.9 | **0.508** | 63 | 8.61 | 15.44 | **0.557** |
| 14 | 7.32 | 13.92 | **0.525** | 64 | 8.48 | 16.46 | **0.515** |
| 15 | 7.27 | 15.76 | **0.461** | 65 | 8.17 | 14.65 | **0.557** |
| 16 | 5.68 | 13.78 | **0.412** | 66 | 7.4 | 12.47 | **0.593** |
| 17 | 8.24 | 15.29 | **0.538** | 67 | 10.14 | 17.67 | **0.573** |
| 18 | 6.79 | 13.07 | **0.519** | 68 | 9.18 | 18.49 | **0.496** |
| 19 | 7.16 | 12.27 | **0.583** | 69 | 9.49 | 16.15 | **0.588** |
| 20 | 7.34 | 14.94 | **0.491** | 70 | 7.73 | 14.32 | **0.539** |
| 21 | 8.73 | 14.43 | **0.604** | 71 | 7.11 | 15 | **0.474** |
| 22 | 6.33 | 12.66 | **0.5** | 72 | 9.06 | 15.00 | **0.604** |
| 23 | 6.96 | 12.78 | **0.544** | 73 | 10.14 | 17.36 | **0.584** |
| 24 | 7.4 | 14.68 | **0.504** | 74 | 11.53 | 18.33 | **0.629** |
| 25 | 8.31 | 16.62 | **0.5** | 75 | 8.70 | 15.58 | **0.558** |
| 26 | 7.82 | 16.92 | **0.462** | 76 | 8.83 | 15.97 | **0.552** |
| 27 | 7.44 | 16.79 | **0.443** | 77 | 8.31 | 16.49 | **0.503** |
| 28 | 7.62 | 14.88 | **0.512** | 78 | 7.27 | 15.84 | **0.458** |
| 29 | 7.75 | 15.12 | **0.512** | 79 | 7.68 | 13.38 | **0.588** |
| 30 | 8.68 | 17.11 | **0.507** | 80 | 8.00 | 14.25 | **0.561** |
| 31 | 9.21 | 18.16 | **0.507** | 81 | 7.84 | 17.97 | **0.436** |
| 32 | 8.98 | 15.95 | **0.525** | 82 | 8.36 | 18.49 | **0.452** |
| 33 | 8.21 | 15.13 | **0.542** | 83 | 8.57 | 15.19 | **0.564** |
| 34 | 8.13 | 15.59 | **0.547** | 84 | 8.57 | 14.16 | **0.605** |
| 35 | 6.18 | 11.76 | **0.525** | 85 | 7.56 | 15.9 | **0.475** |
| 36 | 8.53 | 16.47 | **0.517** | 86 | 6.36 | 13.12 | **0.484** |
| 37 | 8.89 | 14.65 | **0.565** | 87 | 9.75 | 15.82 | **0.616** |
| 38 | 6.81 | 12.55 | **0.542** | 88 | 8.61 | 15.06 | **0.571** |
| 39 | 7.07 | 15.37 | **0.459** | 89 | 8.46 | 15.9 | **0.532** |
| 40 | 7.57 | 14.59 | **0.539** | 90 | 7.56 | 17.31 | **0.436** |
| 41 | 9.46 | 17.3 | **0.546** | 93 | 8.85 | 17.69 | **0.5** |
| 42 | 8.96 | 15.84 | **0.565** | 94 | 8.59 | 16.79 | **0.511** |
| 43 | 7.79 | 17.53 | **0.444** | 95 | 8.23 | 16.59 | **0.496** |
| 44 | 8.08 | 16.28 | **0.496** | 96 | 7.30 | 14.63 | **0.498** |
| 45 | 8.33 | 16.92 | **0.492** | 97 | 7.63 | 15.82 | **0.482** |
| 46 | 7.82 | 12.31 | **0.63** | 98 | 8.4 | 16.30 | **0.515** |
| 47 | 7.18 | 16.41 | **0.437** | 99 | 9.13 | 17.11 | **0.533** |
| 48 | 7.16 | 15.06 | **0.473** | 100 | 8.48 | 16.46 | **0.515** |
| 49 | 7.65 | 15.80 | **0.484** | | | | |
| 50 | 7.8 | 15.73 | **0.495** | | | | |

R: root size (from the cemento-enamel junction to the apex of the longest root) in millimetres.
C/R: ratios of the two sizes.
*C: crown size (from the summit of the highest coronal cusp to the cemento-enamel junction) in millimetres.

This outcome, furthermore, was supported by results from an inferential study that enabled us to determine, with 95% confidence intervals, an interval ranging between 0.509 and 0.528, within which falls the C/R ratio of the reference population (Italian) from which our sample was taken.

The confidence interval emerges from the distribution of the crown and root values and their ratios according to a normal (Gaussian) curve, calculated by the formula:

$$[\bar{x} - z_{\alpha/2}\hat{\sigma}(\bar{x});\ \bar{x} + z_{\alpha/2}\hat{\sigma}(\bar{x})]$$

$\hat{\sigma}(\bar{x})$ is the standard deviation of the mean of the sample. $z_{\alpha/2}$ is the value of the standardized "normal" (Gaussian curve).

In the second phase of our study, we analyzed a sample of 322 third molars with developing roots belonging to individuals aged between 16 and 19 years, subdivided by sex (Table 2). In this phase, we drew the parallels to the straight line which join the two points of the cemento-enamel junction (AC), tangentially to the apex of the highest coronal cusp and the most apical part of the calcified root in the developing roots, respectively.

So, the value obtained from the first phase of the study was used in the successive phase, establishing in the third molars with developing roots, the total measurements of the roots lengths (lt), knowing the crown height (*h*):

Lt = *h*/(C/R mean).

After obtaining the estimated root growth, on the basis of identification of the constant ratio, we calculated the ratio between the length of incomplete roots (ir) and complete roots, according to the growth estimate (cr).

fr (final ratio): ir/cr incomplete root/complete root (Tables 3 and 4).

Statistical analysis was then made on the basis of the "normal" (Gaussian curve) distribution of the values of the root/crown ratios, using as reference value the ratios in adult (18-year-old) subjects, creating two groups: older and younger than 18 years of age. Then specific indicators of variability were examined, to see how far the phenomenon was *statistically normally* distributed within various confidence intervals.

It must be noted that the sample size (322 cases, 143 males and 179 females) is not enough to represent a world population, but is sufficient for a first "experimental" phase. Starting therefore from the root size values, a first macro differentiation was made, for both sexes, distinguishing minors from those over age, established as 18 years old (Table 2).

Analysis was made with 90%, 95%, and 99% confidence intervals, obtaining two limit values (lower and upper) of the ir/cr ratios in subjects under 18 (16 and 17 years old) and over 18 in our sample, distinguished by sex (Fig. 2).

This yielded, for each confidence interval, the limit values, showing that the width of the range of acceptable values increased according to the confidence interval applied (Fig. 2).

## Results

The results of the ratios for the root length during development and the final length estimated by statistical analysis are shown in Tables 3 and 4, distinguished by sex.

The results of the confidence intervals for these ratios are shown in Table 5 and graphically illustrated in Figs. 2*a*, 2*b,* and 2*c*.

In the sample we analyzed, the ratios show a significant difference according to the age of the subject and the limit values, lower and upper, for subjects aged 16 and 17 years versus those aged 18 and 19.

The lower limits, i.e., the lowest values of the ir/cr ratio for minors and adults, were 0.557 versus 0.737 in our sample; the upper limits were 0.625 versus 0.833 for minors and adults, with 90% confidence intervals (Fig. 2*a*).

TABLE 2—*Cases observed.*

| Cases observed (322) | | | |
|---|---|---|---|
| Males (143) | | Females (179) | |
| Minors | Adults | Minors | Adults |
| 81 | 62 | 108 | 71 |

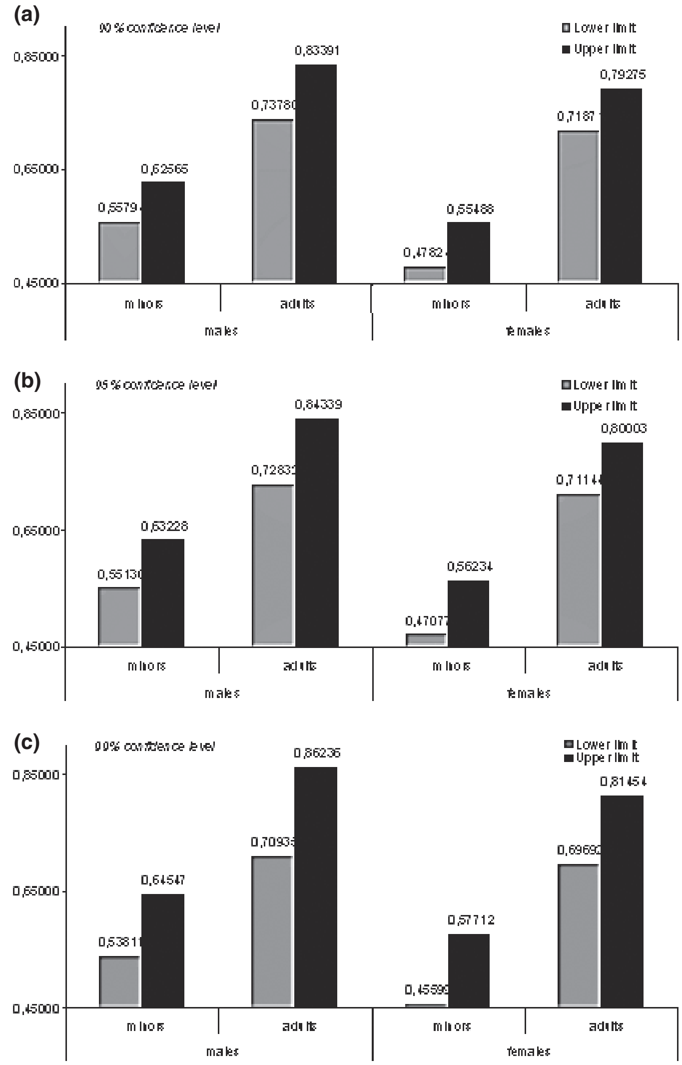


FIG. 2—*(a) Graph of the lower and upper limits by confidence interval levels: 90% confidence level. (b) Graph of the lower and upper limits by confidence interval levels: 95% confidence level. (c) Graph of the lower and upper limits by confidence interval levels: 99% confidence level.*

These limits are therefore those delimiting the class within which there is a 90% possibility that a subject with a given ir/cr ratio is a minor (16 or 17) or an adult (18 or19).

The same analysis was then made with 95% and 99% confidence intervals, showing an increasing width of the limit values (Figs. 2*b* and 2*c*). For each analysis, the width of the class of tolerance and other statistical indicators were calculated (Table 5; Figs 3–4).

Our study showed that the values of the ratios in the female sex, both for the upper and the lower limits, were invariably lower than the values for the male sex, in accordance with other works in this field (4,6,9–12), confirming that development of the third molars, unlike that of the other dental elements, occurs earlier in males than in females.

## Discussion

The results we obtained support the advantage of a morphometric study as opposed to an exclusively morphological study of the stages of maturation of the third molars, and of the use of digital

TABLE 3—*143 Third molars with developing roots belonging to male individuals aged between 16 and 19 years.*

| N | Age | Ir/cr | N | Age | Ir/cr | N | Age | Ir/cr |
|---|---|---|---|---|---|---|---|---|
| 1 | 16 | **0.274** | 50 | 17 | **0.291** | 98 | 18 | **0.551** |
| 2 | 16 | **0.282** | 51 | 17 | **0.267** | 99 | 18 | **0.715** |
| 3 | 16 | **0.269** | 52 | 17 | **0.768** | 100 | 18 | **1.116** |
| 4 | 16 | **0.34** | 53 | 17 | **0.734** | 101 | 18 | **1.036** |
| 5 | 16 | **0.331** | 54 | 17 | **0.68** | 102 | 18 | **0.72** |
| 6 | 16 | **0.386** | 55 | 17 | **0.972** | 103 | 18 | **0.731** |
| 7 | 16 | **0.369** | 56 | 17 | **0.558** | 104 | 18 | **0.731** |
| 8 | 16 | **0.395** | 57 | 17 | **0.711** | 105 | 18 | **0.702** |
| 9 | 16 | **0.452** | 58 | 17 | **0.735** | 106 | 18 | **0.747** |
| 10 | 16 | **0.262** | 59 | 17 | **0.836** | 107 | 18 | **0.743** |
| 11 | 16 | **0.193** | 60 | 17 | **0.542** | 108 | 18 | **0.691** |
| 12 | 16 | **0.416** | 61 | 17 | **0.322** | 109 | 18 | **0.698** |
| 13 | 16 | **0.388** | 62 | 17 | **0.402** | 110 | 18 | **0.685** |
| 14 | 16 | **0.534** | 63 | 17 | **0.331** | 111 | 18 | **0.749** |
| 15 | 16 | **0.545** | 64 | 17 | **0.957** | 112 | 18 | **0.794** |
| 16 | 16 | **0.533** | 65 | 17 | **0.792** | 113 | 18 | **0.533** |
| 17 | 16 | **0.564** | 66 | 17 | **0.654** | 114 | 18 | **0.808** |
| 18 | 16 | **0.747** | 67 | 17 | **0.558** | 115 | 18 | **0.766** |
| 19 | 16 | **0.585** | 68 | 17 | **0.735** | 116 | 18 | **0.682** |
| 20 | 16 | **0.251** | 69 | 17 | **0.741** | 117 | 18 | **0.73** |
| 21 | 16 | **0.354** | 70 | 17 | **0.685** | 118 | 19 | **0.79** |
| 22 | 16 | **0.633** | 71 | 17 | **0.706** | 119 | 19 | **1.226** |
| 23 | 16 | **0.586** | 72 | 17 | **0.655** | 120 | 19 | **1.019** |
| 24 | 16 | **0.621** | 73 | 17 | **0.48** | 121 | 19 | **1.052** |
| 25 | 16 | **0.531** | 74 | 17 | **0.512** | 122 | 19 | **1.004** |
| 26 | 17 | **0.675** | 75 | 17 | **0.682** | 123 | 19 | **0.96** |
| 27 | 17 | **0.662** | 76 | 17 | **0.64** | 124 | 19 | **0.87** |
| 28 | 17 | **0.756** | 77 | 17 | **0.545** | 125 | 19 | **0.922** |
| 29 | 17 | **0.817** | 78 | 17 | **0.704** | 126 | 19 | **0.326** |
| 30 | 17 | **0.727** | 79 | 17 | **0.676** | 127 | 19 | **0.437** |
| 31 | 17 | **0.66** | 80 | 17 | **0.674** | 128 | 19 | **0.893** |
| 32 | 17 | **0.654** | 81 | 17 | **0.412** | 129 | 19 | **0.922** |
| 33 | 17 | **0.575** | 82 | 18 | **0.678** | 130 | 19 | **0.857** |
| 34 | 17 | **0.704** | 83 | 18 | **0.607** | 131 | 19 | **0.777** |
| 35 | 17 | **0.684** | 84 | 18 | **0.755** | 132 | 19 | **0.879** |
| 36 | 17 | **0.604** | 85 | 18 | **0.909** | 133 | 19 | **0.785** |
| 37 | 17 | **0.642** | 86 | 18 | **0.887** | 134 | 19 | **1.061** |
| 38 | 17 | **0.79** | 87 | 18 | **0.918** | 135 | 19 | **0.871** |
| 39 | 17 | **0.74** | 88 | 18 | **1.054** | 136 | 19 | **0.934** |
| 40 | 17 | **0.727** | 89 | 18 | **0.892** | 137 | 19 | **1.004** |
| 41 | 17 | **0.917** | 90 | 18 | **0.845** | 138 | 19 | **1.261** |
| 42 | 17 | **0.748** | 91 | 18 | **0.482** | 139 | 19 | **1.26** |
| 43 | 17 | **0.806** | 92 | 18 | **0.869** | 140 | 19 | **0.533** |
| 44 | 17 | **0.798** | 93 | 18 | **0.853** | 141 | 19 | **0.354** |
| 45 | 17 | **0.693** | 94 | 18 | **0.549** | 142 | 19 | **0.251** |
| 46 | 17 | **0.576** | 95 | 18 | **0.555** | 143 | 19 | **1.003** |
| 47 | 17 | **0.586** | 96 | 18 | **0.418** | | | |
| 48 | 17 | **0.811** | 97 | 18 | **0.273** | | | |
| 49 | 17 | **0.785** | | | | | | |

TABLE 4—*179 Third molars with developing roots belonging to female individuals aged between 16 and 19 years.*

| N | Age | Ir/cr | N | Age | Ir/cr | N | Age | Ir/cr |
|---|---|---|---|---|---|---|---|---|
| 1 | 16 | **0.711** | 61 | 17 | **0.556** | 121 | 18 | **0.32** |
| 2 | 16 | **0.731** | 62 | 17 | **0.499** | 122 | 18 | **0.461** |
| 3 | 16 | **0.307** | 63 | 17 | **0.894** | 123 | 18 | **0.793** |
| 4 | 16 | **0.243** | 64 | 17 | **0.881** | 124 | 18 | **0.769** |
| 5 | 16 | **0.366** | 65 | 17 | **0.448** | 125 | 18 | **0.755** |
| 6 | 16 | **0.454** | 66 | 17 | **0.358** | 126 | 18 | **0.731** |
| 7 | 16 | **0.911** | 67 | 17 | **0.921** | 127 | 18 | **0.594** |
| 8 | 16 | **0.919** | 68 | 17 | **0.717** | 128 | 18 | **0.733** |
| 9 | 16 | **0.464** | 69 | 17 | **0.909** | 129 | 18 | **0.272** |
| 10 | 16 | **0.479** | 70 | 17 | **1.09** | 130 | 18 | **0.55** |
| 11 | 16 | **0.345** | 71 | 17 | **0.341** | 131 | 18 | **0.668** |
| 12 | 16 | **0.38** | 72 | 17 | **0.232** | 132 | 18 | **0.725** |
| 13 | 16 | **0.48** | 73 | 17 | **0.23** | 133 | 18 | **0.899** |
| 14 | 16 | **0.43** | 74 | 17 | **0.654** | 134 | 18 | **0.833** |
| 15 | 16 | **0.263** | 75 | 17 | **0.842** | 135 | 18 | **0.984** |
| 16 | 16 | **0.276** | 76 | 17 | **0.629** | 136 | 18 | **0.657** |
| 17 | 16 | **0.584** | 77 | 17 | **0.635** | 137 | 18 | **0.597** |
| 18 | 16 | **0.604** | 78 | 17 | **0.844** | 138 | 18 | **0.764** |
| 19 | 16 | **0.612** | 79 | 17 | **0.864** | 139 | 18 | **0.705** |
| 20 | 16 | **0.771** | 80 | 17 | **0.374** | 140 | 18 | **0.785** |
| 21 | 16 | **0.423** | 81 | 17 | **0.385** | 141 | 18 | **0.728** |
| 22 | 16 | **0.349** | 82 | 17 | **0.397** | 142 | 18 | **0.701** |
| 23 | 16 | **0.64** | 83 | 17 | **0.431** | 143 | 18 | **0.79** |
| 24 | 16 | **0.713** | 84 | 17 | **0.414** | 144 | 18 | **0.682** |
| 25 | 16 | **0.526** | 85 | 17 | **1.03** | 145 | 18 | **0.663** |
| 26 | 16 | **0.576** | 86 | 17 | **0.853** | 146 | 18 | **0.647** |
| 27 | 16 | **0.222** | 87 | 17 | **0.46** | 147 | 18 | **0.639** |
| 28 | 16 | **0.268** | 88 | 17 | **0.464** | 148 | 18 | **0.687** |
| 29 | 16 | **0.633** | 89 | 17 | **1.216** | 149 | 18 | **0.706** |
| 30 | 16 | **0.541** | 90 | 17 | **1.091** | 150 | 18 | **0.533** |
| 31 | 16 | **0.254** | 91 | 17 | **0.666** | 151 | 19 | **0.714** |
| 32 | 16 | **0.179** | 92 | 17 | **0.561** | 152 | 19 | **0.691** |
| 33 | 16 | **0.159** | 93 | 17 | **0.634** | 153 | 19 | **0.377** |
| 34 | 16 | **0.158** | 94 | 17 | **0.68** | 154 | 19 | **0.369** |
| 35 | 16 | **1.143** | 95 | 17 | **0.268** | 155 | 19 | **0.81** |
| 36 | 16 | **0.98** | 96 | 17 | **0.416** | 156 | 19 | **0.614** |
| 37 | 16 | **0.381** | 97 | 17 | **0.554** | 157 | 19 | **0.879** |
| 38 | 16 | **0.413** | 98 | 17 | **0.558** | 158 | 19 | **0.985** |
| 39 | 16 | **0.403** | 99 | 17 | **0.489** | 159 | 19 | **1.069** |
| 40 | 16 | **0.375** | 100 | 17 | **0.534** | 160 | 19 | **1.019** |
| 41 | 16 | **0.28** | 101 | 17 | **0.586** | 161 | 19 | **1.084** |
| 42 | 16 | **0.306** | 102 | 17 | **0.621** | 162 | 19 | **1.124** |
| 43 | 16 | **0.312** | 103 | 17 | **0.639** | 163 | 19 | **1.109** |
| 44 | 16 | **0.241** | 104 | 17 | **0.562** | 164 | 19 | **0.675** |
| 45 | 16 | **0.205** | 105 | 17 | **0.498** | 165 | 19 | **0.804** |
| 46 | 16 | **0.225** | 106 | 17 | **0.211** | 166 | 19 | **0.599** |
| 47 | 16 | **0.267** | 107 | 17 | **0.518** | 167 | 19 | **0.492** |
| 48 | 16 | **0.251** | 108 | 17 | **0.57** | 168 | 19 | **0.751** |
| 49 | 16 | **0.208** | 109 | 18 | **0.688** | 169 | 19 | **0.819** |
| 50 | 16 | **0.237** | 110 | 18 | **0.526** | 170 | 19 | **0.705** |
| 51 | 16 | **0.441** | 111 | 18 | **0.825** | 171 | 19 | **0.958** |
| 52 | 16 | **0.23** | 112 | 18 | **0.811** | 172 | 19 | **0.979** |
| 53 | 17 | **0.326** | 113 | 18 | **0.587** | 173 | 19 | **0.822** |
| 54 | 17 | **0.395** | 114 | 18 | **0.588** | 174 | 19 | **0.863** |
| 55 | 17 | **0.454** | 115 | 18 | **0.819** | 175 | 19 | **0.887** |
| 56 | 17 | **0.517** | 116 | 18 | **0.98** | 176 | 19 | **0.893** |
| 57 | 17 | **0.572** | 117 | 18 | **1.026** | 177 | 19 | **0.63** |
| 58 | 17 | **0.564** | 118 | 18 | **0.969** | 178 | 19 | **0.851** |
| 59 | 17 | **0.485** | 119 | 18 | **1.051** | 179 | 19 | **0.962** |
| 60 | 17 | **0.382** | 120 | 18 | **0.882** | | | |

technology as opposed to traditional measurements, both in terms of better image definition and of the possibility of applying, with the appropriate software, a standardized method of crown and root measurement.

It must be borne in mind that with a larger sample, the dispersion index (standard deviation) and the width of the confidence intervals would diminish, obtaining a more circumscribed range of values and hence a greater precision for the two age groups. In addition, the sample we studied cannot be considered representative of the whole world population, because it consisted of subjects of Caucasian race and Italian nationality, although not of socio-economically homogeneous extraction. A useful development of this study would be to extend it to other populations, including among these some of the many immigrants now present in Italy.

It must also be stressed that 100% confidence in dental age assessment has never yet been reached, and no one can make an exact judgment or a certain prediction of age, because no extremely precise and accurate age-determination technique has yet been devised, owing to the great complexity and variability of human development (13).

For this reason, all the techniques used to determine the age of a living subject can provide only indications of the biological age, but no certainties as regards chronological age. The aim of our

TABLE 5—*Synoptic table by confidence tables and statistical indicators.*

| | Males | | Females | |
|---|---|---|---|---|
| | Minors | Adults | Minors | Adults |
| With 90% confidence intervals | | | | |
| Mean | 0.59179 | 0.78585 | 0.51656 | 0.75573 |
| Lower limit | **0.55794** | **0.73780** | **0.47824** | **0.71871** |
| Upper limit | **0.62565** | **0.83391** | **0.55488** | **0.79275** |
| *Width class* | *0.06771* | *0.09612* | *0.07664* | *0.07405* |
| Median | 0.64000 | 0.78750 | 0.47950 | 0.75100 |
| Variance | 0.03352 | 0.05133 | 0.05761 | 0.03502 |
| Mean square error | 0.18310 | 0.22657 | 0.24001 | 0.18715 |
| Minimum | 0.19300 | 0.25100 | 0.15800 | 0.27200 |
| Maximum | 0.97200 | 1.26100 | 1.21600 | 1.12400 |
| Range | 0.77900 | 1.01000 | 1.05800 | 0.85200 |
| Interquartile range | 0.29650 | 0.23775 | 0.29275 | 0.23500 |
| Skewness index | −0.36017 | −0.27873 | 0.80377 | −0.23612 |
| Kurtosi index | −0.63159 | 0.10556 | 0.19099 | 0.02606 |
| With 95% confidence intervals | | | | |
| Mean | 0.59179 | 0.78585 | 0.51656 | 0.75573 |
| Lower limit | **0.55130** | **0.72832** | **0.47077** | **0.71144** |
| Upper limit | **0.63228** | **0.84339** | **0.56234** | **0.80003** |
| *Width class* | *0.08097* | *0.11507* | *0.09157* | *0.08859* |
| Median | 0.64000 | 0.78750 | 0.47950 | 0.75100 |
| Variance | 0.03352 | 0.05133 | 0.05761 | 0.03502 |
| Mean square error | 0.18310 | 0.22657 | 0.24001 | 0.18715 |
| Minimum | 0.19300 | 0.25100 | 0.15800 | 0.27200 |
| Maximum | 0.97200 | 1.26100 | 1.21600 | 1.12400 |
| Range | 0.77900 | 1.01000 | 1.05800 | 0.85200 |
| Interquartile range | 0.29650 | 0.23775 | 0.29275 | 0.23500 |
| Skewness index | −0.36017 | −0.27873 | 0.80377 | −0.23612 |
| Kurtosi index | −0.63159 | 0.10556 | 0.19099 | 0.02606 |
| With 99% confidence intervals | | | | |
| Mean | 0.59179 | 0.78585 | 0.51656 | 0.75573 |
| Lower limit | **0.53811** | **0.70935** | **0.45599** | **0.69692** |
| Upper limit | **0.64547** | **0.86236** | **0.57712** | **0.81454** |
| *Width class* | *0.10736* | *0.15301* | *0.12114* | *0.11762* |
| Median | 0.64000 | 0.78750 | 0.47950 | 0.75100 |
| Variance | 0.03352 | 0.05133 | 0.05761 | 0.03502 |
| Mean square error | 0.18310 | 0.22657 | 0.24001 | 0.18715 |
| Minimum | 0.19300 | 0.25100 | 0.15800 | 0.27200 |
| Maximum | 0.97200 | 1.26100 | 1.21600 | 1.12400 |
| Range | 0.77900 | 1.01000 | 1.05800 | 0.85200 |
| Interquartile range | 0.29650 | 0.23775 | 0.29275 | 0.23500 |
| Skewness index | −0.36017 | −0.27873 | 0.80377 | −0.23612 |
| Kurtosi index | −0.63159 | 0.10556 | 0.19099 | 0.02606 |

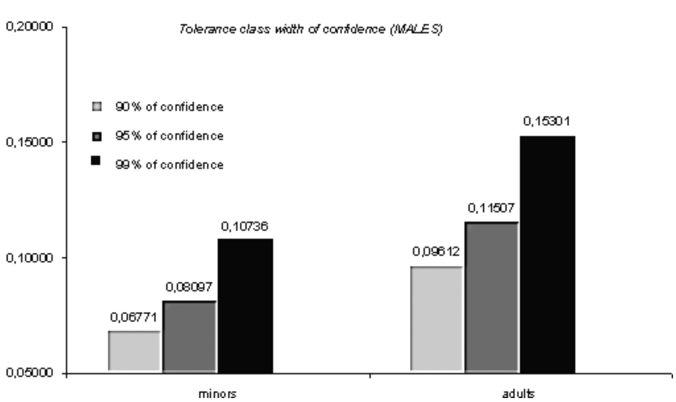


FIG. 3—*Graph of the width by tolerance classes for males.*

study was to provide a more objective determination method based on the root development of the inferior third molar, overcoming the limits of a purely morphological study in which the stages lead to an unknown final length, and which also suffers from considerable observer bias.

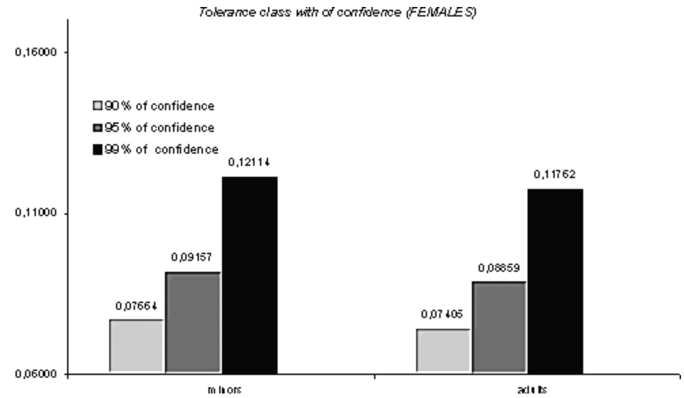


FIG. 4—*Graph of the width by tolerance classes for females.*

However, age estimation can be made more precise by comparing the standard deviation with other skeletal age calculation techniques based on some ossification nuclei of the scapula, clavicle, and femur, for instance, which are completed between the ages of 18 and 25 years.

In fact, according to Ubelaker, it is generally agreed that assessment of age reflects a greater accuracy when derived from multiple indicators (14). Finally, it must be stressed that another advantage in using a digital technique is its lesser invasiveness, because radiation is reduced by $\frac{3}{4}$ as compared with traditional orthopantomography, thus better complying with the principles of medical ethics.

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Additional information and reprint requests:
Valeria Santoro, Ph.D.
Section of Legal Medicine
University of Bari
P.zza Giulio Cesare n.11
70124 Bari
Italy
E-mail: vasantoro@virgilio.it