RELATIONSHIP BETWEEN TYPES OF AXIAL TRIRADII AND TRUE HYPOTHENAR PATTERNS

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ABSTRACT The paper examines the extent and nature of the relationship between types of axial triradii (*t*) and true hypothenar patterns (HP). 3257 palms of males of four endogamous Dhangar castes (Ahir, Hatkar, Khutekar and Mendhe) of Maharashtra, India were analysed for types of *t* and HP. The main findings of the study are: 1) the distribution of *t* in all the four groups is bimodal; 2) HP are formed by three palmar elements: proximal radiant of triradius *a* (Pa), extra-limital triradius, including t^u and t^b, (Ext) and axial triradii (*t*); 3) a strong relationship is indicated between the type of *t* and HP; 4) at level t, HP are formed only by Ext and Pa; 5) at level *t'*, *t''* and *t'''* HP are formed by ulnar radiants of t's and Ext; 6) in case of two t triradii, irrespective of their levels, they are always associated with a pattern; 7) in the case of three *t*'s a duplex or triplex pattern occurs; 8) in the case of a *t*, irrespective of its level, it is associated with only loops which never open towards ulnar margin; and 9) in the case of two *t*'s, irrespective of their levels, a loop or a whorl occur but a loop never opens towards the radial margin.

A review of the literature, with respect to the six palmar configurational areas in man, shows that the hypothenar area has at least six distinguishing features:

1) A large variety of patterns, both true and vestigal, are present. Cummins and MIdlo (1961) list three primary true patterns (whorl, loop and tented arch), and four other 'primary configurational types' (plain arch, open field, multiplication and vestige).
2) This area has the highest frequency of whorls as compared to the other 5 configurational areas (Cummins and Midlo 1961, Plato and Wertelecki 1972).
3) The area is characterized by the highest frequency of duplex and triplex patterns as compared to other areas (see references mentioned in (2) above).
4) The loops in this area open towards all the four borders of the palm - radial, ulnar, proximal and distal. In other areas the loops open, with rare exceptions, to only one border.
5) The incidence of true patterns in this area is less only to that of the IIIrd and IVth interdigital areas (Schaumann and Alter 1976).
6) The hypothenar patterns are formed by three different palmar features: a) proximal radiant of digital triradii *a*, b) extralimital triradii [this includes t^u and t^b hypothenar triradii], and c) axial triradii, in contrast to the other areas where the patterns are formed either by the proximal radiants of the digital triradii independently, or in conjunction with the accompanying accessory triradii.

Morphologically in terms of occurrence of a variety of patterns, the hypothenar area as compared to other configurational areas is most complex (Mavalwala 1978) and therefore of special interest. Although numerous published papers reporting the incidence of hypothenar patterns in different populations are readily available, and in spite of the many unique or at least special features listed above, to our knowledge no worthwhile attempt has as yet been made to understand and interpret the relationship between hypothenar patterns and the three palmar features mentioned above.

In fact, Cummins and MIdlo (1961) did indicate that the ".. axial triradii are intimately associated with the hypothenar configuration, their radiants forming boundaries or penetrating the configuration. When *t'* is present, its ulnar radiant commonly divides the hypothenar configuration into distal and proximal elements..." (p. 100). Further, these authors also elucidated the relationship between extralimital triradii and a hypothenar whorl. They write "...typically, however, there are three triradii instead of two (in the case of a hypothenar whorl). The triradius on the ulnar margin may be extralimital, potentially present at a point lying outside the area of ridged skin" (p.101). Recently, Schaumann and Alter (1976) also mentioned that the extralimital triradii (t^u and t^b) "are mostly connected with W,L^r and A^r patterns in the hypothenar area." (p. 53).

Thus, while Cummins and Midlo (1943) did recognize the possible relationship between axial triradii, extralimital triradii (Schaumann and Alter also recognize this) and hypothenar patterns, to our knowledge no one has explicitly indicated the nature of the morphological relationship between proximal radiant of triradius *a* and the hypothenar patterns. In fact, as will be seen later, the proximal radiant of triradius *a* when terminating at positions 4 and 3 mostly forms a loop in the hypothenar area, opening commonly towards the radial border, but occasionally also towards the distal border. Strikingly enough, such loops never open towards the ulnar or proximal borders.

From the above account, it is clear that a certain type of relationship exists between the three palmar features and the hypothenar patterns. If the nature of this relationship could be understood then not only should it be possible to explain the morphological basis of the various hypothenar patterns but also it should be possible to predict the type of patterns if the distribution of these three palmar features in a population is known.

The purpose of this paper, therefore, is to examine the nature of the relationship that might exist between types of axial triradii (number and position on the palm) and the types of true hypothenar patterns among four endogamous castes of Western India.

MATERIALS AND METHODS

A total of 3,257 palms, right and left considered together, of males of four endogamous Dhangar castes of Maharashtra, India, were analysed for hypothenar patterns and axial triradii. The studied Dhangar castes are: Ahir (577 palms), Hatkar (1294 palms), Khutekar (1026 palms) and Mendhe (360 palms). Details of sampling techniques used in generating the data, ethnographic information, and other biologic data on these castes are given in: Mukherjee *et al* (1976); Malhotra (1979, 1979a); and Malhotra *et al* (1977, 1978).

The axial triradii were evaluated as per the method proposed by Cummins and Midlo (1961). "An axial triradius at or very near the proximal margin is formulated *t*. The most distally situated position of an axial triradius near the center of the palm is *t*", and one which lies at an intermediate level is *t'*. When two or three axial triradii occur they are formulated in proximo-distal order." (p. 99). Levels beyond *t'* distalwards were scored as *t'''*. In order to minimize the

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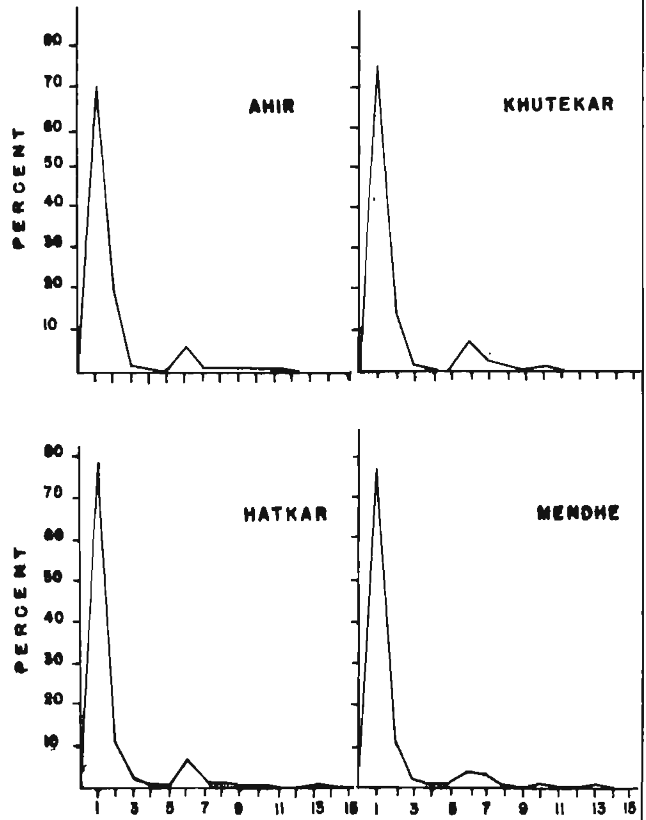

AHIR
KHUTEKAR
HATKAR
MENDHE
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PERCENT
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50
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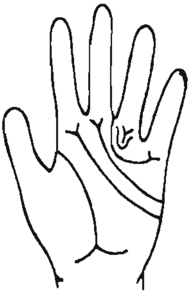
FIG-1



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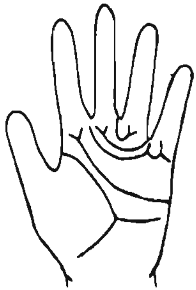

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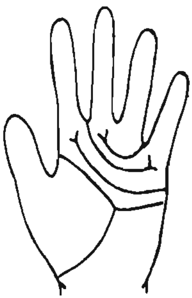

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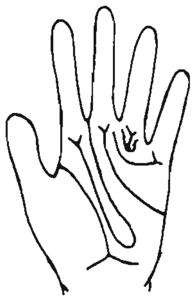

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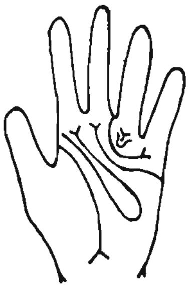

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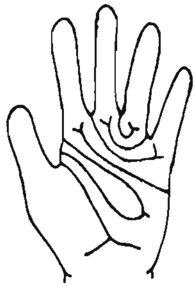

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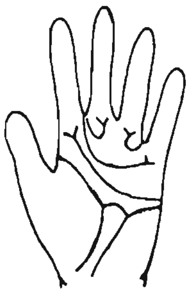

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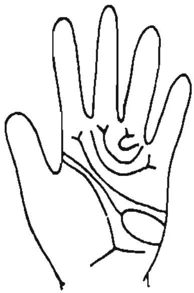

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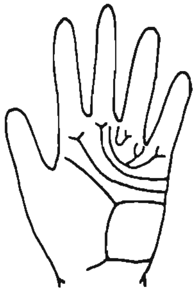

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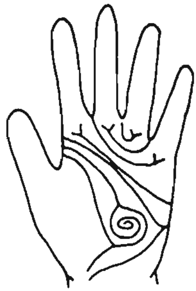

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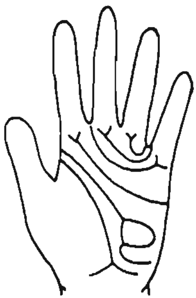

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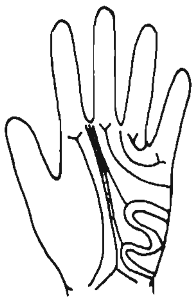

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subjective error involved in evaluating the *t* levels, all the prints were independently evaluated by two of us and in the cases of disagreement, which were very few, after discussions and further examination the mutually accepted levels were scored.

For the evaluation of patterns the methods proposed by Cummins and Midlo (1961), Plato and Wertelecki (1972) and Mavalwala (1978) were slightly modified as below:

a) Pattern Types

1) Only true patterns, whorls and loops, have been considered here: configurations such as open fields, vestiges, and plain arches were treated as configurations and not patterns. 2) The true patterns were further classified into three categories, namely, single - when they occurred alone, duplex - when two patterns occurred,and triplex - when three patterns occurred. 3) Various types of whorls were scored as whorls (W) and were not further subclassified (Cummins and Midlo 1961, Fig. 74, p. 101).

b) Direction of the opening of the core of loops

The human palm has four margins: radial, ulnar, proximal and distal. As such, the core of a hypothenar loop (or even some of the whorls), theoretically, can open to any one of these margins. In fact, earlier studies have demonstrated that the loops, in varying proportions, do open towards all the four margins (Plato and Wertelecki 1972). However, our data showed that occasionally a loop (mostly in duplex and triplex situations) facing the radial border does not open towards it, but is closed, bounded by distal and proximal radiants of two axial triradii. (See Figure 12).

It may be pointed out here that Cummins and Midlo (1961) recognized only three margins: radial, ulnar and proximal. Plato and Wertelecki (1972) justifiably suggested inclusion of the distal border along with the other three proposed by Cummins and Midlo, and defined a distal loop as "a hypothenar loop is designated as distal when the direction of its opening lies between *a* and *d* triradii" (p. 98).

Accordingly, the loops were classified into five categories: radial (LR), ulnar (LU), distal (LD), proximal (LP), and LE, which is the abbreviation for loops facing the radial border but closed.

Since parathenar loops are characterized by special morphological features (Cummins and Midlo 1961), these have been separately scored and abbreviated as PTh. In the case of duplex or triplex patterns, they were formulated with a dual symbol, for example LU/LU/ or LR/LU/LR, etc.

Table 1

Percent distribution of types and combination of axial triradii in males of different populations

pp-la-ion	No.of palms[a]	Types of axial triradii																
		t	t'	t"	t	tt	tt'	tt"	tt	t't'	t't"	tt	ttt'	ttt"	tt't"	t't't"	tt't'	tt"t"
H[1]	577	69.5	19.8	1.0	0.2	0	6.1	1.0	0.7	0.5	0.7	0	0	0.2	0.2	0.3	0	0
T[1]	1294	78.2	10.0	1.6	0.2	0.1	5.8	2.4	0.5	0.2	0.3	0	0.1	0	0.6	0	0	0.1
T[1]	1026	74.8	13.7	1.1	0.2	0.1	6.6	1.9	0.5	0.2	0.6	0.1	0.1	0	0.1	0	0	0
E[1]	360	76.7	11.7	1.9	0.3	0.6	4.0	3.3	0.3	0	0.8	0	0.3	0	0.3	0	0	0
A[2]	192	67.2	15.1	0.5	1.1	0.5	15.1	0	0	0	0	0	0	0	0.5	0	0	0
H[2]	99	76.8	13.1	1.0	0	2.0	5.0	0	0	0	0	0	0	0	1.0	0	1.0	0
M[2]	124	83.1	8.0	0	0	0	7.2	0	0.8	0	0.8	0	0	0	0	0	0	0
R[3]	2562*	62.9	21.2	2.1	0	0.2	6.3	5.3	0	0.3	0.6	0	0	0	0.3	0	0	0

[a] includes right and left palms; AH=Ahir, HT=Hatkar, KT=Khutekar, ME-Mendhe, Pa=Patil, CH=Chougule, KM=Komti, GR=Germans; [1]present study; [2]Malhotra et al (1979)
[3]Cummins and Midlo (1943); *0.8% palms could not be ascertained.

RESULTS

The analysis of the data has been carried out according to the following scheme:

1. The distribution of types of axial triradii in four castes.
2. The distribution of hypothenar true patterns among the four castes.
3. Bivariate distribution of types of triradii and patterns in four castes.

1. Distribution of types of axial triradii in four castes.

In Table 1 are presented the distribution of axial triradii among the four castes, as well as among three other Indian castes and the Germans; the latter four population samples, selected arbitrarily, have been included for comparative purposes. It is evident from this Table that altogether 17 types of axial triradii occur among these eight groups; among the four Dhangar castes,however, only 15 types have been found. The incidence of types of axial triradii varies slightly among these four castes, thus, while among the Hatkars and Khutekars there are 13 different types of triradii, among the Ahir and Mendhe there are only 11 types.

When all the eight groups are considered the incidence varies from a total of 5 types among the Komtis to 13 types among the Hatkar and Khutekars. A great deal of inter-population differences are thus obvious.

Considerable variation is also seen with respect to the incidence of various types of axial triradii among the four castes: *t* varies from 69.5% among the Ahir to 78.2% among the Hatkars. *t'* ranges from 10% among the Hatkars to 19.8% among the Ahirs. *tt'* depicts a range of 3.9% among the Mendhes to 6.6% among the Khutekars. Other types of axial triradii occur in trivial frequencies.

In order to examine whether the incidence of various types of axial triradii is homogeneous in the four castes, a 2 x 4 contingent chi-square table was used, separately for *t*, *t'* and *tt'* types. Owing to rather small numbers in many cells, chi-square was not calculated for other types. Except in the case of *tt'* (X^2 = 3.65, d.f.3) in the other two cases the four castes showed significant differences (for *t*, X^2 = 16.25, d.f. 3, and for *t'*, X^2 = 34.66, d.f.3).

The distribution of types of axial triradii is plotted separately for each caste in Figure 1. The distribution in all the castes is bimodal; the first peak is formed by the frequency of a single triradius at the level *t*, and the second peak, much lower compared to the first one, is formed by the frequency of the type *tt'*. To our knowledge, the distribution of types of axial triradii has never before

Table 2

Percent distribution of the types of true hypothenar patterns in four Dhangar castes

p- a- on	No.of palms	Pattern Absent %	Single LR	Single LU	Single LP	Single LD	Single PTh	Single W	Duplex LR/LU	Duplex LU/LR	Duplex LU/LE	Duplex LR/LR	Duplex LU/LU	Duplex LR/LD	Duplex LU/LD	Duplex PTh/LD	Duplex PTh/W	Triplex LR/LR/LR	Triplex LR/LE/LE	Triplex LU/LE/LR	Triplex LU/LR/LU
	577	73.8	10.9	6.4	1.4	4.7	0.3	0.7	0.2	1.0	0	0	0.5	0	0	0	0	0	0	0	0
	1294	74.7	12.3	7.4	0.5	2.4	0.1	0.5	0.1	0.6	0.1	0.2	0.5	0	0	0.1	0	0	0.1	0.1	0
	1026	74.0	12.3	7.7	0.8	2.7	0	0.5	0.1	0.9	0	0.7	0.1	0.1	0.1	0	0	0.1	0	0	0
	360	76.9	9.7	5.6	0.8	3.1	0.6	0.6	0.1	1.7	0.6	0	0	0	0	0	0.3	0	0	0	0.3

LR = loop opening on radial border
LD = loop opening on distal border
LE = loop facing radial border but enclosed
W = whorl
LU = loop opening on ulnar border
LP = loop opening on proximal border
PTh= parathenar loop

been examined, and we feel that the observed bimodality in distribution may provide useful clues in understanding the genetics of hypothenar patterns; several studies indicate that the inheritance is rather complex and can not be explained on the basis of di-allele models (Pons 1979; Loesch 1971, 1974; Sognier, Kloepfer and Cummins 19 9).

2. Distribution of hypothenar true patterns among the four castes.

Table 2 incorporates, separately for each caste, the occurrence of various types of hypothenar patterns. A total of 20 different types of patterns - single, duplex and triplex- have been encountered in the four castes; it varies from 9 among the Ahirs to 14 among the Hatkars; Khutekar and Mendhe depict 12 and 10 types respectively.

The loops - single, duplex or triplex - are most preponderant among all the groups, followed by whorls. Of the single loops, LR occur with maximum frequency in all groups, followed by LU, LD and LP. It is noteworthy that loop LE is conspicuous by its absence. Parathenar loops and whorls occur in low frequency.

In the present series, 9 different types of duplex patterns have been observed; the incidence, however, is rather low in all the groups. Pattern LU/LR is most common and its incidence varies from 0.6% (Hatkar) to 1.7% (Mendhe).

Four types of triplex patterns, all loop combinations, have been found among these four castes. Notably the loop LE type occurs only in duplex and triplex formation.

3. Bivariate distribution of types of axial triradii and pattern types in four castes.

The purpose of this analysis is to examine whether or not a particular type of axial triradii is associated with a particular type of pattern(s). It is, therefore, necessary that we examine separately each of the axial triradii types and the associated pattern(s). Such an analysis, however, could be performed only for the types *t*, *t'*, *t"* and *tt'*. Other types occur but in frequencies so low that statistical analysis is rendered unfeasible.

i) Pattern types in the case of a single axial triradius at level *t*.

From Table 3 it is evident (a) that about 82% of the palms (range 81.8% to 84.8%) lack true patterns (Figure 2); (b) That when a pattern is present it is always a single loop (the only exception being a duplex formation, LR/LR (0.1%) among the Khutekars); and (c) that the loops open toward only two margins, radial and distal, the incidence of the former always exceeding the latter.

Table 3

Percent distribution of types of hypothenar patterns in the case of a single axial triradius at level *t*

Population	No. of palms with *t*	Pattern Absent (%)	Pattern Types: Single LR	Single LD	Duplex LR/LR
AH	401	81.8	12.7	5.5	0
HT	1010	82.2	14.8	3.0	0
KT	767	81.0	15.4	3.5	0.1
ME	276	84.8	11.6	3.6	0

Table 4

Percent distribution of types of hypothenar patterns in the case of a single axial triradius at level *t'*

Population	No. of palms with *t'*	Pattern absent (%)	Pattern Types Single: LR	LP	LD
AH	114	81.6	10.5	4.4	3.5
HT	129	90.7	6.2	2.3	0.8
KT	141	88.6	5.0	5.0	1.4
ME	42	90.5	7.1	0	2.4

Table 5

Percent distribution of types of hypothenar patterns in the case of a single triradius at level *t"*

Population	No. of palms with *t"*	Pattern absent (%)	Pattern Types Single: LR	LP
AH	6	66.7	0	33.3
HT	21	80.9	4.8	14.3
KT	11	90.9	0	9.1
ME	7	71.4	0	28.6

An inspection of the palms having loops, revealed that these loops are formed mostly by the proximal radiant of triradius *a* . Occasionally, however, an extralimital triradius may also form such loops.

Notably, the incidence of these patterns shows a homogeneous distribution among the four castes (X^2 = 8.49, d.f.6) despite the fact that, as indicated earlier, the four castes differ significantly in the incidence of *t*.

The above analysis thus clearly establishes that, irrespective of the frequency of type *t* in different populations, the incidence and the type of pattern remains the same.

ii) <u>Pattern types in the case of a single triradius at level *t'*.</u>

From Table 4, where the pattern types among the four castes are presented separately, it is obvious that(a) about 84% of the palms (range 81.6% to 90.7%) lack true patterns (Figure 3);(b) where a pattern occurs it is always single and a loop and (c) the loops open at three margins, radial, proximal and distal, in decreasing order of magnitude.

A scrutiny of the palms having patterns shows that the loops LR and LD are formed by the proximal radiant of triradius '*a*' (Figures 5 and 6), while the LP are formed by the ulnar radiant of axial triradius *t'* (Cummins and Midlo 1961)

The chi-square test of homogeneity shows that the incidence of hypothenar patterns among the four castes is homogeneous (X^2 = 6.2, d.f.4). It may be recalled here that the incidence of *t'* among these castes is heterogeneous (X^2 = 34.66, d.f.3). This analysis also strongly suggests an association between the axial triradius *t'* and a particular type of hypothenar pattern.

iii) <u>Pattern types in the case of a single triradius at level *t"* .</u>

The joint distribution of pattern types and the triradius *t"* among the four castes reveal the following (Table 5): (a) nearly 77% of the palms (range 66.7% to 90.9%) lack true patterns (Figure 4). (b)When present, only loops occur and, (c) the opening of the loops is nearly always toward the proximal border. A few loops of the type LR are present among the Hatkars. Because of the rather low incidence of patterns in the four castes, a test of homogeneity was not performed.

An inspection of the palms with patterns, however, reveals that except for the radial loops, which are fomred by an extralimital triradius (Figure 7), the proximal loops are formed by the ulnar radiant of triradius *t"*. When the axial triradius occurs at level *t"*, the proximal radiant of

Table 6

ercent distribution of types of hypothenar patterns in the case of two axial triradii at level tt'

op-la-ion	No. of palms with tt'	Pattern Absent (%)	Pattern Types: Single LU	LP	LD	PTh	W	Duplex LU/LR	LU/LE	LR/LR	LU/LD	PTh/D
H	35	0	77.1	0	2.9	5.7	0	14.3	0	0	0	0
T	75	0	76.0	1.3	0	0	6.7	9.3	1.3	4.0	0	1.3
T	68	0	75.0	0	0	0	4.4	13.2	0	5.9	1.5	0
E	14	0	57.1	0	0	0	0	42.9	0	0	0	0

Table 7

Types of axial triradii and occurrence of hypothenar patterns among the Ahirs

Types	n	Pattern Absent (%)	Pattern Types: Single LU	LP	W	Duplex LR/LU	LU/LR	LU/LU
t'''	1	100	0	0	0	0	0	0
tt''	6	0	16.7	0	50.0	16.7	16.7	0
tt'''	4	0	50.0	25.0	25.0	0	0	0
t't'	3	0	100.0	0	0	0	0	0
t't''	4	0	100.0	0	0	0	0	0
tt't''	1	0	0	0	0	0	0	100.0
t't't''	2	0	0	0	0	0	0	100.0

triradius *a* commonly terminates at position 5' and 5" and occasionally at position 1 and does not form a loop. (Figures 3 and 13).

iv) Pattern types in the case of two axial triradii occurring at levels *tt'*

The joint distribution of pattern types and the triradii *tt'* among the four castes is given in Table 6. The following inferences are obvious. (a) None of the palms lack a pattern (Figures 8-12). (b) Both single and duplex patterns occur. (c) Single loops predominantly open towards the ulnar margin, occasionally towards the proximal and distal margins but never towards the radial margin. (d) In conjunction with extralimital triradii a small number of whorls also occur (Figure 11). (e) A low frequency of parathenar patterns is also found, and (f) in the case of duplex patterns, though five different types are seen, the type LU/LR is most preponderant.

Due to rather low incidence of various other types of axial triradii in the castes studied the type of analysis presented above has not been possible. We have, however, provided detailed data for each caste separately in Tables 7-10. From these tables, the following general statements can be made: (a) Whenever there are two or more axial triradii, irrespective of their levels on the palm, a pattern always occurs, and in the case of single loops, the pattern never opens on the radial margin. (b) Only when two axial triradii occur is a duplex pattern possible. (c) A triplex pattern is only possible when more than two triradii occur (Figure 13). (d) In the case of three triradii, with duplex patterns, the most common pattern is UL/UL.

From the preceding analysis and the data summarized in Table 11 the following conclusions with respect to the relationship between types of axial triradii and hypothenar true patterns can be advanced.

A. Presence or absence of a hypothenar pattern

i) True hypothenar patterns (HP) are formed by three different palmar elements: Proximal radiant of triradius *a* (Pa), extralimital triradii (Ext), and axial triradii (t). The relationship is expressed as HP=f(Pa, Ext, t)-------(1) where f(x) denotes a general function of the variable x.

ii) In the case of a single axial triradius at level *t*, HP, if present, are formed by Pa and Ext, and the triradius t^0 itself does not form any pattern. This can be expressed as Hp^{t^0} =f (Pa, Ext)------------ (2)
where superscript t^0 (=t) indicates the level of *t* on the palm.

Table 8

Types of axial triradii and percent occurrence of hypothenar patterns among the Hatkars

Types	n	Pattern Absent (%)	Pattern Types								
			Single			Duplex				Triplex	
			LU	PTh	W	LR/LU	LU/LR	LU/LE	LU/LU	LR/LE/LE	LU/LE/LR
t'''	3	100.0	0	0	0	0	0	0	0	0	0
tt	1	0	0	100.0	0	0	0	0	0	0	0
tt"	31	0	93.6	0	6.4	0	0	0	0	0	0
tt'''	7	0	57.1	0	0	28.6	14.3	0	0	0	0
t't'	3	0	100.0	0	0	0	0	0	0	0	0
t't"	4	0	75.0	0	0	0	0	25.0	0	0	0
ttt'	1	0	0	0	0	0	0	0	0	0	100.0
tt't"	8	0	0	0	0	0	0	0	75.0	25.0	0
tt"t"	1	0	0	0	0	0	0	0	100.0	0	0

iii) When the level of a single triradius is t' and above levels (t'', t''') then the HP are formed by ulnar radiants (ur) of t', t'', t''' (t^iur), $i=','',''''$ and an extralimital triradius. This can be expressed as

$HPt^i = f(t\ t^{i,ur}, Ext)$--------------------------(3)
where $i=','',''''$.

iv) When two axial triradii occur, irrespective of their levels on the palm, then such palms will always have a pattern formed by the distal (dr) and/or ulnar radiant (ur) of a proximally (Px) placed triradius and the two radiants (r), not well defined in terms of margins, of a distally (Dt) placed triradius. This can be written as

HPt^it^j =f(ur, dr,ur dr of Px t, any two r's of Dt,t) ----(4)
where i,j=0-----'''.

v) In the case of three axial triradii,irrespective of their position on the palm, such palms will always have a duplex or triplex pattern. As in the case of (iv) above the patterns will be formed by the most proximally placed triradius and the radiants of the other two triradii. This can be written as

$HPt^it^jt^k$ = f(ur,dr,ur dr of Px t, andy two r's of other two Dt t)---------------------(5)
where i,j,k = 0,------------'''.

B.Type of patterns.

In terms of the type of occurrence of patterns - loop,whorl, single, duplex or triplex - the above 5 equations can be expressed as follows:

Eqn.(1) HP $\longrightarrow$ loop, whorl, parathenar.
where loop = single, duplex or triplex.

Eqn.(2) $HPt^o \longrightarrow$ only loop
where loop = single.

Eqn.(3) $HPt^i \longrightarrow$ loop
where loop = single and i = ','',''''.

Eqn.(4) $HPt^it^j \longrightarrow$ loop, whorl, parathenar
where loop = single, duplex and i,j =0, ','',''''.

Eqn.(5) $HPt^it^jt^k \longrightarrow$duplex, triplex.
where i,j,k =0, ', ...'''.

C.Direction of Opening of the loop.

In terms of the direction of the opening of the single loop, equations (1) to (4) above can be expanded as:

Table 9

Types of axial triradii and percent occurrence of hypothenar patterns among the Khutekars

Types	n	Pattern Absent (%)	Pattern Types: Single			Duplex				Triplex
			LR	LU	W	LR/LU	LR/LR	LU/LU	LR/LD	LR/LR/LR
t'''	2	100.0	0	0	0	0	0	0	0	0
tt	1	0	100.0	0	0	0	0	0	0	0
tt"	20	0	0	85.0	5.0	5.0	5.0	0	0	0
tt'''	5	0	0	100.0	0	0	0	0	0	0
t't'	2	0	0	50.0	0	0	50.0	0	0	0
t't"	6	0	0	66.6	16.7	0	0	0	16.7	0
t't'''	1	0	0	100.0	0	0	0	0	0	0
ttt'	1	0	0	0	0	0	0	0	0	100.0
tt't"	1	0	0	0	0	0	0	100.0	0	0

Table 10

Types of axial triradii and percent occurrence of hypothenar patterns among the Mendhes

Types	n	Pattern Absent (%)	Pattern Types: Single				Duplex		Triplex
			LU	LP	PTh	W	LU/LE	PTh/W	LU/LR/LU
t'''	1	0	0	100.0	0	0	0	0	0
tt	2	0	0	0	100.0	0	0	0	0
tt"	12	0	75.0	0	0	16.7	8.3	0	0
tt'''	1	0	100.0	0	0	0	0	0	0
t't"	3	0	66.7	0	0	0	33.8	0	0
ttt'	1	0	0	0	0	0	0	100.0	0
tt't"	1	0	0	0	0	0	0	0	100.0

Table 11

Joint distribution of types of axial triradii and hypothenar patterns
(based on pooled data of four Dhangar castes)

Types	Pattern Types																			
	Single							Duplex									Triplex			
	LR	LU	LP	LD	LE	PTh	W	LR/ LU	LU/ LR	LU/ LE	LR/ LR	LLU/ LU	LR/ LD	LU/ LD	PTh/ LD	PTh/ W	LR/ LR/ LR	LR/ LE/ LE	LU/ LE/ LR	LU/ LR/ LU
t	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
t'	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
t"	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
t'''	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
tt	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
tt'	-	+	+	+	-	+	+	-	+	+	+	-	-	+	+	-	-	-	-	-
tt"	-	+	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-
tt'''	-	+	+	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-
t't'	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
t't"	-	+	-	-	-	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-
t't'''	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ttt'	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-
tt't"	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	+	+
t't't"	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
tt"t"	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-

+ = pattern present — = pattern absent

Eqn. (1) $HP \longrightarrow$ loop, whorl, parathenar
loop = single, duplex, triplex
single = LR, LU, LP, LD, LE
duplex = combination of loop, whorl and parathenar pattern
triplex = as in duplex above

Eqn. (2) $HP^{t^{o}} \longrightarrow$ single loop
loop = LR, LD

Eqn. (3) $HP^{t'} \longrightarrow$ single loop
loop = LR, LP,LD

(3.1) $HP^{t''} \longrightarrow$ single loop
loop = LR, LP

(3.2) $HP^{t'''} \longrightarrow$ single loop
loop = LP

(3.3) $HP^{t^{i}}$(i=0, ----,''') $\longrightarrow$ loop $\neq$ LU

Eqn. (4) $HP^{t^{i}t^{j}} \longrightarrow$ loop, whorl, parathenar
where i,j =0, ---'''.
loop = LU,LP,LD
loop $\neq$ LR

DISCUSSION

From the analysis presented in the previous section it is abundantly clear that a strong relationship exists between the types of axial triradii and type(s) of true hypothenar patterns. It is also well established that striking variation exists in the incidence of hypothenar patterns, both true as well as other configurations, among major ethnic groups (Cummins and Midlo 1961; Plato, Cereghino and Steinberg 1975; Steinberg, Cereghino and Plato 1975). Significant differences have also been reported among the major ethnic groups with respect to the sub-types of single loops, radial and ulnar (Plato and Wertelecki 1972). It is also well known that the frequency of types and combinations of axial triradii vary considerably in human populations.

Thus, since the hypothenar patterns are strongly associated with the type of axial triradii, and the latter show marked inter-population differences, it is expected that the overall patterns will also show inter-population differences.

Since the extent and nature of the relationship between the two variables, axial triradii and hypothenar patterns, is known, it should therefore be possible to predict either of the two variables if one of the two is known. However, as shown earlier, two other palmar features, proximal radiant of triradius a and extralimital triradii, also contribute to the formation of the hypothenar patterns. Therefore, for predictive purposes the incidence of each of these should also be known. In the case of extralimital triradii, when present on the palm and accompanied by one or more axial triradii, a pattern always results. In case, however, an extralimital triradius is present but the axial triradius is absent, a radial arch will form, the incidence of which is rather low, 1-2% (Holt 1975). As mentioned earlier, the proximal radiant of triradius a, in general, only forms a pattern when it terminates at positions 4 and 3.

If therefore, in a population the frequency occurrence of all these three variables is known then it should be possible to predict with reasonable certainty, the probability of the occurrence of hypothenar true patterns in a population.

We are at the moment analysing data in the above direction, and will, in a subsequent paper, report details of such predictive models.

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