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# Tooth Mineralization Standards for Blacks and Whites from the Middle Southern United States

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**ABSTRACT:** Normative standards are provided for permanent tooth mineralization stages for blacks and whites of the middle southern United States. The data cover tooth development from 3.5 to 13 years of age. Females develop more rapidly than males, and blacks are nearly twice as sexually dimorphic (7.2%) as whites (3.7%). Within each sex, blacks achieve mineralization stages significantly earlier, by about 5%, than whites. This complements earlier findings that teeth *erupt* at appreciably earlier mean ages in blacks.

**KEYWORDS:** odontology, dentition, dental development, age identification, dental age, American blacks, sex dimorphism

"Dental age" is one of just a few measures of physiologic development that is uniformly applicable from infancy through late adolescence [*1,2*]. This contrasts with the use of tooth eruption alone and is more broadly applicable than, say, the onset of secondary sexual characteristics in determining subadult age. Moreover, dental development appears to be well buffered, being comparatively unaffected by nutritional [*3,4*], endocrine [*5*], and other factors that impact on the tempo of an individual's progress toward maturity. In these respects, dental development is less labile than hand-wrist bone development [*6*] or the measurement of long bone growth velocities in the estimation of age [*7*].

To date, there are no standards for the estimation of dental age in blacks in the United States and, for that matter, rather few for whites. The forensic science and clinical utility of population norms for tooth development is reflected in several comprehensive but, of course, group-specific studies by Moorrees et al. [*8*] on children from Boston and Yellow Springs, Ohio; by Anderson and co-workers [*9*] on the series in the Burlington Growth Centre, Ontario, Canada; by Demirjian, Goldstein, and Tanner [*10*] on children from Montreal, Canada; and by Haavikko [*11*] and Nielsen and Ravn [*12*] on Danish children. The interested reader is directed to the extensive review of the substance and concepts of dental development by Demirjian [*13*].

It is rather recent that the unqualified applicability of time-honored tooth mineralization standards has been examined [*14,15*], even though population differences documented for bone age are strongly suggestive that dental differences both within and among races ought to exist [*16,17*]. It is well documented that, within a group, the dentitions of females are developmentally advanced over those of their male counterparts [*8,18*]. Studies have

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also indicated that American blacks exhibit precocious tooth eruption relative to whites [*17,19*].

The present study was undertaken to provide sex-specific standards for blacks and a regionally and economically comparable series for whites. Several prior studies, primarily focusing on tooth eruption, indicate that commonly applied standards based on whites [*1,3,14,15,20*] can markedly underestimate the chronologic age of American blacks.

## Materials and Methods

The data are cross-sectional; standardized orthopantomographs of 990 phenotypically normal children were examined from dental records at the University of Tennessee College of Dentistry, in Memphis, Tennessee. Medical histories were reviewed on each subject to eliminate children with handicapping conditions or other abnormal developmental parameters. "Race" classification was based on cultural criteria and physical appearance. Studies of genetic admixture, based largely on serologic traits, suggest that contemporary American blacks are admixed with whites on the order of 10% in rural areas to about 20% in urban settings, such as the present study [*21–23*]. Subsets in the present analyses consist of 300 white males, 355 white females, 151 black males, and 184 black females.

Maxillary and mandibular teeth on either the right or left side were assigned mineralization stages according to the classification scheme of Moorrees, Fanning, and Hunt [*8*]. All 16 tooth types were scored on each subject. Right-left symmetry was assumed, since no statistical difference has been noted between sides in developmentally normal individuals [*24–27*]. Incisors, canines, and premolars were assigned stage numbers from 1 to 13, and molars from 1 to 14 (Table 1). The molars were assigned one additional stage for initial cleft formation, a status that does not generally apply to other teeth. The teeth were scored to the closest morphologic full stage without recourse to interpolation. Double determinations on 80 cases produced identical readings for 96% of all teeth, with no difference exceeding one stage.

The statistics were machine calculated using custom-written programs. Cases were assigned to six-month chronologic age intervals without "correcting" for gestational age. Once the data set was segregated by race, sex, tooth, and mineralization category, descriptive statistics were computed for the age of attainment of each formation stage [*9,27*]. This procedure was employed to provide comparability with other studies, even though some statistical advantage might have been gained if logarithmic transformations had been employed to guard against positive skewness [*2*]. Samples of less than five are omitted from the tables.

The weighted average variance [*28*] was computed for each mineralization stage of each tooth. The standard deviation (square root of the variance) thus derived is included in the tables. One-way analysis of variance was used for each stage of each tooth to test for significant race (within sex) and sex (within race) differences. This is analogous to performing a series of $t$-tests when the residual mean square for all four race-sex categories is employed rather than the pooled standard deviation. Two-tail tests of significance were used at an alpha of 0.05; this is conservative since, if a difference occurs, the literature strongly suggests that females will be advanced over males and blacks over whites [*14,17,19*].

The harmonic mean sample size [*28*] was computed for each tooth and development category. These values are more appropriate than arithmetic averages if additional statistical treatments are desired. The mean cell size is 9.81 individuals for black males, 11.14 for black females, 17.83 for white males, and 17.39 for white females.

TABLE 1—*Definitions of stages of tooth formation used to grade the 16 tooth types (the scheme depends on radiographic, not histologic, criteria and is identical to that developed at Moorrees, Fanning and Hunt* [8]*).*

| Single-Rooted Teeth | Defintion | Multiple-Rooted Teeth |
|---|---|---|
| 1 | initial cusp formation: amelogenesis has begun on the individual cusp tips | 1 |
| 2 | coalescence of cusps: centers of calcification are merged but the border is not everywhere radiopaque | 2 |
| 3 | cusp outline complete: the coronal outline of the tooth is mineralized | 3 |
| 4 | crown ½ formed: amelogenesis has proceeded half way to the crown-root as judged from the morphology of the radiopaque portion | 4 |
| 5 | crown ¾ complete | 5 |
| 6 | crown complete: morphologically, all the crown has mineralized but root formation has not begun | 6 |
| 7 | initial root formation: there is just a trace of root radiopacity below the crown outline | 7 |
| ... | initial cleft formation: mineralization is evident in the interradicular area | 8 |
| 8 | root length ¼: the radiographic morphology of the root is ¼ its projected final size | 9 |
| 9 | root length ½ complete | 10 |
| 10 | root length ¾ complete | 11 |
| 11 | root length complete | 12 |
| 12 | apex half closed: the lateral borders of the root tip become convex rather than tapered as earlier | 13 |
| 13 | apical closure complete: size of the apical foramen is reduced to its mature size | 14 |

## Results and Discussion

Average ages of attainment for each mineralization stage are listed in Table 2 for maxillary teeth and Table 3 for mandibular teeth. Events occurring before about 3.5 years of age or after about 13.0 years are not reflected in this (or most other) samples.

It is common that a child will have his or her first dental examination at about 3.5 years of age. At this time, the typical child will exhibit the following: The crown of the upper central and the lower incisors will be three-fourths complete. Half the upper lateral crown and both the upper and lower canine crowns will be mineralized. The first premolars will possess complete cusp outlines, while the second premolars and the second molars will have just begun cusp mineralization. Only the first molars will have completed crown mineralization by this age, and the third molars will not have begun hard tissue deposition.

Apart from such generalizations, several differences are evident in these data: Each mandibular tooth tends to reach a developmental stage ahead of its maxillary counterpart; this is particularly notable for the incisors. Within each morphogenetic field (incisors, premolars, molars), the mesial tooth is developmentally advanced over the more distal tooth or teeth. This holds within each race and sex. Similarly, the more distal tooth in

TABLE 2—*Age (in years) of achievement of mineralization stages of maxillary teeth in white males (WM), black males (BM), white females (WF), and black females (BF).*[a]

| | | Incisors | | | Premolars | | Molars | | |
|---|---|---|---|---|---|---|---|---|---|
| Stage | Subjects | Central | Lateral | Canine | First | Second | First | Second | Third |
| 1 | WM | ... | ... | ... | ... | ... | ... | 3.9 | 9.3 |
| | BM | ... | ... | ... | ... | ... | ... | 4.3 | 8.6 |
| | WF | ... | ... | ... | ... | ... | ... | 4.0 | 8.9 |
| | BF | ... | ... | ... | ... | ... | ... | 3.3 | 9.2 |
| | (SD) | ... | ... | ... | ... | ... | ... | (0.49) | (0.99) |
| 2 | WM | ... | ... | ... | ... | 4.0 | ... | 4.5 | 9.7 |
| | BM | ... | ... | ... | ... | 4.3 | ... | 4.0 | 9.2 |
| | WF | ... | ... | ... | ... | 4.6 | ... | 4.4 | 10.0 |
| | BF | ... | ... | ... | ... | 3.9 | ... | 3.6 | 9.0 |
| | (SD) | ... | ... | ... | ... | (0.83) | ... | (0.55) | (1.32) |
| 3 | WM | ... | ... | ... | 4.1 | 4.8 | ... | 4.8 | 10.8 |
| | BM | ... | ... | ... | 3.3 | 4.2 | ... | 4.4 | 9.9 |
| | WF | ... | ... | ... | 3.9 | 4.4 | ... | 5.1 | 10.7 |
| | BF | ... | ... | ... | 3.3 | 4.7 | ... | 4.6 | 9.2 |
| | (SD) | ... | ... | ... | (0.70) | (0.67) | ... | (0.77) | (1.06) |
| 4 | WM | ... | 3.6 | 3.8 | 4.7 | 5.6 | ... | 5.7 | 11.5 |
| | BM | ... | 3.5 | 3.6 | 4.2 | 5.0 | ... | 5.3 | 9.9 |
| | WF | ... | 4.3 | 4.2 | 4.7 | 5.8 | ... | 5.6 | 10.6 |
| | BF | ... | 3.8 | 3.5 | 4.2 | 5.3 | ... | 4.8 | 9.7 |
| | (SD) | ... | (0.70) | (0.80) | (0.79) | (0.78) | ... | (0.65) | (1.03) |
| 5 | WM | 3.6 | 4.5 | 4.8 | 5.8 | 6.4 | 3.4 | 6.7 | 11.9 |
| | BM | 3.7 | 4.6 | 4.1 | 5.7 | 6.7 | 2.7 | 6.3 | 11.1 |
| | WF | 4.3 | 4.5 | 4.6 | 6.0 | 6.4 | 3.5 | 6.5 | 11.9 |
| | BF | 3.8 | 3.8 | 4.1 | 5.2 | 6.0 | 3.0 | 6.0 | 9.9 |
| | (SD) | (0.77) | (0.78) | (0.83) | (0.77) | (0.92) | (0.53) | (0.93) | (1.17) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | WM | 4.3 | 5.3 | 6.0 | 7.3 | 7.7 | 4.0 | 7.4 | 12.4 |
| | BM | 3.9 | 4.2 | 5.5 | 6.8 | 7.9 | 3.4 | 7.3 | 10.8 |
| | WF | 4.6 | 4.9 | 5.6 | 6.5 | 7.3 | 3.8 | 7.2 | 11.6 |
| | BF | 4.1 | 4.8 | 4.7 | 6.2 | 7.0 | 3.7 | 6.8 | 11.3 |
| | (SD) | (0.79) | (0.90) | (0.93) | (1.14) | (1.04) | (0.71) | (0.99) | (0.70) |
| 7 | WM | 5.3 | 6.5 | 6.7 | 8.0 | 8.5 | 4.6 | 8.5 | 13.2 |
| | BM | 5.4 | 5.8 | 6.1 | 8.2 | 8.4 | 4.2 | 8.6 | 13.1 |
| | WF | 5.4 | 5.9 | 6.1 | 7.7 | 8.4 | 4.3 | 8.4 | 13.4 |
| | BF | 5.1 | 5.4 | 5.9 | 7.2 | 8.2 | 4.3 | 7.9 | 12.1 |
| | (SD) | (0.90) | (1.22) | (1.14) | (0.90) | (0.98) | (0.87) | (0.99) | (1.37) |
| 8 | WM | 6.3 | 7.1 | 7.8 | 9.0 | 9.4 | 4.3 | 9.7 | ... |
| | BM | 5.9 | 7.0 | 7.9 | 8.6 | 9.5 | 3.9 | 9.1 | ... |
| | WF | 6.1 | 6.7 | 7.3 | 8.7 | 9.0 | 4.7 | 9.1 | ... |
| | BF | 6.0 | 6.4 | 6.9 | 7.9 | 9.1 | 4.2 | 8.9 | ... |
| | (SD) | (0.75) | (0.83) | (0.90) | (0.95) | (0.98) | (0.58) | (1.13) | ... |
| 9 | WM | 7.5 | 8.1 | 8.9 | 9.2 | 10.1 | 5.3 | 10.5 | ... |
| | BM | 7.2 | 7.8 | 8.3 | 9.7 | 9.9 | 5.3 | 9.7 | ... |
| | WF | 6.9 | 7.4 | 8.1 | 9.5 | 10.1 | 5.5 | 10.0 | ... |
| | BF | 6.4 | 6.9 | 7.9 | 8.9 | 9.3 | 4.8 | 9.5 | ... |
| | (SD) | (0.82) | (0.90) | (0.88) | (0.85) | (1.12) | (0.78) | (0.81) | ... |
| 10 | WM | 8.1 | 8.5 | 10.2 | 10.7 | 11.4 | 6.4 | 11.8 | ... |
| | BM | 7.6 | 8.3 | 9.7 | 9.7 | 10.4 | 6.9 | 11.5 | ... |
| | WF | 7.5 | 8.2 | 9.4 | 10.0 | 10.5 | 6.3 | 11.3 | ... |
| | BF | 7.1 | 8.5 | 9.1 | 10.3 | 10.0 | 6.0 | 10.8 | ... |
| | (SD) | (1.04) | (0.75) | (0.92) | (0.96) | (1.06) | (0.74) | (1.10) | ... |
| 11 | WM | 8.8 | 9.6 | 11.9 | 12.3 | 12.6 | 7.5 | 12.6 | ... |
| | BM | 8.9 | 9.7 | 11.3 | 12.1 | 12.3 | 7.5 | 12.5 | ... |
| | WF | 8.1 | 9.1 | 11.0 | 11.2 | 11.2 | 7.3 | 11.5 | ... |
| | BF | 8.5 | 9.1 | 10.1 | 10.5 | 11.4 | 6.6 | 11.4 | ... |
| | (SD) | (0.86) | (0.84) | (1.07) | (1.02) | (0.81) | (1.03) | (0.93) | ... |

TABLE 2—*Continued.*

| | | Incisors | | | Premolars | | Molars | | |
|---|---|---|---|---|---|---|---|---|---|
| Stage | Subjects | Central | Lateral | Canine | First | Second | First | Second | Third |
| 12 | WM | 9.7 | 10.5 | 12.5 | 12.7 | 12.3 | 8.5 | 12.4 | ... |
| | BM | 9.3 | 9.6 | 12.7 | 11.9 | 12.8 | 8.5 | 12.8 | ... |
| | WF | 9.1 | 9.7 | 11.8 | 11.6 | 12.0 | 8.0 | 12.1 | ... |
| | BF | 8.8 | 9.6 | 11.5 | 11.1 | 12.2 | 8.4 | 12.2 | ... |
| | (SD) | (0.91) | (1.00) | (0.95) | (0.85) | (0.77) | (1.05) | (1.06) | ... |
| 13 | WM | ... | ... | ... | ... | ... | 9.5 | 12.5 | ... |
| | BM | ... | ... | ... | ... | ... | 9.3 | 13.0 | ... |
| | WF | ... | ... | ... | ... | ... | 9.2 | 12.9 | ... |
| | BF | ... | ... | ... | ... | ... | 8.8 | 11.8 | ... |
| | (SD) | ... | ... | ... | ... | ... | (1.07) | (1.43) | ... |

[a]Data are unreported (...) when the sample size is less than 5 and for the first and last mineralization stages which cross-sectional data do not define accurately. The values are the arithmetic mean ($\overline{X}$) and the standard deviation (SD) weighted for the four race-sex subgroups of each tooth and stage.

TABLE 3—*Age of achievement of mineralization stages of mandibular teeth.*[a]

| | | Incisors | | | Premolars | | Molars | | |
|---|---|---|---|---|---|---|---|---|---|
| Stage | Subjects | Central | Lateral | Canine | First | Second | First | Second | Third |
| 1 | WM | ... | ... | ... | ... | 3.9 | ... | 4.1 | 9.0 |
| | BM | ... | ... | ... | ... | 3.2 | ... | 3.7 | 8.2 |
| | WF | ... | ... | ... | ... | 5.0 | ... | 3.6 | 9.6 |
| | BF | ... | ... | ... | ... | 3.7 | ... | 3.5 | 8.4 |
| | (SD) | ... | ... | ... | ... | (1.17) | ... | (0.51) | (1.23) |
| 2 | WM | ... | ... | ... | ... | 4.6 | ... | 4.2 | 9.9 |
| | BM | ... | ... | ... | ... | 3.8 | ... | 3.9 | 9.0 |
| | WF | ... | ... | ... | ... | 4.3 | ... | 4.7 | 10.0 |
| | BF | ... | ... | ... | ... | 3.6 | ... | 3.6 | 9.0 |
| | (SD) | ... | ... | ... | ... | (1.02) | ... | (0.58) | (1.21) |
| 3 | WM | ... | ... | ... | 4.0 | 5.3 | ... | 5.0 | 11.0 |
| | BM | ... | ... | ... | 3.4 | 4.4 | ... | 4.7 | 9.6 |
| | WF | ... | ... | ... | 4.0 | 4.8 | ... | 5.2 | 10.6 |
| | BF | ... | ... | ... | 3.4 | 4.8 | ... | 4.5 | 9.4 |
| | (SD) | ... | ... | ... | (0.63) | (0.94) | ... | (0.81) | (1.10) |
| 4 | WM | ... | ... | 3.5 | 4.5 | 5.4 | ... | 5.9 | 11.5 |
| | BM | ... | ... | 3.7 | 4.3 | 5.1 | ... | 5.5 | 10.4 |
| | WF | ... | ... | 4.2 | 4.6 | 5.7 | ... | 5.6 | 11.2 |
| | BF | ... | ... | 3.2 | 4.2 | 4.9 | ... | 5.2 | 9.8 |
| | (SD) | ... | ... | (0.62) | (0.63) | (0.73) | ... | (0.74) | (1.03) |
| 5 | WM | ... | 3.8 | 4.3 | 5.8 | 6.1 | ... | 6.3 | 12.5 |
| | BM | ... | 3.6 | 4.2 | 5.8 | 6.7 | ... | 6.4 | 11.3 |
| | WF | ... | 4.1 | 4.2 | 5.5 | 6.4 | ... | 6.4 | 12.0 |
| | BF | ... | 3.5 | 4.4 | 5.2 | 5.7 | ... | 6.0 | 10.7 |
| | (SD) | ... | (0.79) | (0.64) | (0.73) | (0.90) | ... | (1.03) | (1.22) |

TABLE 3—*Continued.*

| | | Incisors | | | Premolars | | Molars | | |
|---|---|---|---|---|---|---|---|---|---|
| Stage | Subjects | Central | Lateral | Canine | First | Second | First | Second | Third |
| 6 | WM | 3.7 | 4.1 | 5.6 | 6.8 | 7.6 | 3.5 | 8.0 | 12.6 |
| | BM | 4.0 | 4.4 | 5.5 | 6.3 | 7.2 | 3.0 | 7.3 | 12.2 |
| | WF | 3.9 | 4.5 | 5.0 | 6.4 | 7.3 | 3.5 | 7.4 | 11.7 |
| | BF | 3.4 | 4.1 | 4.9 | 6.2 | 6.6 | 3.2 | 6.8 | 12.2 |
| | (SD) | (0.57) | (0.73) | (0.75) | (1.14) | (1.12) | (0.29) | (1.04) | (0.74) |
| 7 | WM | 4.7 | 5.3 | 6.4 | 7.7 | 8.6 | 4.3 | 8.1 | 13.0 |
| | BM | 4.1 | 4.9 | 6.6 | 7.8 | 8.5 | 4.0 | 8.7 | 13.2 |
| | WF | 4.4 | 4.7 | 5.8 | 7.3 | 8.0 | 4.2 | 8.1 | 13.5 |
| | BF | 4.0 | 5.1 | 6.1 | 7.0 | 7.6 | 3.5 | 7.6 | 12.6 |
| | (SD) | (0.75) | (0.77) | (1.21) | (0.84) | (0.89) | (0.64) | (0.95) | (1.34) |
| 8 | WM | 5.5 | 6.1 | 7.6 | 9.0 | 9.8 | 4.3 | 9.0 | ... |
| | BM | 5.4 | 6.0 | 8.3 | 9.0 | 9.4 | 4.0 | 8.7 | ... |
| | WF | 5.2 | 5.8 | 6.9 | 8.5 | 8.8 | 4.5 | 8.9 | ... |
| | BF | 5.4 | 5.7 | 6.8 | 8.4 | 8.9 | 4.1 | 8.6 | ... |
| | (SD) | (0.70) | (0.76) | (0.94) | (0.86) | (0.96) | (0.68) | (0.92) | ... |
| 9 | WM | 6.4 | 6.9 | 8.8 | 9.4 | 10.2 | 5.2 | 10.2 | ... |
| | BM | 5.8 | 6.7 | 8.8 | 9.7 | 10.0 | 5.2 | 9.7 | ... |
| | WF | 6.2 | 6.3 | 8.0 | 9.0 | 9.7 | 5.2 | 9.8 | ... |
| | BF | 5.5 | 5.9 | 7.7 | 9.0 | 9.5 | 4.8 | 9.5 | ... |
| | (SD) | (0.72) | (0.73) | (0.99) | (0.90) | (1.16) | (0.70) | (1.03) | ... |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | WM | 6.6 | 7.7 | 9.7 | 10.8 | 11.3 | 6.1 | 11.5 | ... |
| | BM | 6.5 | 7.7 | 9.9 | 9.8 | 10.7 | 6.6 | 11.2 | ... |
| | WF | 6.3 | 7.3 | 9.1 | 10.0 | 10.7 | 6.3 | 10.8 | ... |
| | BF | 5.9 | 6.9 | 9.3 | 9.6 | 9.7 | 5.8 | 10.7 | ... |
| | (SD) | (0.74) | (0.86) | (0.95) | (0.91) | (1.03) | (0.71) | (1.02) | ... |
| 11 | WM | 8.0 | 8.2 | 11.5 | 11.7 | 12.4 | 7.5 | 12.2 | ... |
| | BM | 7.4 | 8.4 | 11.3 | 11.4 | 11.9 | 7.4 | 12.1 | ... |
| | WF | 7.4 | 8.0 | 10.1 | 11.1 | 11.7 | 7.0 | 11.6 | ... |
| | BF | 6.5 | 8.0 | 9.4 | 11.2 | 11.7 | 6.6 | 12.0 | ... |
| | (SD) | (0.85) | (0.99) | (1.04) | (1.00) | (0.99) | (1.05) | (0.93) | ... |
| 12 | WM | 8.6 | 9.2 | 12.4 | 12.5 | 12.5 | 8.4 | 12.6 | ... |
| | BM | 8.6 | 9.4 | 11.6 | 12.0 | 12.8 | 8.4 | 12.5 | ... |
| | WF | 8.3 | 8.9 | 11.3 | 11.5 | 11.8 | 8.1 | 12.2 | ... |
| | BF | 7.8 | 8.6 | 10.7 | 11.7 | 11.4 | 7.8 | 11.5 | ... |
| | (SD) | (0.97) | (1.01) | (0.91) | (0.95) | (0.97) | (0.87) | (1.01) | ... |
| 13 | WM | ... | ... | ... | ... | ... | 9.2 | 12.8 | ... |
| | BM | ... | ... | ... | ... | ... | 9.5 | 13.0 | ... |
| | WF | ... | ... | ... | ... | ... | 9.0 | 13.2 | ... |
| | BF | ... | ... | ... | ... | ... | 8.4 | 13.2 | ... |
| | (SD) | ... | ... | ... | ... | ... | (1.01) | (1.21) | ... |

[a] Details are the same as for Table 1.

each field is more variable in its development, as indicated by larger standard deviations (Tables 2 and 3).

The systematic sex differences noted for most sorts of growth data—with females developmentally advanced over males—are readily evident in these data, both for blacks and whites. When univariate tests are performed for all tooth and stage combinations (omitting cells with fewer than 20 degrees of freedom), 43% achieve statistical significance, and this percentage is the same for blacks and whites. However, when the percentage of dimorphism (that is, the male-female difference divided by the female mean) is examined, blacks (7.2%) are nearly twice as sexually dimorphic as whites (3.7%). Root development is more dimorphic than crown development. In whites, average sex dimorphism is 2% for Stages 1 through 6 and 5% for Stages 7 through 12. In blacks, these values are 6% and 8%, respectively.

Nolla [*27*] and others have commented that the two sexes devote the same amount of time to tooth formation: females initiate tooth mineralization earlier than males on average, but they also finish ahead of males. This phenomenon does not hold for either blacks or whites in these data. We were obliged to focus on root formation because the records of crown development are missed unless much younger children are examined. Still, assessments of the time spans involved in (*a*) crown formation (Stages 1 through 6) of the second and third molars and (*b*) crown and root formation (Stages 1 through 11) of all teeth except third molars both confirm that females spend significantly *less* time completing these stages of development. The mean difference is 0.5 years for whites and 0.3 years for blacks. Consequently, females begin tooth formation at an earlier age chronologically *and* they complete this aspect of development proportionately faster than males [*7,29*].

For all the teeth, but notably some of the later developing units (for example, the maxillary canine and third molar), blacks achieve tooth development stages significantly ahead of the white subset. Calculations on all usable tooth and stage combinations (that is, with over 20 degrees of freedom), reveal that black males are *significantly* advanced over white males in 26% (28/106) of the comparisons, while black females achieve statistical significance over white females in 42% (48/114) of the cases. While it is not clear-cut, inspection suggests that racial differences are proportionately greater during the earlier. crown formation stages (Stages 1 through 6) than for root formation (Fig. 1). As an approximation, discounting small and missing cells, blacks achieve a tooth formation stage 4% ahead of white males and black females are 6% ahead of white females.

One might assume that differences among racial groups would overshadow regional differences within an ethnic group. Clearly, this is not the case when these middle southern series are compared with the Caucasian data published by Anderson and co-workers [*9*] which were analyzed in a comparable manner. All mineralization stages for all teeth for each sex were tested for differences between this series of whites and the Burlington standards. Omitting empty cells, 259 tests were performed. While this may well involve a multiple comparison problem, the simple point to be made is that 214 (83%) of these achieve statistical significance. These middle southern whites consistently attain tooth formation stages later than the children enrolled in the Burlington Growth Centre, Ontario (Fig. 2). It is important to recognize that previous authors have been quite circumspect in their claims. Moorrees and co-workers [*8*] stated that, "until much more is known about the determination of the pattern of tooth formation, one cannot properly anticipate that other populations of children will follow the same time schedules as the present one."

It is of interest that females differ substantially more within these two racial groups than the male subsets (Fig. 3). Overall, these middle southern males are 10% slower to attain a tooth formation stage, and the difference is 15% for females. Very similar results occur when these data for the middle southern states are plotted on the standards developed by Moorrees and co-workers [*8*] based on children from Massachusetts and Ohio.

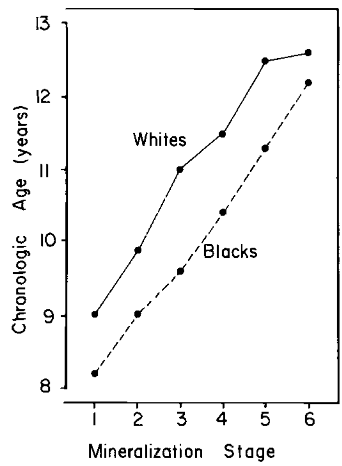


FIG. 1—*Plot of stages of crown mineralization of the mandibular third molar in males. Third molars exhibit the greatest differences in developmental timing among blacks and whites. In this instance, blacks on average achieve crown formation stages one year (10%) earlier than the whites in this study.*

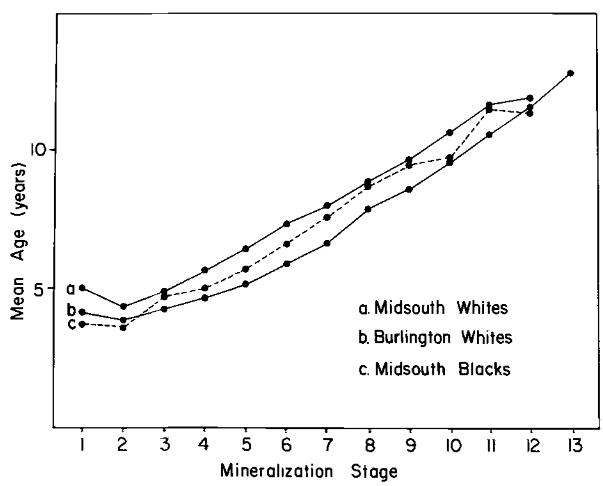


FIG. 2—*Mean age of attainment of a morphologic stage plotted against chronologic age. Data are for the mandibular second premolar in females. (This tooth is illustrated simply because its development is most fully reflected in the ages studied.) Ages for blacks and whites from the middle south are more alike than either is to the series of whites from Burlington, Ontario* [9]. *The difference between middle south blacks and whites averages 9% for this tooth, while the difference between the two Caucasian samples is 16%. In other words, the Burlington series of females attained each stage about one year earlier than these middle south whites.*

## Overview

Several trends shown in these data are confirmatory of studies on geographically and racially different samples. It has come to be expected (1) that earlier developing teeth within a class are more stable than more distal teeth, (2) that mandibular teeth reach each developmental stage sooner than their maxillary antagonists (especially among the anteriors), and (3) that females are significantly advanced relative to males within a

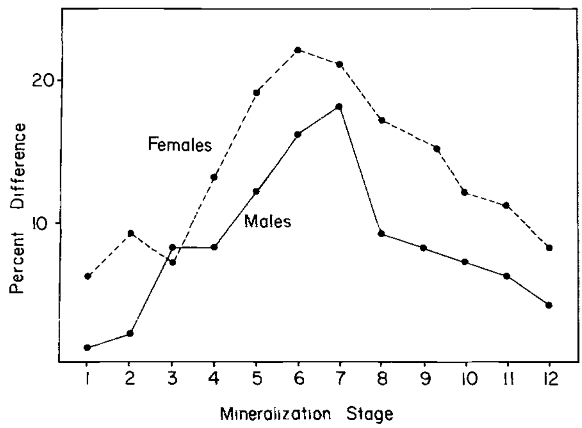


FIG. 3—*Plot of the percentages by which the middle south whites are slower to attain each mineralization stage relative to the sex-specific Burlington standards* [9]. *At all but one stage, females are proportionately more different (later to achieve a stage) than males. However, the patterns are fairly similar, with their peaks at Stages 6 and 7, which are crown completion and initial root formation.*

population. In this latter regard, our data show that American blacks are more sexually dimorphic (about 7%) than whites (4%). As has been appreciated [*18*], while the two sexes become absolutely more dimorphic into adolescence, the *percentage* of dimorphism remains relatively constant.

Differences between studies derived from various countries or regions also may be due in part to contrasting methodologies. In longitudinal data, the age at which a tooth transforms from one morphologic stage to the next can be recorded with a range of accuracy equal to the recall interval. The resulting average is the age of onset of a stage *providing* the correction is made of subtracting half the time between examinations from the age at which a stage is first observed [*2,30*].

With cross-sectional data, individuals will be recorded at ages anywhere from the onset to termination of a stage, with uniform probability throughout. So, a mean mineralization age from cross-sectional data necessarily reflects the midpoint of that stage. If serial data were treated both longitudinally and cross-sectionally, the cross-sectional mean mineralization ages will be greater (older) by half a stage.

On inspection, this technical consideration does not account for the geographic differences observed between these middle southern states data and those from northeastern communities [*8,9*]. Instead, just as has been shown for hand-wrist bone ages [*16,31,32*], dental age standards are not uniformly applicable for the whole continental population. Regional differences in genetic and environmental parameters appear to place such standards in question statistically as well as clinically. This is even more critical when the age of nonwhites is determined from Caucasian norms. (In addition, most longitudinal growth study participants are exceptionally well-off medically and socioeconomically and consequently do not reflect conditions of the median population.) Application of the broadly-used northeastern standards [*8,9*] significantly overestimates the physiologic maturity of children from the middle southern states and, thus, significantly underestimates their growth potential. Such systemic biases are of concern in forensic science applications, but they also impact on expectations of pediatricians, endocrinologists, and others involved in monitoring children's growth.

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