Sex Discriminatory Effectiveness Using Combinations of Root Lengths and Crown Diameters

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ABSTRACT   Using optical-scanner (OPTOCOM) and radiogrammetric measurements on mandibular permanent teeth, root length alone affords sex-discriminatory effectiveness equal to or exceeding conventional crown diameters. Combinations of root lengths and crown dimensions yield up to 80% accuracy in sexing with as few as two teeth, and discriminatory effectiveness of 87% with mandibular teeth alone.

Root lengths of the permanent teeth are systematically characterized by a degree of sexual dimorphism greater than that for the corresponding crown dimensions of the same teeth (Garn et al., '78a). The root lengths of the permanent teeth moreover, prove to be largely independent of the conventional mesiodistal and buccolingual crown diameters (Garn et al., '78b). Under these circumstances, it might be expected that root lengths, alone, would show sex discriminatory effectiveness at least equal to the corresponding mesiodistal and buccolingual crown dimensions (cf. Garn et al., '77; Black, '78) and that combinations involving root lengths *and* crown diameters should further improve odontometric sex discrimination beyond levels previously attained (cf. Ditch and Rose, '72).

To test these various possibilities we have explored the value of radiogrammetrically-determined mandibular root lengths measured from the cemento-enamel junction to the apex of C-M2. This was done on 45° oblique-jaw radiographs of 83 16- to 17-year-old participants in the University of Michigan Longitudinal Study (Garn et al., '78a,b). Descriptions of the measuring technique, replicability and considerations of radiographic enlargement are given in our previous publications. In addition to the dial-reading caliper measurements of root lengths, made directly on the radiographs, we also employed mesiodistal and buccolingual crown diameters of C-M2. These were measured with an X-Y

coordinate optical-scanner (OPTOCOM) as described by Van der Linden, Boersma, Zelders, Peters and Raaben in 1972 (Van der Linden et al., '72). Sex-discriminatory effectiveness using all 15 measures (3 for each tooth considered) was tested with a stepwise discriminant function program that allowed the incorporation of N variables, one at a time (Fox and Guire, '76). In this way, it was possible both to ascertain the discriminatory effectiveness of different combinations of crown size and root length and to determine those crown and root dimensions that contribute most to sex discrimination.

In the first of the analytic steps, we explored the proportion of individuals correctly sexed, using both individual measurements for each tooth (mesiodistal, buccolingual and root length) as well as combinations of crown measurements and root lengths. As shown in the first table (table 1), root length by itself attains discriminatory effectiveness generally equal to or greater than individual mesiodistal or buccolingual crown diameters alone. Despite unequal samples for the different teeth considered—a function of the age and eruption status—single root lengths slightly exceed single crown diameters in the proportion correctly sexed for most of the measurements paired. Moreover, the combination of root and crown measurements (MD + BL + RL) generally achieve superior discriminatory effectiveness over single crown or root dimensions, tooth by tooth.

With expectancy thus confirmed in the test sample, we then investigated the sex-discriminatory effectiveness of combinations of teeth and combinations of measurements from one through the maximum of 15 theoretically possible. Since only complete data sets could be used in the program, involving 15 measurements on five mandibular teeth for each subject, sample size was thus restricted to an N of 49. Additional crown dimensional data on I_1 and I_2 were employed in a later analytical step as will be described.

Starting with the mandibular canine alone (the tooth with the greatest sex-discriminatory value in this subsample) single measurements yielded up to 73% correct identifications as shown for the buccolingual and mesiodistal crown dimensions in table 2. However, increasing the number of tooth measurements to six raised effective sex discrimination to 80% as also shown in the table. Beyond this level, increases in the number of teeth and the

number of measurements raised discriminatory effectiveness only slightly. As shown in the table, and with each "new" dimension indicated at each step by underlining, some 84% discriminatory effectiveness was attained with a total of 13 odontometric measurements—comprising four root lengths, five mesiodistal crown diameters and four buccolingual dimensions. Beyond that level, there was no improvement in sex discriminatory effectiveness. It will be noted, however, that near-maximum sex discrimination can be achieved with a total of only six measurements on two mandibular teeth, i.e., C and M2.

In a third analytic step, we introduced crown-size data (but not root length data) on the mandibular incisors, thereby raising the tooth complement to seven of the eight teeth possible for any arch quadrant. With the addition of I_1 and I_2, there was a slight improvement in discriminatory effectiveness to a maximum of 87%. For the record, this level

TABLE 1

Percent of single teeth correctly sexed [1]

Tooth	N	Mesiodistal (MD)	Buccolingual (BL)	Root length (RL)	MD + BL + RL
C	73	70	74	70	73
P_1	75	52	57	64	56
P_2	70	56	56	63	67
M_1	83	60	59	63	61
M_2	56	64	57	63	70

[1] Using stepwise discriminant function program as given in Fox and Guire ('76: pp. 155-156).

TABLE 2

Discriminatory effectiveness of combinations of root lengths and crown diameters [1]

Mandibular root lengths	Crown diameters		Percent correctly sexed
	Mesiodistal	Buccolingual	
C	—	—	63
—	—	C	73
—	—	$\underline{C}$	73
—	M_2	C	76
$\underline{C}$	M_2	C	76
C	M_2	C, $\underline{P_1}$	76
C, $\underline{M_1}$	M_2	C, P_1	78
C, M_1	$\underline{C} M_2$	C, P_1	80
C, M_1	C, M_2	C, P_1, $\underline{P_2}$	80
C, M_1, $\underline{M_2}$	C, M_2	C, P_1, P_2	80
C, M_1, M_2	C, M_1, M_2	C, P_1, P_2	80
C, M_1, M_2	C, M_1, M_2	C, P_1, P_2, $\underline{M_1}$	78
C, M_1, M_2	C, $\underline{P_1}$, M_1, M_2	C, P_1, P_2, M_1	80
C, $\underline{P_2}$, M_1, M_2	C, P_1, M_1, M_2	C, P_1, P_2, M_1	82
C, P_2, M_1, M_2	C, P_1, $\underline{P_2}$, M_1, M_2	C, P_1, P_2, M_1	84
C, $\underline{P_1}$, P_2, M_1, M_2	C-M_2	C, P_1, P_2, M_1	84
C-M_2	C-M_2	C-$\underline{M_2}$	82

[1] Sample restricted to individuals with all 15 measurements. Measurements were introduced by the algorithm according to attained significance level. Underscoring indicates measurement newly included in that step.

was attained with the following combination of teeth and dimensions:

Root length:	C P_1 P_2 M_1 M_2
Mesiodistal crown diameter:	I_2 C P_1 M_1 M_2
Buccolingual crown diameter:	C P_2 M_2.

Given the sample sizes employed in different parts of this study (49 for complete data and 83 for the incomplete data set), the levels of sex discrimination here attained with five to seven permanent teeth should not be taken as final estimates. Indeed, working with different-sized samples and up to 94 boys and girls and for root lengths alone, we have attained levels of sex-discriminatory effectiveness both above and below the values in the tables. The major point is the contribution of root lengths and discriminatory effectiveness attained by various combinations of root lengths and conventional crown diameters.

Nor are the present data on the relative importance of specific root lengths and particular crown diameters necessarily definitive because of the unique nature of the crown diameters (optical-scanner measurements made on an average of three casts per individual) and the inherent limitations of radiogrammetric root lengths on sub-adult individuals. The odontometric approach used would tend to increase discriminatory effectiveness as compared with measurements taken on single casts and with conventional calipers while the problems of radiographic positioning in vivo are necessarily greater than those that would obtain with skeletal material. Finally, it is important to emphasize that any discriminant function program is necessarily most effective for the particular sample from which it was derived.

It is heartening, nonetheless, to introduce the potential utility of root lengths in "sexing" human teeth, since root lengths have been but little employed in odontometric analyses either for the living or on skeletalized material as we have pointed out. It is further heartening to discover that close to 90% sex discriminatory effectiveness may be attained with mandibular teeth alone—ignoring the facial skeleton, the postcranial skeleton, and especially the pelvis. Clearly this approach may be of value to forensic anthropology where the teeth are often the best-preserved remains, and to skeletal collections. As one of the reviewers of this paper has pointed out, in fragmental collections and in cremated material, roots may be preserved and crowns not, thus adding to the potential utility of roots. Finally, and of additional interest to the living, there is the question asked of how these discriminant programs would "sex" the karyotypic abnormalities—XO, XO/XX, XO/XY, XXX, XXY, XYY, etc. against established odontometric dimensions based on the normal XX and XY, whether or not the sexes are equally well-discriminated in samples of truly adequate size.

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