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Contents

Origins and Interactions of the Ethnic Groups of Greater Dardistan I:

A Tooth Size Allocation Analysis of the Khow of Chitral District

Brian E. Hemphill

Abstract: This study has two objectives. The first is to assess allocation of tooth size across the permanent dentition of Khow females and males. The second is to investigate Khow biological origins in light of three models offered for the population history of Greater Dardistan. Mesiodistal and buccolingual dimensions of the permanent teeth were measured among 209 Khow volunteers. Principal component analysis was used to assess variation in the patterning of tooth size among Khow females and males. Discriminant function analysis was used to determine the accuracy of identifying Khows odontometrically by sex. Khows were compared to members of six living peninsular Indian ethnic groups and 12 sex–pooled prehistoric samples. Group centroids from canonical variates were plotted in three dimensions to assess similarities among samples. Principal components analysis identifies tooth size allocation differences between Khow females and males. Discriminant functions identify sex correctly in 74-83% of Khows. Canonical variates identify Khows as possessing closer affinities to prehistoric Central Asians than to prehistoric inhabitants of the Indus Valley or living peninsular Indian ethnic groups. Tooth size allocation analysis identifies systemic differences among females and males of living South Asian ethnic groups. Khows possess tooth size allocation patterns most similar to Central Asians, but not to BMAC samples. Hence, the Aryan Invasion model is not supported. Affinities between Khows and Namazga III inhabitants of Geoksyur provide weak support for the Indo-Iranian model, but long-standing residence within Greater Dardistan, expected under the Indigenous model, is also supported.

Keywords: Odontometrics, Sex Dimorphism, Principal Components Analysis, Canonical Variates Analysis.

Chitral's location (Fig. 1) has had a major impact on its past heritage, for it is located close to the nexus of three of the world's great mountain ranges (Hindu Kush, Himalayas, Karakoram) and though it is one of the most isolated regions in Eurasia it has long served as one of the great link valleys providing a primary avenue for the passage of people and goods between West Asia, Central Asia, South Asia, and China (Guha 1935:x; Young, Coningham, Batt, & Ali 2000:134). Although it is part of the modern nation of Pakistan today, Chitral has had strong cultural links with Afghanistan, Central Asia and China in the past (Israr-ud-Din 1979; Stein 1921, 1933). Indeed, while the prehistory of Chitral remains largely unknown archaeologically, what has been discovered supports the valley's role as an important causeway of contact between the populations of other regions (Allchin 1970:3; Stacul 1969b:98; Stein 1921:35, 37; Young *et al.* 2000).

Chitral District covers an area of nearly 15,000 square kilometres and the land is dominated by ridges and spurs of the eastern Hindu Kush that form a vast network of high mountains and deep, narrow valleys that present a jumbled, difficult and inhospitable terrain that constrains communication and human inhabitance significantly (Khan 1975/2013; Pervez 2014:2). Chitral is bounded on the north and northwest by the crest of the Hindu Kush range. The Doral Pass (4,300 m), exiting westward out of Chitral, provides access to the Badakhshan Province of Afghanistan, while the Broghol Pass (3,768 m) provides passage to the Wakhan Corridor, from which southern Uzbekistan, southern Tajikistan and Xinjiang may be accessed (Pervez 2014:3). Historically, the former was used for small-scale trade and for the collection of tributes by the ruler of Chitral (Khan 1975/2013:4; Shah 1974:24), while the latter was used as a primary route for caravans to and from Kashgar oases, Khotan and

Yarkhand in Xinjiang (Dichter 1967:27). To the east, the Moshabar Range, a subsidiary spur of the Hindu Kush, branches off just southeast of the Broghal Pass and runs to the Hindu Raj range at the Shandur Pass (3,734 m), which divides Chitral from Tehsils Yasin and Gupis of Ghizer District, Gilgit-Baltistan to the east and from Swat District to the southeast before trending westward where the Lowari Pass (3,118 m) divides Chitral from Dir District to the south (Ali, Shah, Samad, Zahir, & Young 2013:79; Dichter 1967:27; Khan 1975/2013).

Fundamentally a steep, narrow river valley, the territory encompassed by Chitral District ranges in elevation from just under 1,000 m to greater than 7,600 m AMSL (Dichter 1967:29-30, 40; Haserodt 1996:3; Israr-ud-Din 1996:19). As such, Chitral is an area of great physical challenges, with over 40 peaks of 6000 m or more, alongside river valleys that run through steep gorges up to 900 m below the level of some settlements (Ali *et al.* 2013:79; Dichter 1967:42; Haserodt 1996:4; Israr-ud-Din 1996:19; Young *et al.* 2000:133). Villages and cultivated areas are found between 1,000 and 3,000 m. Level ground is rare and hence cultivation is mostly confined to alluvial fans or to certain river terraces where soil fertility coincides with easily available water and these naturally occurring terraces have been expanded and maintained with vast investments of labor (Khan 1975/2013). Villages are also located on the beds of former river courses where similar conditions prevail (Haserodt 1996; Marsden 2010:54). As such, the district's two major physical features, topographic relief and water supply, are widely recognized as having modeled the valley's social organization as well as its settlement and subsistence patterns significantly (Haserodt 1996:9; Israr-ud-Din 1996:19).

The inhabitants of Chitral call the country Khow, dividing it into three sections: Torkhow (Upper), Mulkhow (Middle), and Ludkhow (Great) (Biddulph 1880/1977:59; Ibbetson and Rose: 1883/1990:175). The majority of inhabitants of Chitral may be found in a series of small villages located in the central valley (Chitral Valley or Kashgar Bela) formed by the confluence of the swift-flowing and unnavigable Yarkhun, Mastuj and Torkhow Rivers, which form the Chitral River.

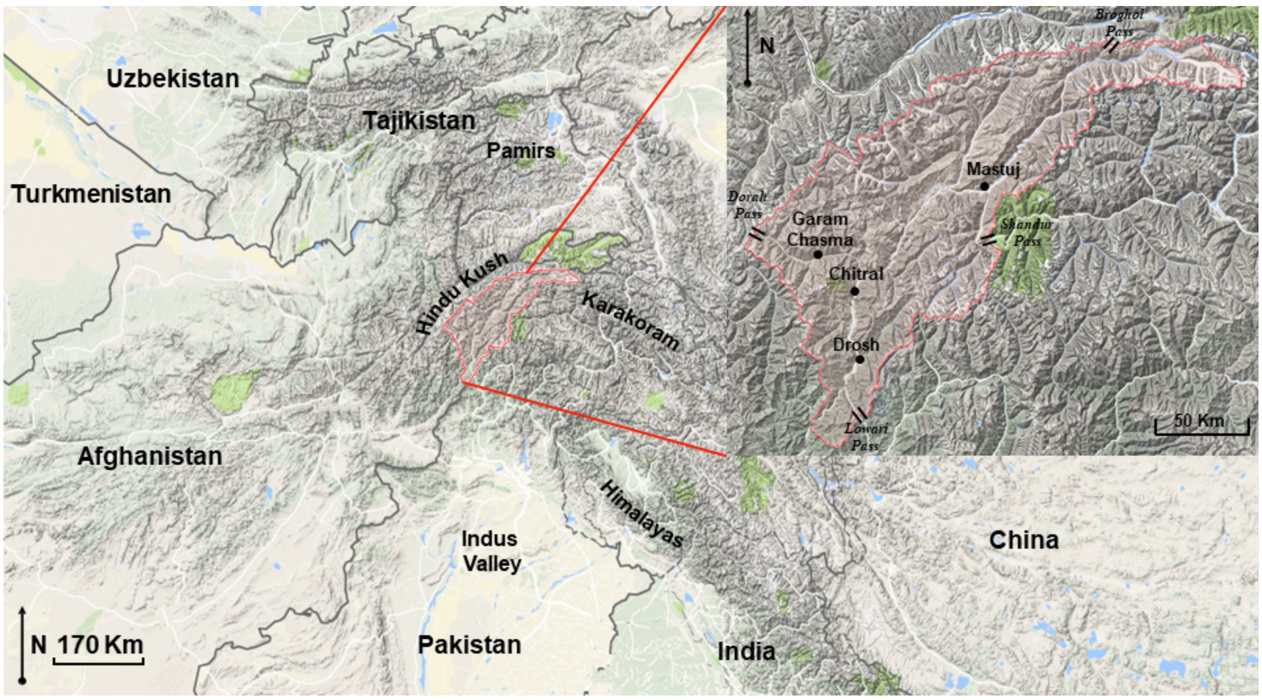

Figure 1. Chitral District and its location in the mountainous nexus of Central, South and West Asia. Inset: Sampling localities of Khow volunteers within Chitral District.

According to the 1998 census about 350,000 people are residents of Chitral (Marsden 2005:14; Pervez 2014:13) and between 80-90% of them are speakers of Khowar and self-identify as Khows (Decker 1992:11; Haserodt 1996; Kreutzmann 2005; Young *et al.* 2000). Virtually all Khows are Muslims, conversion having taken place between the 14th to 16th centuries, and while between 65-70% are Sunni Muslims, the overwhelming majority of those residing in Upper Chitral are Shi'a Ismailis (Decker 1992; Pervez 2014; Sloan 2013).

While Khowar represents the primary language spoken within Chitral District, Khowar-speakers are also found in the adjacent regions of Gilgit-Baltistan and Swat. In Gilgit-Baltistan, Khowar-speakers may be found across the Shandur Pass in the Ghizer Valley as far as Gupis, as well as in the southern and central portions of the Yasin and Ishkoman valleys (Bashir 1996; Decker 1992; Kreutzmann 2005; Radloff 1992; Schomberg 1935:68). According to Lorimer (1939:19), the presence of Khowar speakers east of the Shandur Pass is a direct consequence of the Chitrali ruling family's success in capturing this region in the early 18th century, thereby initiating a movement of Khowar-speakers eastward over the last several centuries (Decker 1992:29; Schomberg 1935:172; Sloan 2013). In addition, there are small communities of Khowar-speakers in Upper Swat.

Khowar represents but one of the more than 25 languages of four different linguistic stocks (Indic, Iranian, Sino-Tibetan, Altaic) spoken in the region encompassed by the eastern Hindu Kush, Pamirs, Karakoram, and northwestern Himalayas (Kreutzmann 2005). Some researchers have found it useful to divide this linguistically heterogeneous region into four subregions (Kreutzmann 2005:5). The eastern sub-region, composed of the Ladakh and Leh regions of Kashmir and the Baltistan District of Gilgit-Baltistan, is dominated by speakers of the westernmost Sino-Tibetan language, Balti (Clark 1977; O'Leary 1992). By contrast, the central sub-region, which includes Chitral District and the Gilgit District of Gilgit-Baltistan, is dominated speakers of languages assigned to the Dardic branch within the large Indic (Indo-Aryan) family of languages (Fussman 1972; Masica 1991; Morgenstierne 1932; Strand 1973). These include Khowar, along with Kalashwar, Shina, and the several varieties of Kohistani. In the northern two-thirds of this sub-region these communities of Dardic-speakers are separated geographically into a western group composed of Khowar- and Kalashwar-speakers and an eastern group of Shina- and Kohistani-speakers by communities whose primary language is Burushaski, a linguistic isolate (Lorimer 1935-1938, III:384; O'Leary, 1992; Tikkanen 2015:305). The western sub-region, which includes a large portion of eastern and northeastern Afghanistan, is dominated by speakers of Iranian languages. Iranian languages spoken in this region include Pashto, Wakhi, and Yidgha (all Eastern Iranian languages), Dari and Farsi (Western Iranian languages), and an array of at least six languages assigned to the Nuristani branch (Morgenstierne 1974:6; O'Leary 1992; Strand 1973). Finally, along the northern periphery of this western sub-region in southern Tajikistan are speakers of Tajik (a Western Iranian language) and, in southern Xinjiang, speakers of such Turkic languages as Uyghur and Kirghiz (Kreutzmann 2005). The tremendous diversity of languages spoken by the inhabitants of this geopolitical nexus between West, Central, South and East Asia, perched in the narrow defiles of the "roof of the word," has naturally raised interest in the origins and interactions of these peoples in general and of the Khow in particular.

The objectives of the current study are two-fold. The first is to describe and assess the allocation of tooth size across the permanent dentition among Khow females and males. This investigation will explore the degree of similarity in the allocation of tooth size between Khow females and males to investigate the impact of developmental stress and the utility of odontometric variables to distinguish Khow females from their male counterparts. The second objective is to provide an examination of Khow biological origins and interactions based upon tooth size allocation analysis. The results obtained from this analysis will be evaluated in light of the three scenarios offered by an array of researchers for reconstruction of the population history of the various ethnic groups of this region. This study represents the first in a series of investigations based on odontometric and dental morphology variation of the permanent tooth crown among over 3,800 female and male members of 12 ethnic groups of what may be termed Greater Dardistan (Leitner 1893/1996:67).

The current study is organized into three phases. In the first phase, the patterning of odontometric variation in Khow females and males is explored to determine sex-based differences in tooth size allocation and the degree of sex dimorphism in permanent tooth size. In the second phase, the pattern of tooth size allocation among Khow females and males is compared to that observed among living individuals of six different ethnic groups from two different regions of peninsular India. The goal is to determine in what ways and to what degree the allocation of tooth size varies among living South Asians and whether tooth size allocation analysis yields interpretable patterns with regard to geographic propinquity, social status, and/or primary language spoken. In the third phase, consideration of differences in the patterning of tooth size allocation is extended spatially and temporally through the inclusion of prehistoric dental samples that derive from Central Asia, the Indus Valley of Pakistan and west-central peninsular India, which range in antiquity from the early Neolithic (*ca.* 6,000 BCE) to the last quarter of the 1st millennium BCE.

Three models for Khow origins

The proto-historic Indo-Iranian model

Excavations by Soviet scholars at a number of sites in the lower reaches of the Syr Darya and Amu Darya river valleys of Uzbekistan during the late 1940s, 50s, and 60s (Tolstov 1961) led to the discovery of a series of mortuary structures that suggested a change in funerary practices from one of cremation to one of exposure of the corpse for decomposition within funerary towers (Rapoport 1962; Tolstov 1962:101) and above-ground kurgans (Akishev 1959; Akishev and Kushev 1963:88-105). These funerary structures were commonly divided into four rooms or chambers; the skeletal remains found in the eastern half were identified as male, while whose those found in the western half were identified as female. Subdivisions within each half appear to have been based upon age at death, separating younger from older individuals (Jettmar 1967:66). Given the size of these structures of the first millennium BCE and the first millennium CE (Tolstov 1948), it is claimed that these structures housed the deceased members of an entire clan (Jettmar 1967:66-67). Similar buildings for mass funerary accommodation have been described at a number of sites associated with the Achaemenid Empire further west that likewise date to the first millennium BCE (Ghirshman 1952:18).

Jettmar (1967:68) suggests the same conceptualizations of death and remembrance symbolized by the funerary towers and above-ground exposure of the body for decomposition in proto-historic southern Central Asia also underpin pre-Islamic funerary behaviors among the Dardic-speaking ethnic groups of the western Himalayas, the Karakoram, and eastern Hindu Kush and he provides examples from the eastern, central, and western portions of this region to assert a prehistoric Iranian presence that extends from the last millennium BCE and continues, albeit in an Islamicized form, to the present day. In the eastern portion, in the Punyal region of Gilgit District, Jettmar describes a collective tomb that serves as the funerary crypt for members of a single clan. There is an aperture that opens into the depths of the tomb where human bones lie partially articulated on the floor. In the village of Singal, there is a crypt that features a four-room lay-out for exposure of the remains upon death. Jettmar (1967:72) concludes, “there can be no further doubt…that the buildings in Punyal we have described bear a structural resemblance to the mortuary towers of central Asia. The same funerary rites are presupposed in both cases: exposure of the dead person in a construction belonging to his clan, and preservation of the skeleton in the same locality—e.g. in an underground chamber.”

In the central portion of this region Jettmar (1967) notes the presence of mortuary structures composed of a platform covered with stones and surrounded by a round wall made of large boulders at several sites within the Yasin and Iskhkoman valleys. Analysis of associated artifacts suggests these structures date to the dawn of the Christian era and hence are contemporaneous with funerary structures found in the Syr Darya and Amu Darya valleys. Jettmer (1967:75) concludes that the external appearance of these monuments are so similar to those described by Soviet scholars that "some relationship plainly suggests itself," while observing that the Yasin and Ishkoman Valleys terminate in passes that afford easy passage to the Wakhan Corridor and western Pamirs (see also Biddulph 1880/1971:57-58; Litvinsky 1964:157; Zelinski 1960).

In the western portion, Jettmar (1967) draws attention to the funerary practices of the Kalasha of southern Chitral and Nuristani groups of eastern Afghanistan. Here the death of an individual is commemorated by a prolonged series of ceremonies that begins with the dressing of the corpse and construction of a straw effigy (Robertson 1896/1974:635-6). After a period of weeping, oratory, dancing and feasting, the body is placed in a wooden coffin atop the ground surface and the bones of the previous occupants swept to the side to accommodate the newly deceased. A year after the death of an adult individual it is expected that the family will erect a wooden effigy in honor of the deceased. This is considered both a duty and a privilege, for the size and complexity of the effigy figure, as well as the lavishness of the food distributed at the ceremony provide an opportunity for the family to assert a claim for status. The above-ground disposal of the dead, the communal nature of inhumation, and the association with feasting are all cited by Jettmar (1967) as evidence of close parallels with the funerary behaviors of the ancient Iranians of the first millennium BCE and the dawn of the Christian era.

Although Jettmar does not specify a specific *Urheimat* for the Indo-Iranians, he notes the discovery of a hoard near the village of Manichal in the Darel Valley in Diamer District, in southwestern Gilgit-Baltistan. Two key objects included in this hoard are axes made of bronze or copper. The first is a "trunnion" axe that has been compared to western-type axes, while the second is a shaft-hole axe, whose affinities may be traced to a typological series whose origin is in the Caucasus and northwestern Iran (Litvinsky 1964:143-147).

This northwestern Iranian attribution has been further strengthened by the discovery of the Gandharan Grave Culture[1], known primarily through the excavation of graves in the valleys of Dir (Dani 1967, 1968, 1992) and Swat (Stacul 1966, 1969a, 1973; Stacul, Compagnoni, & Constantini, 1987), as well as in the Vale of Peshawar (Khan 1973) and Taxila (Dani 1986). In addition to a red ware pottery, there is a plain gray ware that is part of a tradition "very different from those of the periods immediately preceding and immediately following, in shapes and in decoration and in the production techniques of the vessels" (Stacul 1973:197). Indeed, parallels have been drawn between this gray ware pottery and the black gray burnished ware associated with the IIB-IIIC period occupations of the Bronze Age site of Tepe Hissar, located in northwestern Iran (Silvi Antonini 1963; Dani 1978; Stacul 1969a:86-7; 1970:93; Sarianidi 1971).

In light of this evidence, Jettmar (1967, 1974, 1996) suggests that Indo-Iranian invaders emerged from southwestern Central Asia or northwestern Iran during the 1st millennium BCE and spread eastward across southern Central Asia and the Iranian Plateau. During this diaspora these proto-historic Iranians encountered some of the most inaccessible areas of the world. Those that kept to the northern rim of the Iranian Plateau faced the challenges of the southern reaches of the Karakum Desert before entering Badakhshan and the upper reaches of the Amu Darya and Syr Darya river valleys, while those migrating across the center of the Iranian Plateau faced the challenges of the tortuous mountain valleys south of the main range of the Hindu Kush and east of the Anjuman Pass. The physical topography thus channeled routes of migration into two primary conduits: a northern route via Badakhshan, the Wakhan Corridor and across the Pamir Knot, and a southern route, known as the "Indus road," through the Kabul Valley and over the Khyber Pass into vale of Kashmir. Consequently, proponents of the proto-historic Iranian hypothesis such as

Jettmar (1974:ix, 1996:84) argue that the northern route led to the establishment of the Dards, not only in the eastern Hindu Kush, Karakoram and the western Himalayas, but beyond in the oases rimming the Täklamakan Desert of Xinjiang by the early centuries of the 1st millennium CE, while the presence of the Protohistoric Grave Complex in Dir, Swat, the Vale of Peshawar and Taxila signaled their arrival via the southern route (Dani 1978) perhaps a full millennium earlier.

The prehistoric Indo-Aryan model

A number of researchers believe Khowar-speakers came to Chitral as part of a prehistoric Aryan invasion into South Asia during the mid-2nd millennium BCE (Decker 1992:28). Indeed, Morgenstierne (1932, 1973) contended that Khowar and Kalashwar were two languages that belong to the first wave of Indo-Aryan immigrants (Sloan 2013:13; but see Witzel 1999). In a similar vein, Guha (1935:xxi) claimed evidence for an Indo-Aryan invasion by the appearance of a tall, dolichocephalic, leptorrhine element with light skin, eye and hair colors in the eastern Hindu Kush, especially among Pathans, "Red Kafirs" of Nuristan, Kalashas and, to a lesser extent, Khows of Chitral. Proponents of this model further maintain that after crossing the Hindu Kush, these Central Asians initially entered the Indus Valley (Erdosy 1995; Nichols 1997, 1998; Parpola 1988, 1995) and later this intrusive population expanded eastward into the Upper Doab of North India where Vedic culture initially became established (Parpola 1993b). Proponents of this model contend that Vedic culture eventually spread throughout peninsular India via elite dominance (Bamshad *et al.* 1998, 2001; Cavalli-Sforza, Menozzi, & Piazza 1994; Renfrew 1988).

During the 1950s, 60s, and 70s archaeological excavations in southern Central Asia revealed the presence of a previously unknown urban complex located along the northern slopes of the Kopet Dagh foothill plain in south-central Turkmenistan, the Margiana oasis of eastern Turkmenistan, and the northern, southern, and eastern Bactrian oases of southern Uzbekistan and northern Afghanistan (Askarov 1977, 1981; Masson and Sarianidi 1972; Sarianidi 1977, 1981). Dated to the last quarter of the third and the first half of the second millennia BCE (*c.* 2285 – 1520 BCE: Hiebert 1994:77-80; Kohl 1981, 1984, 1992), and designated as the Bactria-Margianan Archaeological Complex (BMAC: Hiebert 1994, 1998, 2002a; Jarrige 1994; Jarrige and Hassan 1989; Mallory and Mair 2000; Parpola 1995; P'yankova 1993; Sarianidi 1981), this urban complex is believed to have been founded by immigrants from earlier occupations within the Kopet Dagh foothill plain (Askarov 1974, 1977, 1981, 1988; Biscione 1977; Hiebert and Lamberg-Karlovsky 1992; Lamberg-Karlovsky 1993; Masimov 1981; Masson 1981, 1988, 1992a, b; Masson and Sarianidi 1972) whose ultimate origins are most likely to be found in northwestern Iran (Masson and Sarianidi 1972). Craniometric assessments of biological affinities of the individuals recovered from cemeteries of these BMAC urban centers largely support this scenario, but with the caveat that contributions from a local, indigenous population also appear to have played a role (Hemphill 1998; 1999a; Hemphill and Mallory 2004).

Artifacts characteristic of the BMAC have been found scattered widely throughout the Indo-Iranian borderlands around the dawn of the second millennium BCE (Erdosy 1995; Hemphill 1999b; Hiebert 1994, 1995; Hiebert and Lamberg-Karlovsky 1992; Lamberg-Karlovsky 1993, 1994; Sarianidi 1993a, b, 1994) and beyond the Hindu Kush and Karakoram to the periphery of the greater Indus Valley (Jarrige & Hassan 1989; Parpola 1988, 1993a, b). Indeed, the discovery of the BMAC has led a number of scholars to identify it, or the adjacent Vakhsh/Beshkent cultures of southern Tajikistan, as the likely source of the protohistoric cultures of northern Pakistan, including those of the Protohistoric Grave Complex (Chlenova 1984; Kuzmina 2007; Lyonnet 1994; Mandel'shtam 1966; Müller-Karpe 1983; Parpola 1993, 1995; P'yankova 1994; but see Silvi Antonini 1963, 1973:239-244; Dani 1978; Stacul 1969a:86-7, 1970:93), which is known primarily through the excavation of graves in the valleys of Dir and Swat, as well as in the Vale of Peshawar, and Taxila, all of which are located in the foothill zone immediately north of the Indus Valley. Using relative dating methods, it has been suggested that the Protohistoric Grave Complex likely dates between *c.* 1700 – 500 BCE (Dani 1967, 1968, 1992), the beginning of which is contemporaneous with the later periods of the BMAC and the Vakhsh/Beshkek cultures (Gupta 1979; Hiebert 1994; Masson 1992b).

However, no Protohistoric Grave Complex sites or artifacts had been found in the region in between where BMAC and Vakhsh/Beshkek sites occur on the one hand (northern Afghanistan, southern Uzbekistan, southern Tajikistan) and the Protohistoric Grave Complex of northern Pakistan (Lower Dir, Lower Swat, Vale of Peshawar, Taxila) on the other—that is Greater Dardistan—until the late 1960s. In 1968 Stacul (1969a:69) discovered a number of protohistoric cemetery sites near Chitral town, the capital of Chitral District, and he identified them as bearing close similarities to the Protohistoric Grave Complex sites reported further south. This conclusion was corroborated by Allchin's (1970) study of three ceramic vessels recovered from the town of Ayun in Lower Chitral. These too, were found to bear close affinities to vessels recovered from Protohistoric Grave Complex sites. In 1999 a joint Pakistani-British team carried out a survey in Chitral and recorded 15 cist graves identified as likely Protohistoric Grave Complex sites (Ali, Batt, Coningham, & Young 2002). This initial effort led to further survey and excavation in Chitral by a team of Pakistani archaeologists that resulted in the identification of additional large cemeteries and the excavation of a series of graves at the sites of Shah Mirandeh and Gankoreneotek, located near Chitral town (Ali, Zahir, & Qasim 2005b; Hemphill, Zahir, & Ali 2017), and at Parwak, located near Mastuj (Ali, Hemphill, & Zahir 2005a; Ali & Zahir 2005).

In light of this evidence, proponents of the Indo-Aryan model suggest that just after the split of Iranian and Indic (Indo-Aryan) language stocks there was a movement of people from the southern steppes, most likely from the urban centers of the BMAC and/or the Vakhsh/Beshkek cultures, southward across the Hindu Kush into Greater Dardistan and beyond into the lower reaches of Dir, Swat and the Indus Valley. They further maintain that this migratory event likely took place during the mid-second millennium BCE and subsequently led to a dispersal of this intrusive population into North India that resulted in the establishment of Vedic culture and Indo-Aryan languages in the northern two-thirds of the Indian subcontinent.

The results of a recent study of newly reported whole genome ancient DNA data from some 379 individuals from Central and South Asia analyzed in tandem with previously reported aDNA data from 333 individuals and published genome-wide information on 1789 present-day individuals from 246 ethnic groups in South Asia by Narasimhan *et al.* (2018) have been offered in support of the prehistoric Indo-Aryan model. The newly reported individuals come from six different geographic and temporal settings that include 132 from 12 Chalcolithic and Bronze Age (5600 – 1200 BCE) sites located in Iran, Uzbekistan, Turkmenistan, and Tajikistan designated as "eastern Iran and Turan"; 165 individuals from early ceramic-using hunter-gatherers from two sites located in the western Siberian forest zone (6200 – 4000 BCE); 20 Chalcolithic and Bronze Age pastoralist sites located in the steppe east of the Urals (4700 – 1000 BCE); and 56 individuals from eight Iron Age and Early Historic sites located in the Swat Valley of northern Pakistan.

A principal component analysis based on variation among present-day Eurasians (Galinsky *et al.* 2016; Patterson, Prince, & Reich 2006) was conducted and the prehistoric individuals were projected into the array. Three sample aggregates were identified: 1) Forest zone/Steppe individuals, 2) Iran/Turan individuals, and 3) South Asians. Using *qpAdm*, the authors were able to model almost every sample as a mixture of seven deeply divergent ancestry sources. These may be identified as: 1) Anatolian agriculturalist-related: Represented by 7th millennium BCE Anatolian agriculturalists (Mathieson *et al.* 2015); 2) Western European Hunter-Gatherer (*WHG*)-related: Represented by Mesolithic western Europeans (Haak *et al.* 2015; Lazardis *et al.* 2014; Olalde *et al.* 2014, Lazardis *et al.* 2016); 3) Iranian agriculturalist-related: Represented by 8th millennium BCE pastoralists from the Zagros Mountains of Iran (Broushaki *et al.* 2016;

Lazaridis *et al.* 2016); 4) Eastern European Hunter-Gatherer (*EHG*)-related: Represented by hunter-gatherers from diverse sites in Eastern Europe (Haak *et al.* 2015; Mathieson *et al.* 2015); 5) West Siberian Hunter-Gatherer (*West Siberian HG*)-related: A newly documented deep source of Eurasian ancestry represented by three samples; 6) East Asian-related: Represented in this study by Han Chinese; and 7) Ancient Ancestral South Indian (*AASI*)-related: A hypothetical South Asian hunter-gatherer lineage related deeply to present-day Andaman Islanders.

The results obtained confirm previous studies (Broushaki *et al.* 2016; Lazaridis *et al.* 2016) which indicate that early agriculturalists from the Zagros Mountains of Iran possess a distinctive type of European ancestry, while later agriculturalists from the same region exhibit evidence of contributions from both Anatolian and earlier Zagros Mountain residents. The contribution from Anatolia was found to decrease clinally from a high of 70% in Chalcolithic Anatolia, to ~33% in eastern Iran, to a low of ~3% in far eastern Turan. The timing of the establishment of this cline is consistent with the spread of wheat and barley agriculture from west-to-east; however, in the far eastern part of this cline, in eastern Iran and Turan, there is evidence of admixture from Western European Hunter-Gatherer (*WHG*)-related populations. Such admixture long predates the spread of Yamnaya-related steppe pastoralists (Anthony 2007). BMAC individuals were found to be characterized by a three-way mix of Early Iranian agriculturalist-related (~60%), Anatolian agriculturalist-related (~21%), and *West Siberian HG*-related ancestry (~13%). Narasimhan *et al.* (2018) interpret these results as indicating that BMAC populations likely arose from local pre-urban populations, who themselves were likely the consequence of an earlier spread of agriculturalists from Iran.

These researchers further note that the absence of the Steppe Early to Middle Bronze Age (*Steppe_MLBA*) ancestry in these BMAC individuals that is ubiquitous in present-day South Asians, which when coupled with *qpAdm* analyses, rule out BMAC populations as a source of substantial ancestry for South Asians. Nevertheless, the evidence suggests that while BMAC populations were affected by the same demographic dynamic that affected South Asian populations—a southward dispersal of Middle to Late Bronze Age Steppe pastoralists (*Steppe_MLBA*)—BMAC populations were bypassed by these steppe pastoralists who mixed with populations further south. The question remains: With which southern populations did members of these *Steppe_MLBA* bearing steppe populations mix with? Narasimhan *et al.* identify a single outlier at the BMAC site of Gonur tepe and two outlying individuals from the eastern Iranian site of Shahr-i Sokhta that date broadly between 2100 – 1700 BCE as possessing *Steppe_ EMBA* in the admixed form characteristic of Middle to Late Bronze Age steppe populations (*i.e., Steppe_MLBA*). Intriguingly, a similar ancestry profile was observed among 41 individuals recovered from two temporal phases of the Iron Age Protohistoric Grave Complex sites located in the Swat Valley of northern Pakistan that date from *c.* 1500/1400 – 1100 BCE and 1000 – 800 BCE, respectively (Vidale & Micheli 2017:399-402; Vidale, Miceli, & Olivieri 2016:199). They designate this shared ancestry between the outliers from Gonur tepe and Shahr-i Sokhta, with the individuals from the Protohistoric Grave Complex as "*Indus_Periphery*."

Narasimhan *et al.* (2018) attribute *Steppe_MLBA* to a relatively homogenous population spread across an extensive portion of the southern steppe from the trans-Urals in the west to The Minusinsk Basin in the east between 2000 – 1400 BCE. Samples from this group encompass individuals buried with artifacts associated with the Corded Ware, Srubnaya, Petrovka, Sintashta and Andronovo complexes and they attest to a mixture of *Steppe_EMBA* and European Middle Neolithic agriculturalists (*Europe_MN*). Ancient DNA studies by Lazaridis *et al.* (2016) indicate that South Asian populations stem from at least three ancestral populations: Early Iranian agriculturalist-related, Onge, and *Steppe_EMBA*. Since the BMAC samples lack *Steppe_EMBA*, this means that the source for steppe ancestry among South Asians must derive from the admixed form of *Steppe_EMBA* found in *Steppe_MLBA* populations and an alternative candidate is the *Indus_Periphery* found among outliers at Shahr-i Sokhta, Gonur tepe, and the Iron Age individuals from the Protohistoric Grave Complex of the Swat Valley.

Narasimhan *et al.* used *qpAdm* to search for triples of source populations to account for ancestry found among four South Asian samples: 1) a sample with high Ancient North Indian ancestry, 2) a sample with high Ancient South Indian ancestry, the early Iron Age Protohistoric Grave Complex samples from the Swat Valley, and their later Iron Age counterparts from Butkara II. The only models that fit all four South Asian samples were combinations that involve *AASI, Indus_Periphery,* and *Steppe_MLBA*. According to Narasimham *et al.* such findings provide direct evidence for *Steppe_MLBA* ancestry being integrated into South Asian groups during the second millennium BCE and the fact that the Protohistoric Grave Complex samples from Swat have higher proportions of Steppe and *AASI*-derived ancestry show that there was an increase in accumulation of Steppe-derived ancestry into the region and additional admixture with Ancient South Indian (*ASI*)-related individuals over time that is wholly consistent with the movement of Steppe-derived ancestry and Indo-Aryan languages called for by proponents of the prehistoric Indo-Aryan model.

A second recently published genome-wide study by deBarros Damgaard *et al.* (2018) examined aDNA obtained from 74 ancient individuals ranging in antiquity from the Mesolithic (~9000 BCE) to the Medieval period, encompassing an area spanning some 5000 km across Eastern Europe, Central Asia, and East Asia. Of particular importance for the current study is the inclusion of samples from Yamnaya period Kazakhstan, four Copper Age (Chalcolithic, Namazga Period III: 3500 – 3000 BCE: Kohl 1992) samples from the sites of Kara depe and Namazga depe located in the Kopet Dagh piedmont strip of southeastern Turkmenistan and one Iron Age individual from the site of Takhirbai (~800 BCE), located just to the east of the Kopet Dagh piedmont in Margiana (Hiebert 1994:16; Sarianidi 1990). These ancient individuals were compared to a wide array of living individuals from the Levant, Anatolia, Europe, East Asia and South Asia taken from the literature. Particularly important for this study are samples from Iran, Tajiks and Yagnobis from Uzbekistan and the Pamirs, as well as Gujars, Kohistanis, Tarkalanis, Uthmankhels, and Yusufzais from Khyber Pakhtunkhwa (northern Pakistan), Kashmiris from Kahsmir, and Tharus from Nepal.

Following a similar procedure as that employed by Narasimhan et al (2018), deBarros Damgaard *et al.* conducted a principal components analysis of genomic variation on the large battery of living individuals, projected the prehistoric individuals into the array, and then used *qpAdm* to model ancestral contributions to selected samples. These researchers found their high-coverage Yamnaya sample from Kargash to be consistent with previously published Yamnaya and Afansievo genomes. With the addition of ancient samples from Central Steppe sites, Okunevo sites, and sites from the Lake Baikal region, deBarros Damgaard *et al.* found a previously unreported pattern of clinal variation across a west-to-east gradient of increasing Ancient East Asia-related ancestry (*AEA*) that extends from the *EHG*-related western steppe populations (*Steppe_EMBA*), to *ANE*-related central steppe (*CentralSteppe_EMBA*) populations, to Neolithic Lake Baikal hunter-gatherers (*Baikal_EN*). When the genomic signature of Early Bronze Age Yamnaya and Afansievo steppe individuals are compared to their Late Bronze Age Andronovo and Sintashta counterparts, both are characterized by substantial *EHG* and *CHG* (Caucasus hunter-gatherer: Jones *et al.* 2015) contributions, but Andronovo and Sintashta individuals can be distinguished from their earlier Yamanaya and Afanasievo counterparts by their possession of a genetic component (*Europe_MN*) acquired through admixture with Eastern European farmers (Allentoft *et al.* 2015; Haak *et al.* 2015) that results in the characteristic *Steppe_LMBA* signature described by Narasimhan *et al.* (2018).

The four Copper Age individuals from Kara depe and Namazga depe (Namazga_CA) occupy an intermediate position in a plot of the first two principal components between Iran Neolithic/

Late Neolithic and Western Steppe clusters. The Namazga_CA carry a significantly larger fraction of *EHG*-related ancestry than Neolithic individuals from Iran, and these researchers were not able to reject a two-population *qpAdm* model in which Namazga_CA ancestry was derived from a mixture of Neolithic Iranians and *EHG*, but importantly there is no *CHG*-related ancestory to be found among them, which means that the *EHG* contribution had to come from Narasimhan *et al.*'s *West Siberian_HG* than from either the *Steppe_EMBA* characteristic of Yamanaya and Afanasievo populations or the *Steppe_LMBA* characteristic of Andronovo and Sintashta populations. Acquisition of an unadmixed *EHG* contribution prior to the Namazga III period (~3500 BCE) is entirely consistent with restriction of the Yamanaya dispersal to the steppe-pine-forest zone north of the Aral Sea and Lake Balkash (Anthony 2007:307-311).

In contrast, the Iron Age individual (~900 – 200 BCE) individual from Takhirbai occupies a position closer to the the steppe cluster in the PCA plot. Model based *qpAdm* clustering shows that this sample has a substantial amount of admixture with CHG-related ancestry. However, it also has European farmer-related ancestry typical of Late Bronze Age Sintashta and Andronovo steppe populations. Such contributions, not found in the earlier NMG III period material from Kara depe and Namazga depe, suggest that the sample from Takhirbai received admixture from Late Bronze Age Andronovo and Sintashta populations (*i.e., Steppe_MLBA*), rather than from Early Bronze Age Yamnaya and Afanasievo (*i.e., Steppe_EMBA*) populations.

When the principal component analysis is focused on South Asian samples, the first component describes a west-to-east clinal gradient, while the second component describes a north-to-south gradient. According to deBarros Damgaard *et al.* placement of the South Asian cluster indicates the presence of three major ancestry contributions coming from West Eurasians, South Asians, and East Asians. As the Namazga III period individuals from Kara depe and Namazga depe (Namazga_CA) fall near the opposite end of the South Asian cluster from the Onge, this group was tested as a potential ancestral source in a series of four *qpAdm* models. In the first model, these researchers unable to reject a two-population model using Namazga_CA and the Onge for nine South Indian predominantly Dravidian-speaking samples. However, when this same model was used for seven other populations from the northernmost Indic- and Iranian-speaking groups, it was rejected. In a second model a third contribution from a Late Bronze Age Steppe source (*Steppe_LBMA*) was added and this model was accepted for these seven northernmost groups. When the second model was applied to account for ancestral contributions among seven northeast Indian populations, most of which were Tibeto-Burman or Austro-Asiatic speakers it was rejected; but when the Late Bronze Age Steppe source (*Steppe_MLBA*) was replaced with an East Asian ancestry source—in this case, a Late Iron Age (~200 BCE – 100 CE) Xiongnu (*Xiongnu_IA*) from Mongolia (deBarros Damgaard *et al.* 2018)—the model was accepted. Finally, for the two northernmost non-South Asian groups (Tajiks, Tajiks_Pamir), the only tested model that was not rejected was a two-population model that included the Iron Age (~900 – 200 BCE) individual from the Zeravshan Mountains and the Xiongnu as sources.

DeBarros Damgaard *et al.* (2018) interpret these results as indicating that western influence on South Asian populations stems from two separate admixture events. The first is represented by the ancestry unique to the Namazga III period individuals from Kara depe and Namazaga depe. The ancestry of these individuals appears to be a consequence of admixture between non Indo-European speaking Iranian Neolithic farmers of the Zagros Mountain region of Iran (Narasimhan *et al.*'s Iranian agriculturalist-related) with indigenous hunter-gatherer populations resident in southern Turkmenistan and northeastern Iran (Narasimhan *et al.*'s *West Siberian_HG*). This population, or a related source, spread eastward and southward at the beginning of the third millennium BCE and eventually contributed ancestry all the way to southern India. The second admixture event occurred during the Late Bronze Age (~2300 – 1200 BCE) from steppe populations (*Steppe_LMBA*) through established contacts between pastoral steppe nomads and the Indus Valley, ushering in European Neolithic (Narasimshan *et al.*'s *EHG*-related) and Caucasian-specific ancestry (Narasimhan *et al.*'s *CHG*-related), as well as Indo-Iranian languages into northern South Asia. These researchers maintain that these findings are entirely consistent with the expectations of the prehistoric Indo-Aryan model.

The indigenous model

One of the earliest Europeans to enter Greater Dardistan was Colonel John Biddulph, who on special duty from the Foreign Office, served as a member of Forsyth's mission to Yarkhand, the Pamirs and Wakhan in 1873-74. In 1876 Buddulph was ordered to lead his own mission to Gilgit, Hunza and part of Yasin. He was then appointed by the colonial government to reside at Gilgit in a political capacity during which, in 1878, he undertook a mission to Yasin and Chitral (Gratzl 1971). In was during this latter mission that Biddulph (1880/1977:62) observed, "unlike the Shins and other cognate tribes already mentioned, the existence of these people [the Khow] in the localities in which we now find them appears to date from so far back as virtually to entitle them to be considered aboriginal." This notion of the great antiquity of Khow residence in Chitral is echoed by Hasrat (1996:181) who asserts that the Khow are believed to be the descendants of those who first settled there, the "Pisachas," or eaters of raw flesh, some 5,000 years ago. Hasrat (1996) also notes that a number of customs, such as *jeSTán Dekeék* ("devil diving") and *faqiri maSkík* ("to beg for household goods"), practiced in the past or still practiced today belong exclusively to the Khow, though they may be observed in modified (often truncated) forms among other ethnic groups of Gilgit, Wakhan and Sariqol known to have ethnic and cultural links with the Khow.

Assertions of long-standing *in situ* residency within Chitral have also been based upon the qualities of Khowar, the language spoken by the Khow. Khowar is an Indo-European, Indo-Iranian, Indic (Indo-Aryan) language of the Dardic, Chitral subgroup (Emeneau 1966; Morgenstierne 1961:138-139; Ruhlen 1987:325; Strand 1973:302; Voegelin and Voegelin 1965:284-294). More specifically, Khowar represents an early pre-Sanskrit Indic language (Sloan 2013:13). This is reflected by the fact that Khowar retains a great part of the Sanskrit case inflections, phonemes, and words in near-Sanskritic form that have long been lost in other Indic languages (Morgenstierne 1947:6-8, 1974:3; Sloan 2013:21). The only other Dardic language to which Khowar is closely related is Kalashwar and even then—although they share certain unique grammatical features—there is little lexical similarity between them as the two languages are mutually unintelligible (Cacopardo, A.M., 2001:18; Decker 1992:34-35).

Morgenstierne (1936, 1947:6-8) states that while Khowar has been strongly influenced by Iranian languages to the west, largely in the form of loan words, the underlying syntactic structure is purely Indic. When such loan words are examined closely, their derivation can be traced to four sources: modern Persian, Middle Iranian languages, Pamir languages (such as Wakhi, also of Iranian derivation), and undefinable or unknown sources. According to Morgenstierne (1936:658) the source of the overwhelming majority of Iranian loan words is modern Persian. This should come as no surprise as Chitral was ruled since the 16th century by a Mehtar of the House of Katora, who trace their ancestry from Baba Ayub of Khorasan, and who insisted on Persian as the official language from the 16th century until 1953 (Pervez 2014:9). In contrast to modern Persian, words of Middle Iranian derivation are extremely rare, as are words from Pamir languages and words of undefinable or unknown origin.

Another line of linguistic evidence that has led some scholars to claim great antiquity of Khows in Chitral is the influence the Khowar language has had upon neighboring Iranian-speaking groups found to the north and west of Chitral District. This is especially the case for Yidgha, which has been spoken for many generations in Chitral (Strand 1973), but also with Wakhi, which although separated by a high range of mountains, has been so strongly influenced by Khowar that several personal pronouns commonly used in Wakhi are of clear Khowar origin (Morgenstierne 1936:661; 1938). Still further, Khowar is not just one of the major languages of northern Pakistan; it serves as the *lingua franca* of Chitral District. For a language spoken throughout such a large area, and for a language commonly used in the marketplace, Khowar exhibits a great degree of uniformity. Indeed, several researchers have remarked that among Khowar-speakers there is little to no regional diversity (Lorimer 1939; Morgenstierne 1932; Munnings 1990). An array of explanations for such uniformity has been offered. Morgenstierne (1932:50) suggests this uniformity is due to the fact that in historic times Khow peasants were transferred from one part of the district to another by members of the ruling class. Fussman (1972:23), focusing on the ruling class, explains this linguistic homogeneity as the consequence of *Chirmuži*, or "milk relations." This is the practice in which the sons and daughters of noble Khow families—either of the royal house or of the *adamzada* aristocracy—were fostered to a family other than their own (Cacopardo, A.S., 2001; Jettmar 1975: 416; Schomberg 1938: 225). Munnings (1990:11) believes that, in addition to these factors, the practice of obtaining brides from distant villages accounts for the minimal dialectical variation found within Khowar. Finally, Decker (1992:42) suggests that it is the geographic isolation of the Chitral Valley and its physiographic self-containment, coupled with a long-standing history of fairly stable political and cultural environments enjoyed by the Khows over the course of many centuries, that has led to the remarkable uniformity of spoken Khowar. Thus the unique array of customs practiced by the Khow, the archaic Indic derivation of Khowar, the nearly exclusive restriction of loan words into Khowar to modern Persian, the profound impact of Khowar loan words upon the languages spoken by adjacent ethnic groups, and the remarkable uniformity of Khowar spoken throughout Chitral have led a number of scholars to propose that the Khow represent long-standing indigenous occupants of this region.

The question, however, remains as to whether any significant population incursions into Chitral occurred after the era of the Protohistoric Grave Complex came to an end during the latter half of the 1st millennium BCE in the southern core area of Dir, Swat, the Vale of Kashmir, and Taxila (Vidale & Micheli 2017; Vidale *et al.* 2016) and after the 1st millennium CE in the northern peripheral area (*i.e.,* Chitral) (Ali *et al.* 2008) that may have implications for Khow origins.

While Stellrecht (1997) stresses the openness of the mountainous region known as Dardistan, Cacopardo and Cacopardo (2001:31) find this assertion incompatible with local perception of the present and the past as well as with their own experiences in the Chitral area. These researchers, in direct opposition to Dichter and Stellrecht, maintain that the peoples and cultures of this mountainous region, including the Khow, cannot be considered a part of the lowland cultures, or as participants in the historical processes that affected South and Central Asia. Instead, they assert that the variety and nature of the languages indicates quite the opposite, the distribution of religious denominations indicates that Islam entered Dardistan from different directions, the petroglyphs and rock carvings are limited to a particular artery located east of the Chitral Valley and are limited to a particular period, and apart from that conspicuous exception, the historical records concerning the peoples and cultures are very scarce, both inside and outside the region.

Chitral was apparently more subject to direct contact with the religions of India than Nuristan, but less so than the Shina-Burusho area to the east (Cacopardo & Cacopardo 2001:26). Buddhism has left some traces (Biddulph 1977/1880:109; Stein 1921:37-41; Jettmar 1977:423-4; see also Tucci 1977:63-4), but these are so scarce relative to that seen in the Shina-Burusho area that it likely that Buddhism made only a fleeting appearance in Chitral. As for Hinduism, the only remains found in the Chitral-Kunar basin are some fragments of a Hindu temple discovered at Chighar Sarai in Afghanistan that date to the 7th-9th centuries CE. Hindu influences may have spread further north into Chitral, but contrary to Biddulph 1880:65), there is no indication that Chitral was ever Hindu. Thus, it is only with the advent of Islam, in all likelihood, that trade was again carried across the Hindu Kush-Karakoram.

In Islamic times, the main caravan routes were still the eastern road through Ladakh and the

Karakoram Pass, as well as the ancient silk road across the Tarim Basin, which branched south to Badakhshan and Kabul (Raunig 1978:557-8; Stellrecht 1997:6), but the north-south connection was no longer along the old Indus Road. Instead, the new route had two main branches: one, the Lowri road, led to Peshawar through Chitral, Dir and Bajaur; the other headed to Kashmir through Gilgit and Astor (Cacopardo & Cacopardo 2001:30). With the establishment of Islamic principalities in the Chitral and Gilgit areas, these routes were preferred to the old Indus Road, which now fell within a region controlled by an array of acephalous tribal polities. Yet, Cacopardo and Cacopardo (2001:30) assert, "available data indicate that the Chitral trail through the mountains never became a relevant long-distance trade route before British times, mainly by reason of the constant threat of raids from independent Kafiristan. Equally dangerous (Jettmar 1977:428) was the Astor route leading to Kashmir (Drew 2002/1875:393-404), because of raids from Chilas in the Indus Valley."

The advance of Islam in the areas surrounding Dardistan followed the main trade routes to Central Asia and India. Consequently, the early Islamic waves branched out at the western terminus of the Hindu Kush towards the north and south, leaving the mountainous region and its inhabitants in between long untouched (Cacopardo & Cacopardo 2001:31). The Panjshir Valley, located 150 km north of Kabul, is known to have been under Islamic control for its silver mines by the 9th century CE and the valley facilitated communication between Badakhshan and the plains of northern India. Yet, this area and the route it supported appears to have been parlous, for still in the times of Babur (16th century) the non-Islamic populations of the neighboring Alishar Valley were exacting tribute from the Muslim population of Panjshir. Consequently, it is from the south that one of the earliest attacks against Dardistan was launched by Mahmud of Ghazni in *c.* 1000 CE; however, it was not until the time of Akbar that his son Jahangir attacked the Shia-Posh of the mountains of Kator (1581 CE) (Raverty 2017/1888:141). In the following year a full campaign was launched under the Darvesh Muhammad that fought its way through Langhman and up the Alishang River. A prolonged effort was made by Akbar to extend his rule over the mountain areas between 1585-1598 in response to the threat to the northwest frontier of the Mughal Empire by the Uzbek ruler of Bokhara, who controlled Badakhshan. In response to this threat, Akbar attempted to establish imperial authority over the independent territory that lay in between (*i.e*, Dardistan). Contrary to assertions made by Abul Fazl (1939) in the *Akbar Nama*, it appears that Badakhshan was never conquered by Akbar, for Nuristan and Chitral remained outside his influence, while the people of Swat, Bajaur and Buner never paid tribute (Cacopardo & Cacopardo 2001:32).

Islamic Arabs took over Bactria and Sogdiana in the 7th and 8th centuries CE. Badakhshan fell under their sway at about the same time, and from then on the historical destiny of Badakhshan was contingent upon political affairs in Balkh and Bokhara (Leitner 1895). One of the earliest forays into Dardistan was carried out to protect Badakhshan from the raids of the Kafirs. An example is Timur Lang's expedition in 1398 CE, which led to some successes against the "infidels," but he did not attempt to hold the positions gained, and swiftly withdrew (Cacopardo & Cacopardo 2001:32-3). Holzwarth (1996) argues that Islam did not come to Chitral until the early 16th century and it was a consequence of an expansionist wave of the Chagatai khanate that established sub-centers, possibly in the areas of Mastuj and Yasin (Cacopardo, A.S. 2000:47). To support his argument Holzwarth (1996:121-3) refers to the military expeditions from Yarkand into the Hindu Kush that took place between 1520 and 1550, which ended with the submission of the locals. In this Holzwarth relies on the account of Mirza Haidar, who in 1527-28 led an Islamic incursion into "Balur," describing it as "an infidel country (Kafiristan)" inhabited by "mountaineers" without any "religion or a creed" (Mirza Haidar 1895: 384), located "between Badakhshan and Kashmir" (Mirza Haidar 1895: 136).

In 1527, Mirza Haidar only encountered villages, each of which was described as "never at peace with another," and who obviously were not subjected to any centralized rule. Yet, only a few decades later Islamic centralized political units are reported south of the Hindu Kush. According to the *Tawarikh-i-Afaghina* of 1550, in Kashgar (*i.e*., Chitral) "the ruling race were all Musalmans of the Sunni faith, and spoke Turki, but the bulk of the ruler's subjects were Kafirs or Infidels (in Raverty 2017/1888:232; Holzwarth 1996:122, 131) (Cacopardo, A.S. 2000:48). According to Gul Murad Khan Hasrat (1996:187), it appears that the pre-Islamic culture of the Khow was probably akin to that seen today among the Kalasha, for "before conversion, the Kho people had the same beliefs as the Kalasha have even to this day."

The first independent Muslim ruler in Chitral was probably Shah Babur, who was part of the second Islamic wave, this time coming from Badakhshan, which had fallen to the Uzbeks becoming, with Balkh, a dependency of the Kingdom of Bokhara in 1584 (Leitner 1895). The Uzbeks were Sunni and persecuted the local Shiah "heretics." For Holzwarth, these Shiah were Ismailis, for there are indications that the defeated Ismailis were led by Shah Babur into Chitral between 1600 and 1620, where their creed became the official religion and when it may be inferred that at least of the population converted to Ismailism (Cacopardo, A.S. 2000:49). It may be that the center of Shah Babur's kingdom was in Mulkhow. However, by 1635, Shah Babur submitted to the Khan of Balkh and converted to Sunnism from Ismailism. His conversion, however, appears to have not involved the bulk of the population, for the *Dabistan-i-Mazahib*, a work of 1658, reports an Ismaili area east of Badakhshan including Chitral (Holzwarth 1994:21-2). Thus, it appears that the population of Chitral during the latter half of the 17th century was Shiah (Ismaili) while the rulers were Sunni. This likely held for all of Chitral, except for the Kalash region until the mid-19th century, when the Kator-Afghan alliance, coupled with missionary efforts of Hazrat Muhammad Shuaib and his pupil Abdul Ghafur Sahib, led Sunni conversion throughout Lower Chitral. Upper Chitral, however, remains Shiite to the present day.

According to A.S. Cacopardo (2001:54), as late as the mid-19th century under Shia influence, non-Islamic populations could be found along both banks of the Chitral River in Lower Chitral and even the large village of Drosh does not appear to have been fully Islamicized in the time of Bellew (1891). As long as Ismaili Shiism was present, the bulk of the population of Lower Chitral was *nimcha* (or "half-Mussulman (Masson 2010/1842:206-7). Non-Islamic "Kafir" practices were fully maintained and only verbal allegiance was given to Islam prior to the advent of Sunnism. With Sunnism, Kafir religious practices were abandoned by the communities, but on the right bank of the Chitral River, communities were more influenced by the "kafir" north than by the Afghan south, and hence remained largely Kafir until British times.

Thus, in addition to the unique array of customs practiced by the Khow, the archaic Indic derivation of Khowar, the nearly exclusive restriction of loan words into Khowar to modern Persian, the profound impact of Khowar loan words upon the languages spoken by adjacent ethnic groups, and the remarkable uniformity of Khowar spoken throughout Chitral noted above, it also appears clear that the history of Chitral and of the Khow since the dawn of the historic era following the Protohistoric Grave Complex has been one of long-standing continuity. Neither Buddhism nor Hinduism had little influence in Chitral and in contrast to the assertions of an early n of the Khow populace to Islam in the 7th century made by Murtaza (1962) in the *Nai Tarikh-i-Chitral*, the documentary evidence marshaled by the Carcopardos (2001) and Holzwarth (1994, 1996) make it clear that conversion to Islam did not occur among the bulk of the Khow population until the mid-19th century. Even *if* Islamization occurred earlier, the historical record fails to describe any significant population movement associated with such a change in religion. Rather, the consistent reports of *nimcha* Islam suggest that—apart from the royal family and the landed *adamzada* aristocracy—Islam among the Khow was nothing more that lip service and convenient syncretisms that enabled pre-Islamic religious practices, beliefs, and rituals to continue into the last century among the Khow. Hence, a number of scholars propose that the Khow represent long-standing indigenous occupants of western Dardistan.

Materials and Methods

Materials

This study is based on dental casts collected among 209 Khow volunteers from Buni, Chitral town, Drosh, Garam Chashma, and Mastuj (Fig. 1 inset). All potential participants were informed of the voluntary nature of their participation and provided informed consent in accordance with the research protocol approved by the Institutional Review Board at California State University, Bakersfield. The sampling strategy sought to obtain dental casts from an equal number of unrelated females and males between 14 and 25 years of age. This age profile was targeted in an effort to reduce data loss due to dental pathologies, non-eruption, and antemortem tooth loss. Dental impressions were collected in the field, usually at post-secondary schools with the approval of the headmaster or other responsible educational authority. Once the alginate-based impressions were set die stone was immediately poured into the mold. The cast was removed once the die stone was thoroughly set (usually within 20 minutes), and the impression trays were cleaned, sterilized, and reused.

These data were compared to 965 females and males from six different ethnic groups of two regions of peninsular India (southeast, northwest). The samples from both regions were measured by the author (Hemphill 1991; Hemphill, Lukacs, & Rami Reddy 1992; Lukacs & Hemphill 1993). The data for the members of the seven living ethnic groups was then compared to sex-pooled data reported from 12 prehistoric samples from Central Asia, the Indus Valley and west-central peninsular India. Sample sizes, abbreviations, and antiquity are provided in Table 1.

Methods

Phase one: odonotometric variation among Khow females and males

Mesiodistal (MD) and buccolingual (BL) dimensions were measured for all permanent teeth in accordance with the method of Moorrees and Reed (1964). Measurement repeatability was assessed in accordance with the method of Calcagno (1984) on a random sample of 25 casts measured one year apart. Individuals represented by casts of a single arcade and measurements of third molars were eliminated from further consideration. Measurements of antimeric teeth were tested for significant differences by side with paired-samples t-tests. If no significant differences between antimeres were found measurements made on the left side were retained; if measurements for the left side were unavailable, values for the right side antimere were substituted. The data was examined for outliers through the use of box-and-whisker plots to identify measurements that exceed 1.5 times the interquartile range (Hodge & Austin 2004). Those measurements found to be outliers were removed from further consideration. Descriptive statistics were calculated and the data was submitted to principal component analysis by sex. Scree plots were examined and those unrotated components that explained the greatest proportion of the variation were retained. These components were used to examine the pattern of within-sex odontometric variation among the Khow.

EM estimation (Dempster, Laird, & Rubin 1977) was used to estimate missing values by sex. These

Table 1. Living and prehistoric samples included in the study[1]

Sample	Abb.	Date	N
Altyn Depe	ALT	2500-2000 BC	25
Bhils	BHI	Living	208
Chalcolithic Mehrgarh	ChlMRG	4500 BC	28
Chenchus	CHU	Living	196
Djarkutan	DJR	2100-1950 BC	48
Garasias	GRS	Living	207
Geoksyur	GKS	3500-3000 BC	64
Gompadhompti Madigas	SPD	Living	177
Harappa	HAR	2600-1900 BC	26
Inamgaon	INM	1600-700 BC	38
Khow	KHO	Living	209
Kuzali	KUZ	1950-1800	31
Molali	MOL	1800-1650 BC	52
Neolithic Mehrgarh	NeoMRG	6500-6000 BC	42
Pakanati Reddis	PNT	Living	184
Vaghelia Rajputs	RAJ	Living	190
Sapalli Tepe	SAP	2300-2100 BC	49
Sarai Khola	SKH	200-100 BC	25
Timargarha	TMG	1400-850 BC	21
TOTAL			**1820**

1. For sources of the comparative data see Hemphill (2013).

estimates were based on the greatest combination of the five variables with the highest correlations for the missing variable whose estimation does not yield a singular matrix or violate Little's (1988) MCAR (missing completely at random) test. No more than four of the 28 variables (14.2%) were estimated by individual. Descriptive statistics were calculated by sex after EM estimation to assess how estimation of missing values affect the Khow dataset and tested for normality with the Shapiro-Wilk test along with tests for skewness (G1) and kurtosis (G2). The degree and nature of expression of sex dimorphism was assessed in accordance with the procedure of Garn, Lewis, and Kerewsky (1964). Variables were ranked by the magnitude of percentage sex dimorphism from highest to lowest regardless of polarity (males positive, females negative). Principal component analysis was rerun on the dataset after EM estimation separately for males and females. Scree plots were examined and those unrotated components that explained the greatest proportion of the variation were retained. Discriminant functions were calculated between Khow females and males. These functions were calculated two different ways. First, sex-specific covariance matrices were used and all of the variables were entered into a complete discriminant function analysis regardless of F-value. Second, sex-specific covariance matrices were submitted to a backward stepwise discriminant function analysis in which variables were removed from the function if their associated F-value fell below 2.25 (Engelman, Badashah, & Nath 2004). Classification coefficients and assignment accuracies prior to and after jackknifing were calculated.

While it is true that upward or downward isometric scaling of tooth size is a primary avenue of odontometric variation among modern and recent humans on a global scale (Harris 1998), finer distinctions involve differential allocation of tooth mass across the dentition (Hemphill 2016a, b). To assess differences in tooth size allocation, tooth measurements were size corrected by standardizing them against individual geometric means, which represents a ratio within the Mosiman family of shape ratios (Jungers, Falsetti, & Wall 1995:137). Although such measures are scale-free in the sense that they are dimensionless, they are not completely independent of size (Oxnard 1978), for depending upon how much gross "size" is removed from the data, the reduction in the proportion of total variance in the size-related "shape" data relative to the raw data can vary from moderate to severe (Jungers *et al.* 1995:155). Once the raw measurements were geometrically scaled, the scaled data was submitted to principal components analysis by sex. Scree plots were examined and those unrotated components that explained the greatest proportion of the variation were retained and compared to those obtained from the raw data to assess the influence of gross size upon size-related tooth "shape" as reflected by the patterning of tooth size allocation throughout the dentition.

Phase two: odontometric variation among living South Asian females and males

As with Khow individuals, mesiodistal (MD) and buccolingual (BL) dimensions among individuals of the six comparative living ethnic group samples were measured for all permanent teeth in accordance with the method of Moorrees and Reed (1964). Three samples are of Indo-Aryan-speaking ethnic groups of Gujarat, located in northwestern India, and three are of Dravidian-speaking ethnic groups of Andhra Pradesh, located in southeast India (Fig. 2). Bhils and Chenchus are non-Hindu tribal populations (Fürer-Haimendorf 1943; Mann 1978) Garasias and Gompadhompti Madigas are low-status Hindu castes (Dave 1960; Thurston 1909), while Vaghela Rajputs and Pakanati Reddis are high- and middle-status Hindu castes, respectively (Lukacs & Hemphill 1993; Singhji 1994).

Because these comparative samples from Gujarat and Andhra Pradesh were measured by the author, interobserver repeatability is not an issue. As with the Khow, individuals represented by casts of a single arcade and measurements of third molars were eliminated from further consideration. Measurements of antimeric teeth were tested for significant differences by side with paired-samples t-tests. If no significant differences between antimeres were found measurements made on the left side were retained; if measurements for the left side were unavailable, values for the right side antimere were substituted. The data was examined for outliers in the same manner as described for the Khow and those measurements found to be outliers were removed from further consideration. Individuals represented by fewer than 24 of the 28 measurements were also eliminated from further consideration. Descriptive and distributional statistics were calculated and the data were tested for normality. Missing values were estimated with EM estimation based on the greatest combination of the five variables with the highest correlation with the missing variable whose estimation does not yield a singular matrix or violate Little's (1988) MCAR test. As with the Khow, no more than four variables were estimated by individual.

The amount and patterning of sex dimorphism was examined in the six comparative groups in a manner identical to that described for Khow females and males. That is, the percentage of sex dimorphism was calculated in accordance with the method of Garn *et al.* (1964) and these differences were rank scaled from the most to the least dimorphic regardless of polarity. A Kruskal-Wallis H test was used to test for significant differences in the patterning of sex dimorphism across all seven living samples. In the event that an omnibus statistically significant difference was obtained, rank sum post hoc tests were undertaken to determine which pairwise contrasts contribute

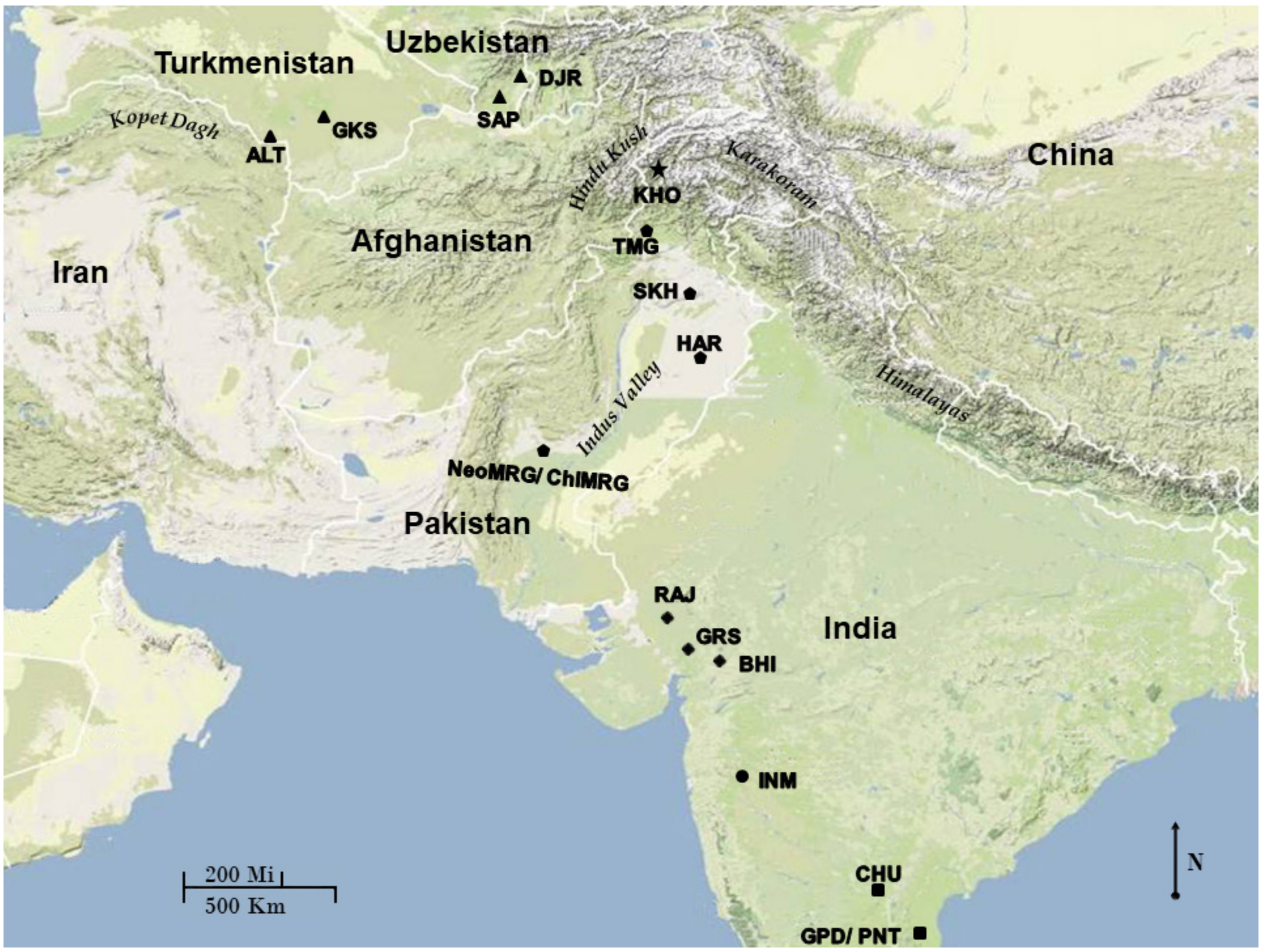

Figure 2. Map of sampling localities for Khows (Chitral town) and all comparative samples, both living and archaeologically derived. Abbreviations from Table 1. Khows represented by star, northwestern peninsular Indians by diamonds, southeastern peninsular Indians by squares, prehistoric Central Asians by triangles, and prehistoric inhabitants of the Indus Valley by pentagons.

to the overall significance.

Raw and estimated data were geometrically scaled by individual. Descriptive and distributional statistics were calculated to test for adherence to normality. The geometrically scaled data were then submitted to two-way analysis of variance to test for the effects of group membership, sex, and the interaction between group membership and sex on the individual variables. Homogeneity of univariate variance was tested across all living ethnic groups with sexes pooled and with sexes separate with Levine's (1960) test. Canonical variates analysis was conducted with sexes pooled. Standardized coefficients, canonical variate correlation coefficients and assignment accuracies prior to and after jackknifing were calculated. Group centroid scores for the first three canonical axes were plotted and a minimum spanning tree imposed to ease interpretation of patterns of intergroup affinities. Pairwise Mahalanobis d^2 distances between group centroids for all canonical axes were calculated and used as input for multidimensional scaling with Kruskal's (1964) stress formula 1 into three dimensions in an effort to determine whether the canonical axes that explain lesser amounts of the overall variance yield differences in the patterning of affinities among groups. The same canonical variates and multidimensional scaling procedures were conducted across members of the living ethnic groups separately by sex to determine whether sex-based differences occur in the patterning of inter-group affinities and to what degree those canonical axes that explain less of the overall variance influence the patterning of inter-group affinities by sex.

Phase Three: Odontometric variation among prehistoric and Living Central Asians and South Asians

Sex-pooled average values for the 28 odontometric variables were obtained for 12 prehistoric samples from Central Asia, the Indus Valley of Pakistan and west-central peninsular India that range in antiquity from the early Neolithic to the last quarter of the first millennium BCE. The samples from Central Asia were measured by the author, while the samples from the Indus Valley and Maharashtra were measured by Lukacs (1983a, b, 1985; Lukacs & Hemphill 1992; Hemphill *et al.* 1991). An interoberver error analysis between the author and Lukacs was conducted on 25 randomly selected casts and no significant differences were observed (Hemphill, nd). Because of the fragmentary nature of these archaeologically derived individuals, the canonical variates obtained from the analysis of living groups with sexes pooled were used to calculate group centroid scores for the sex-pooled prehistoric samples. As in phase two, group centroid scores for the first three canonical axes were plotted and a minimum spanning tree imposed to ease interpretation of patterns of intergroup affinities. Pairwise Mahalanobis d^2 distances between group centroids for all six canonical axes were calculated and were used as input for multidimensional scaling into three dimensions with Kruskal's stress formula 1.

Results

Phase one: odonotometric variation among Khow females and males

Assessment of intraobserver repeatability yielded no significant differences among any of the 28 variables considered (Hemphill 1991:146-149). Paired-samples t-tests of antimeric measurements after removal of outliers likewise yielded no significant differences (Table 2). The lack of significant differences between antimeres permits measurements of the right side to replace measurements of the left side in those cases where left side measurements could not be made. Descriptive statistics of raw measurements among Khow females and males after removal of outliers is presented in Table 3. Distributional statistics of Khow females and males reveals that only two (7.1%) and three (10.7%) of the 28 variables depart from normality by sex, respectively (Table 4). These data were submitted to principal components analysis by sex. The scree plots indicate that the first five components ought to be retained for both females and males, accounting for 66.4% and 64.5% of the total variance, respectively (Table 5).

An examination of the unrotated variable loadings for the first component (Fig. 3) shows

Table 2. Mean values and contrasts between antimeres for base sample of Khowars[1]

Variable	Side	n	$\bar{X}$	sd	n_{cont}[2]	$\bar{X}_{diff}$[3]	sd_{diff}	t_{diff}	p_{diff}
LI1MD	L	171	4.659	0.393	148	-0.010	0.242	-0.511	0.610
	R	164	4.659	0.368					
LI1BL	L	173	5.450	0.626	155	-0.029	0.283	-1.276	0.204
	R	170	5.482	0.619					
LI2MD	L	175	5.265	0.398	150	0.025	0.180	1.721	0.087
	R	171	5.229	0.428					
LI2BL	L	191	5.747	0.574	165	-0.019	0.166	-1.455	0.148
	R	176	5.745	0.605					
LCMD	L	204	5.993	0.395	190	-0.011	0.150	-0.969	0.334
	R	192	6.002	0.405					
LCBL	L	197	6.860	0.690	166	-0.020	0.249	-1.059	0.291
	R	172	6.852	0.655					
LP3MD	L	204	6.159	0.449	201	-0.003	0.330	-0.149	0.881
	R	204	6.164	0.447					
LP3BL	L	193	7.132	0.554	180	-0.019	0.241	-1.084	0.280
	R	192	7.151	0.554					
LP4MD	L	194	6.140	0.543	188	0.006	0.467	0.187	0.852
	R	195	6.152	0.652					
LP4BL	L	190	7.659	0.588	177	0.032	0.404	1.060	0.291
	R	187	7.651	0.557					
LM1MD	L	197	10.225	0.635	182	-0.040	0.346	-1.541	0.125
	R	190	10.266	0.648					
LM1BL	L	189	9.830	0.520	167	0.023	0.236	1.279	0.203
	R	180	9.821	0.553					
LM2MD	L	162	9.634	0.649	138	-0.050	0.434	-1.353	0.178
	R	161	9.704	0.625					
LM2BL	L	164	9.596	0.592	139	0.005	0.370	0.161	0.873
	R	168	9.632	0.532					

1. Base sample refers to Khow sample after individuals less than 12 years of age, individuals represented by only one arcade, as well as third molars and measurements identified as outliers have been eliminated from consideration (see description of procedure in text).
2. n_{cont} is the number of pairwise contrasts between antimeres.
3. $\bar{X}$ and $\bar{X}_{diff}$ do not agree because the former includes all individuals for which the variable could be measured regardless of whether its antimere could also be measured, whereas the latter only includes those individuals for which both antimeres could be measured.

Variable	Side	n	$\bar{X}$	sd	n_{cont}	$\bar{X}_{diff}$	sd_{diff}	t_{diff}	p_{diff}
UI1MD	L	170	7.818	0.540	156	0.017	0.281	0.769	0.443
	R	179	7.815	0.532					
UI1BL	L	167	6.794	0.641	148	0.010	0.193	0.638	0.525
	R	166	6.806	0.667					
UI2MD	L	177	6.011	0.623	159	0.009	0.448	0.266	0.791
	R	181	5.954	0.676					
UI2BL	L	170	5.894	0.720	144	-0.055	0.426	-1.547	0.124
	R	166	5.993	0.709					
UCMD	L	190	6.942	0.450	177	-0.006	0.302	-0.249	0.804
	R	188	6.956	0.438					
UCBL	L	175	7.614	0.667	149	0.028	0.396	0.847	0.398
	R	168	7.545	0.677					
UP3MD	L	201	5.943	0.432	192	0.007	0.147	0.637	0.525
	R	200	5.949	0.426					
UP3BL	L	199	8.355	0.583	187	-0.025	0.187	-1.796	0.074
	R	195	8.390	0.604					
UP4MD	L	201	5.624	0.430	190	0.015	0.197	1.031	0.304
	R	196	5.610	0.449					
UP4BL	L	199	8.470	0.556	187	-0.034	0.367	-1.255	0.211
	R	193	8.508	0.581					
UM1MD	L	194	9.397	0.544	179	-0.011	0.140	-1.011	0.313
	R	188	9.434	0.580					
UM1BL	L	193	10.658	0.601	173	-0.028	0.341	-1.092	0.276
	R	185	10.690	0.594					
UM2MD	L	135	9.139	0.596	107	-0.060	0.457	-1.355	0.178
	R	124	9.251	0.616					
UM2BL	L	162	10.401	0.712	124	-0.025	0.450	-0.618	0.538
	R	141	10.487	0.776					

Table 3. Descriptive statistics of raw measurements among Khow females and males after removal of outliers

		Females					Males		
Variable	n	$\bar{X}$	sd	cv	Variable	n	$\bar{X}$	sd	cv
LI1MD	91	4.616	0.362	0.079	LI1MD	92	4.659	0.336	0.072
LI1BL	93	5.349	0.571	0.107	LI1BL	90	5.660	0.540	0.095
LI2MD	94	5.217	0.319	0.061	LI2MD	95	5.266	0.381	0.072
LI2BL	98	5.654	0.524	0.093	LI2BL	97	5.893	0.492	0.083
LCMD	96	5.860	0.272	0.046	LCMD	96	6.117	0.326	0.053
LCBL	103	6.653	0.538	0.081	LCBL	98	7.058	0.699	0.099
LP3MD	104	6.138	0.472	0.077	LP3MD	100	6.139	0.368	0.060
LP3BL	102	7.015	0.542	0.077	LP3BL	101	7.276	0.499	0.069
LP4MD	102	6.168	0.562	0.091	LP4MD	96	6.085	0.475	0.078
LP4BL	102	7.577	0.537	0.071	LP4BL	94	7.795	0.534	0.069
LM1MD	102	9.991	0.571	0.057	LM1MD	102	10.450	0.605	0.058
LM1BL	100	9.716	0.453	0.047	LM1BL	97	9.997	0.449	0.045
LM2MD	90	9.484	0.576	0.061	LM2MD	92	9.804	0.606	0.062
LM2BL	99	9.495	0.558	0.059	LM2BL	93	9.727	0.550	0.057
UI1MD	94	7.676	0.465	0.061	UI1MD	85	7.900	0.338	0.043
UI1BL	87	6.654	0.509	0.077	UI1BL	94	6.984	0.611	0.087
UI2MD	99	5.934	0.633	0.107	UI2MD	96	6.029	0.562	0.093
UI2BL	92	5.750	0.673	0.117	UI2BL	94	5.963	0.680	0.114
UCMD	98	6.833	0.415	0.061	UCMD	99	7.073	0.395	0.056
UCBL	92	7.380	0.513	0.070	UCBL	97	7.754	0.728	0.094
UP3MD	105	5.901	0.448	0.076	UP3MD	103	5.996	0.393	0.066
UP3BL	103	8.250	0.596	0.072	UP3BL	104	8.483	0.543	0.064
UP4MD	100	5.584	0.424	0.076	UP4MD	101	5.656	0.371	0.066
UP4BL	102	8.382	0.579	0.069	UP4BL	103	8.543	0.530	0.062
UM1MD	102	9.270	0.530	0.057	UM1MD	96	9.488	0.494	0.052
UM1BL	103	10.434	0.567	0.054	UM1BL	100	10.909	0.524	0.048
UM2MD	70	8.999	0.593	0.066	UM2MD	81	9.284	0.529	0.057
UM2BL	87	10.125	0.620	0.061	UM2BL	92	10.721	0.706	0.066

Table 4. Distributional statistics among Khows by sex (significant p-values in bold)

	After Removal of Outliers										After EM Estimation							
	Females (n= 105)					Males (n= 104)					Females (n= 94)				Males (n= 84)			
Variable	n	G1	G2	W_{SW}[1]	p_{SW}[2]	n	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}
LI1MD	83	-0.222	0.053	0.981	0.268	81	0.375	-0.124	0.975	0.115	-0.238	0.406	0.983	0.253	0.026	0.421	0.980	0.229
LI1BL	87	0.014	-0.034	0.990	0.761	80	-0.244	0.013	0.982	0.327	-0.008	0.189	0.988	0.574	0.048	0.574	0.973	0.071
LI2MD	86	-0.032	-0.222	0.983	0.312	85	-0.043	-0.549	0.976	0.106	-0.037	0.025	0.984	0.296	-0.000	-0.193	0.978	0.169
LI2BL	90	-0.054	0.194	0.990	0.766	90	-0.250	0.030	0.983	0.270	-0.060	0.309	0.990	0.681	-0.227	0.149	0.981	0.250
LCMD	86	-0.070	-0.261	0.971	0.052	88	-0.046	-0.119	0.984	0.355	-0.037	-0.053	0.973	0.051	0.022	-0.070	0.984	0.369
LCBL	94	-0.020	-0.353	0.982	0.235	88	-0.105	-0.424	0.984	0.340	-0.020	-0.353	0.982	0.235	-0.041	-0.329	0.985	0.428
LP3MD	94	0.400	-0.504	0.967	**0.016**	91	-0.162	-0.510	0.982	0.240	-0.056	-0.534	0.979	0.146	-0.155	-0.440	0.983	0.350
LP3BL	94	0.175	-0.346	0.987	0.503	89	-0.016	0.390	0.981	0.207	0.175	-0.346	0.987	0.503	0.057	0.478	0.985	0.439
LP4MD	94	0.289	-0.586	0.975	0.069	86	0.045	-0.521	0.980	0.210	0.289	-0.586	0.975	0.069	0.099	-0.444	0.979	0.197
LP4BL	94	0.094	-0.661	0.982	0.231	86	-0.352	-0.226	0.981	0.255	0.094	-0.661	0.982	0.231	-0.397	-0.218	0.977	0.128
LM1MD	92	0.081	-0.425	0.989	0.657	91	0.139	-0.255	0.983	0.270	0.082	-0.368	0.990	0.674	0.124	-0.358	0.986	0.474
LM1BL	90	0.036	-0.315	0.991	0.793	88	-0.086	-0.226	0.983	0.323	0.038	-0.277	0.992	0.841	0.024	-0.113	0.983	0.332
LM2MD	84	0.258	-0.419	0.979	0.199	86	-0.186	-0.247	0.989	0.678	0.238	-0.245	0.984	0.288	-0.143	-0.166	0.991	0.808
LM2BL	90	-0.069	-0.032	0.991	0.816	85	-0.454	-0.304	0.966	**0.025**	-0.064	0.098	0.991	0.787	-0.406	-0.084	0.972	0.066
UI1MD	87	0.449	-0.201	0.971	**0.045**	80	-0.015	-0.426	0.979	0.198	0.027	-0.114	0.984	0.306	-0.009	-0.042	0.972	0.066
UI1BL	80	0.354	-0.378	0.977	0.159	84	-0.231	-0.235	0.987	0.534	0.413	0.036	0.975	0.074	-0.127	0.097	0.985	0.450
UI2MD	89	-0.022	-0.008	0.991	0.823	87	0.567	-0.188	0.959	**0.008**	0.009	0.091	0.990	0.741	0.006	-0.119	0.984	0.398
UI2BL	84	-0.342	0.075	0.979	0.198	85	0.176	-0.179	0.979	0.192	-0.382	0.401	0.978	0.112	0.250	0.127	0.977	0.129
UCMD	92	0.025	-0.123	0.983	0.288	89	-0.069	-0.631	0.978	0.137	0.046	-0.099	0.984	0.306	-0.155	-0.782	0.972	0.066
UCBL	87	-0.101	-0.246	0.988	0.637	88	-0.235	-0.461	0.983	0.316	-0.093	-0.052	0.988	0.563	-0.256	-0.357	0.983	0.350
UP3MD	94	-0.126	-0.344	0.988	0.573	92	-0.231	-0.052	0.987	0.519	-0.126	-0.344	0.988	0.573	-0.361	-0.098	0.977	0.134
UP3BL	94	0.026	-0.448	0.992	0.871	92	-0.211	-0.179	0.989	0.644	0.026	-0.448	0.992	0.871	-0.158	-0.176	0.990	0.776
UP4MD	94	0.161	-0.256	0.976	0.075	91	0.092	0.220	0.974	0.066	0.161	-0.256	0.976	0.075	0.017	0.226	0.975	0.095
UP4BL	94	-0.042	-0.430	0.990	0.726	91	-0.014	-0.435	0.990	0.731	-0.042	-0.430	0.990	0.726	-0.088	-0.368	0.991	0.803
UM1MD	92	0.339	-0.135	0.986	0.428	90	0.093	-0.051	0.984	0.320	0.306	-0.136	0.988	0.522	0.206	0.135	0.981	0.233
UM1BL	94	0.411	0.114	0.976	0.087	89	-0.156	-0.371	0.986	0.486	0.411	0.114	0.976	0.087	-0.070	-0.330	0.988	0.598
UM2MD	69	0.100	-0.383	0.981	0.389	77	-0.301	-0.503	0.960	**0.016**	0.031	0.462	0.973	**0.047**	-0.032	-0.013	0.972	0.062
UM2BL	85	0.019	-0.772	0.977	0.143	87	-0.225	0.016	0.988	0.634	0.020	-0.528	0.981	0.183	-0.258	0.179	0.988	0.606

1. W_{SW}= W statistic of the Shapiro-Wilks (1965) test for normality.
2. p_{SW}= p-value associated with the Shapiro-Wilks test for normality.

Table 5. Unrotated principal component loadings, eigenvalues and percentage of variance explained among Khows by sex based upon raw measurements after removal of outliers

		Component									
		1		2		3		4		5	
Tooth	Dim.	M	F	M	F	M	F	M	F	M	F
I1	MD	0.339	0.491	0.204	0.498	-0.354	0.155	0.219	0.251	-0.343	-0.313
	BL	0.236	0.546	0.638	-0.636	0.403	0.145	0.159	0.204	0.133	-0.055
LI2	MD	0.588	0.554	0.037	0.362	0.218	0.334	-0.003	-0.070	-0.336	-0.324
	BL	0.367	0.621	0.717	-0.624	0.265	0.026	0.258	0.062	-0.042	0.080
LC	MD	0.423	0.511	0.284	0.327	-0.497	0.596	-0.106	-0.240	-0.195	-0.070
	BL	0.213	0.567	0.569	-0.602	0.584	0.209	0.166	0.072	-0.316	0.116
LP3	MD	0.532	0.399	-0.377	0.400	-0.488	0.246	-0.070	-0.167	-0.295	0.435
	BL	0.545	0.754	-0.211	-0.231	0.212	-0.319	0.529	0.038	-0.105	0.050
LP4	MD	-0.078	0.590	-0.178	0.510	-0.592	-0.063	0.262	-0.157	0.007	0.122
	BL	0.158	0.637	-0.391	-0.146	0.103	-0.402	0.822	-0.134	0.015	0.169
LM1	MD	0.320	0.661	0.333	0.219	-0.129	-0.128	-0.184	0.204	0.652	-0.007
	BL	0.777	0.440	-0.091	0.123	0.108	-0.428	0.219	-0.511	0.101	-0.189
LM2	MD	0.422	0.701	0.272	0.215	-0.331	-0.356	0.001	0.128	0.643	0.083
	BL	0.703	0.650	0.336	0.011	0.160	-0.545	0.036	-0.067	0.070	-0.078
UI1	MD	0.617	0.504	0.056	0.134	-0.467	0.020	-0.234	0.150	-0.324	-0.723
	BL	0.536	0.465	-0.116	-0.288	0.303	0.088	-0.497	0.157	0.220	-0.125
UI2	MD	0.565	0.366	0.359	-0.071	-0.007	0.259	-0.338	0.586	-0.330	-0.214
	BL	0.282	0.584	-0.139	-0.369	0.257	0.450	-0.452	-0.089	0.333	-0.043
UC	MD	0.359	0.348	0.340	0.098	-0.060	0.506	-0.159	-0.369	-0.496	-0.159
	BL	0.480	0.552	-0.477	-0.411	0.354	0.234	-0.375	-0.317	-0.072	-0.097
UP3	MD	0.636	0.333	0.036	0.231	-0.103	0.458	-0.076	0.376	-0.050	0.559
	BL	0.382	0.679	-0.719	-0.188	0.266	0.122	-0.101	-0.035	-0.243	0.143
UP4	MD	0.538	0.628	0.083	0.265	-0.181	0.151	0.420	-0.096	0.368	0.250
	BL	0.636	0.775	-0.412	-0.106	0.150	-0.042	0.302	0.096	0.102	0.128
UM1	MD	0.658	0.582	0.091	0.544	-0.569	-0.066	0.018	-0.229	0.118	0.058
	BL	0.710	0.639	-0.341	-0.207	0.250	-0.080	-0.038	-0.374	0.170	-0.000
UM2	MD	0.324	0.474	-0.164	0.448	-0.108	-0.146	-0.138	0.561	0.229	0.020
	BL	0.755	0.556	-0.123	-0.030	0.077	-0.572	0.003	0.161	0.035	0.044
Eigenvalue		7.147	9.058	3.416	3.377	2.846	2.705	2.383	1.901	2.267	1.553
Pct. Var. Expl.		25.526	32.351	12.202	12.062	10.165	9.662	8.511	6.790	8.097	5.545

that, apart from an anomalously low loading for the MD dimension of LP4 among males, all other variables possess the uniformly high loadings indicative of a general size factor. The second component draws different distinctions for females and males. For females, the second component is a simple contrast between MD dimensions with higher loadings and BL dimensions with lower loadings, although this distinction is muted among the mandibular molars. For males, there is a double contrast by dimension in which mandibular anterior teeth and P3s receive higher loadings on their BL dimensions, while all other dental elements, except M2, receive higher loadings for the MD dimension. The third component also draws different distinctions for females and males. For females, this component draws a contrast by jaw and by dimension in which MD dimensions among mandibular teeth tend to receive higher loadings than their BL counterparts, while in the maxilla this pattern holds for all but the incisors. For males, the third component provides a dimensional contrast in which BL dimensions receive higher loadings than MD dimensions for each dental element. The fourth component draws a dimensional distinction by arcade. For males, with the sole exceptions of LI1 and UM2, mandibular teeth have higher loadings for their BL dimensions than for their MD dimensions, while this pattern is reversed among their

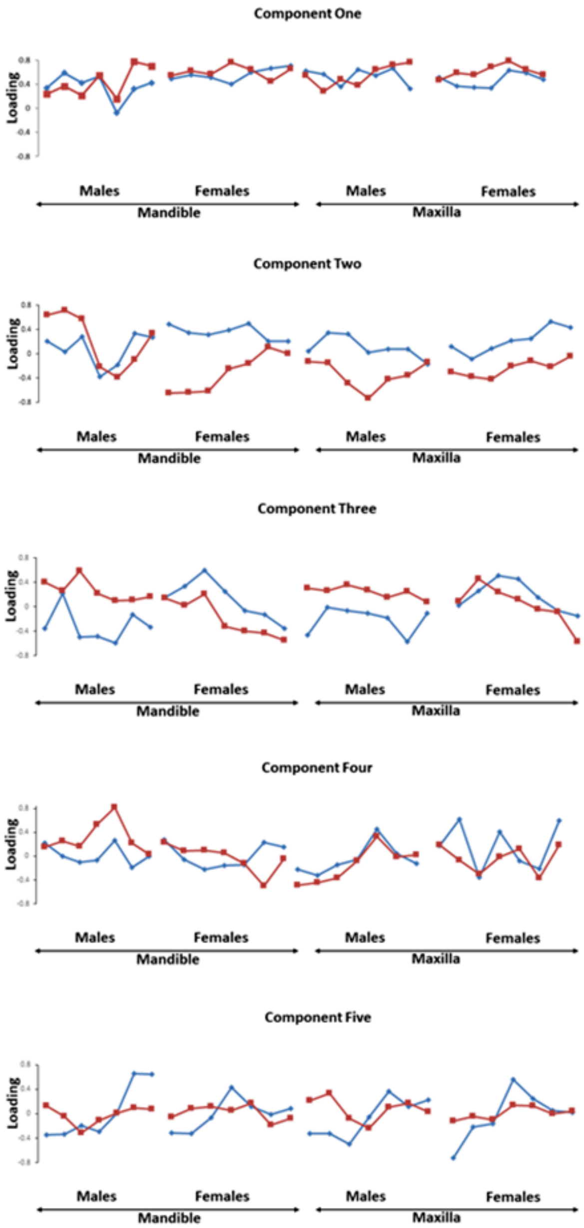

Figure 3. Unrotated component loadings for the first five principal components based on raw measurements from Table 5 among Khow males and females (accounting for 66.4% and 64.5% of the total variance, respectively), plotted to visualize the allocation of tooth size across the dentition as described in the text. Mesiodistal dimensions from I1 to M2 represented by blue diamonds, buccolingual dimensions by red squares.

maxillary isomeres. The same pattern holds for females, but with more exceptions. These include LI1, LM1, UC and UP4. The fifth component draws a dimensional distinction between anterior teeth and posterior teeth among both females and males in which anterior teeth receive higher loadings for their BL dimensions than for their MD dimensions, while the reverse is the case for the posterior teeth. For both females and males there is a pair of exceptions to this pattern; for females it is LP4 and UC, while for males it is LP3 and UM1.

Only 28.6% (30/105) females and 24.0% of Khowar males (25/104) are represented by a complete set of data for all 28 variables (Table 6). EM estimation allows for a great improvement in data completeness by individual, without being compromised by data not missing completely at random, yielding complete datasets for 89.5% (94/105) and 80.1% (84/104) of Khow females and males, respectively. An examination of the descriptive statistics for Khow females and males after EM estimation (Table 7) reveals that averages and standard deviations tend to be smaller after EM estimation relative to the original values. However, these differences are very small, accounting for only a 0.12% difference in variable average values among females and a 0.75% difference among males, coupled with average increases of 2.5% and 5.8% in standard deviations for Khow females and males

The data was submitted to principal components analysis after EM estimation by sex. Examination of the scree plots once again indicated retention of the first five components for both females and males and these components account for 65.0% and 61.8% of the variance for females and males, respectively (Table 8).

An examination of the unrotated variable loadings with EM estimated data (Fig. 4) shows that, as with the unestimated raw data, the first component is marked by the uniformly high and positive loadings indicative of a general size factor. With the sole exception of UM2 in males, the second component draws a distinction between MD and BL dimensions, with the former receiving higher loadings than the latter for teeth of both jaws. The third component draws different distinctions between Khow females and males. Among females a distinction is drawn between anterior and posterior teeth, in which anterior teeth receive higher loadings than posterior

Table 6. Improvement in percentage of complete datasets by individual by sample and by sex with EM estimation

		Base[1]	Complete[2]		-1		-2		-3		-4		MCAR[3]	
Group	Sex	n	n	%	n	%	n	%	n	%	n	%	n	%
KHO	F	105	30	28.6	52	49.5	70	66.7	83	79.1	94	89.5	94	89.5
KHO	M	104	25	24.0	50	48.1	71	68.3	86	82.7	92	88.5	84	80.1
BHI	F	105	50	47.6	66	62.9	81	77.1	92	87.6	98	93.3	69	65.7
BHI	M	103	68	66.0	83	80.6	94	91.3	100	97.1	100	97.1	90	87.4
CHU	F	86	43	50.0	60	69.8	69	80.2	79	91.9	81	94.2	68	79.1
CHU	M	109	58	53.2	82	75.2	94	86.2	103	94.5	107	98.2	103	94.5
GRS	F	99	38	38.4	73	73.7	85	85.9	93	93.9	97	97.9	89	89.9
GRS	M	108	55	50.9	81	75.0	90	83.3	97	89.8	105	97.2	101	93.5
GPD	F	78	21	26.9	47	60.3	63	80.8	66	84.6	70	89.7	70	89.7
GPD	M	96	32	33.3	60	62.5	78	81.3	87	90.6	92	93.8	68	70.8
PNT	F	82	33	40.2	54	65.9	69	84.2	72	87.8	76	92.7	60	73.2
PNT	M	94	46	48.9	72	76.6	88	93.6	90	95.7	93	98.9	93	98.9
RAJ	F	49	18	36.7	29	59.2	38	77.6	46	93.9	47	95.9	27	55.1
RAJ	M	141	70	49.7	110	78.0	123	87.2	134	95.0	137	97.2	127	90.1
TOTAL		1359	587	43.2	919	67.6	1113	81.9	1228	90.4	1287	94.7	1143	84.1

1. Base refers to the number of individuals in excess of 12 years of age represented by casts of teeth from both the maxillary and mandibular arcades and whose dentitions are not affected by excessive wear, pathological affliction, or extensive antemortem tooth loss.

2. Complete= All 28 metric variables are present, -1= One metric variable missing, -2= Two metric variables missing, -3= Three metric variables missing, -4= Four metric variables missing.

3. MCAR= Number of individuals remaining in the sample after those individuals who are missing data for variables identified as violating by Little's (1988) missing completely at random test have been eliminated from further consideration.

Table 7. Descriptive statistics of raw measurements among Khow females and males after EM estimation

	Females (n= 94)				Males (n= 84)						
Variable	$\bar{X}$	sd	cv	Variable	$\bar{X}$	sd	cv	F_L[1]	p	%sexd[2]	Rank[3]
LI1MD	4.610	0.353	0.077	LI1MD	4.638	0.316	0.068	1.251	0.299	0.607	24
LI1BL	5.338	0.558	0.105	LI1BL	5.640	0.498	0.068	1.256	0.290	5.658	1
LI2MD	5.217	0.309	0.059	LI2MD	5.222	0.346	0.066	0.799	0.292	0.096	27
LI2BL	5.655	0.525	0.093	LI2BL	5.820	0.540	0.093	0.943	0.782	2.918	10
LCMD	5.857	0.259	0.044	LCMD	6.067	0.344	0.057	0.563	**0.007**	3.585	5
LCBL	6.663	0.556	0.083	LCBL	6.994	0.682	0.098	0.664	0.055	4.968	3
LP3MD	6.147	0.459	0.075	LP3MD	6.096	0.360	0.059	1.633	**0.024**	-0.830	22
LP3BL	7.023	0.550	0.078	LP3BL	7.219	0.467	0.065	1.385	0.131	2.791	13
LP4MD	6.193	0.560	0.090	LP4MD	6.016	0.400	0.066	1.964	**0.002**	-2.858	12
LP4BL	7.583	0.554	0.073	LP4BL	7.698	0.514	0.067	1.163	0.483	1.517	21
LM1MD	10.009	0.548	0.055	LM1MD	10.363	0.580	0.056	0.891	0.585	3.537	8
LM1BL	9.719	0.439	0.045	LM1BL	9.937	0.449	0.045	0.958	0.840	2.243	17
LM2MD	9.505	0.536	0.056	LM2MD	9.725	0.571	0.059	0.882	0.556	2.315	16
LM2BL	9.501	0.533	0.056	LM2BL	9.675	0.455	0.047	1.372	0.143	1.831	19
UI1MD	7.677	0.444	0.058	UI1MD	7.898	0.322	0.041	1.903	**0.003**	2.879	11
UI1BL	6.663	0.472	0.071	UI1BL	6.899	0.557	0.081	0.718	0.120	3.542	7
UI2MD	5.935	0.596	0.100	UI2MD	5.969	0.479	0.080	1.553	**0.042**	0.573	25
UI2BL	5.765	0.649	0.113	UI2BL	5.904	0.596	0.101	1.185	0.431	2.411	15
UCMD	6.833	0.413	0.060	UCMD	7.014	0.360	0.051	1.323	0.195	2.649	14
UCBL	7.381	0.506	0.069	UCBL	7.710	0.717	0.093	0.499	**0.001**	4.457	4
UP3MD	5.888	0.451	0.077	UP3MD	5.920	0.350	0.059	1.657	**0.020**	0.543	26
UP3BL	8.233	0.598	0.073	UP3BL	8.410	0.532	0.063	1.265	0.275	2.150	18
UP4MD	5.591	0.436	0.078	UP4MD	5.589	0.360	0.064	1.475	0.075	-0.036	28
UP4BL	8.410	0.579	0.069	UP4BL	8.479	0.503	0.059	1.323	0.194	0.820	23
UM1MD	9.278	0.503	0.054	UM1MD	9.446	0.497	0.053	1.026	0.907	1.811	20
UM1BL	10.447	0.564	0.054	UM1BL	10.819	0.492	0.045	1.312	0.208	3.561	6
UM2MD	9.010	0.514	0.057	UM2MD	9.280	0.492	0.053	1.094	0.678	2.997	9
UM2BL	10.132	0.594	0.059	UM2BL	10.663	0.684	0.064	0.754	0.186	5.241	2

1. F_L is Levene's (1960) test for homogeneity of variance (significant differences in bold).

2. %sexd is the percentage of sex dimorphism calculated as $100\left[\frac{\bar{X}_m}{\bar{X}_f}-1\right]$ in accordance with the procedure of Garn et al. (1964).

3. Ranking is based on the absolute value of the %sexd.

Table 8. Unrotated principal component loadings, eigenvalues and percentage of variance explained among Khows by sex based upon raw measurements after EM estimation

		Component									
		1		2		3		4		5	
Tooth	Dim.	M	F	M	F	M	F	M	F	M	F
I1	MD	0.468	0.569	0.469	0.317	-0.114	0.157	0.229	0.402	0.145	0.063
	BL	0.350	0.509	-0.357	-0.458	0.087	0.223	0.408	0.396	0.391	-0.069
LI2	MD	0.462	0.476	0.333	0.409	-0.330	0.187	0.330	0.434	0.317	0.066
	BL	0.596	0.568	-0.415	-0.473	0.190	0.159	0.199	0.338	0.391	-0.329
LC	MD	0.619	0.429	0.226	0.382	0.036	0.556	0.110	0.125	-0.002	-0.185
	BL	0.583	0.564	-0.530	-0.574	0.156	0.254	0.335	0.173	0.110	-0.146
LP3	MD	0.613	0.599	0.377	0.361	0.026	0.110	-0.210	-0.109	-0.076	-0.318
	BL	0.642	0.715	-0.330	-0.280	0.294	-0.128	-0.236	-0.003	0.202	-0.236
LP4	MD	0.283	0.600	0.214	0.410	0.521	-0.174	-0.157	0.043	-0.131	-0.378
	BL	0.657	0.639	-0.146	-0.153	0.381	-0.192	-0.327	-0.186	0.085	-0.469
LM1	MD	0.556	0.670	0.342	0.260	0.122	-0.282	0.315	0.080	-0.264	0.205
	BL	0.762	0.682	-0.038	-0.015	0.131	-0.349	-0.005	-0.016	0.098	0.003
LM2	MD	0.599	0.619	0.162	0.191	0.386	-0.436	0.093	0.109	-0.431	-0.067
	BL	0.700	0.663	-0.099	-0.129	0.343	-0.457	0.232	0.086	-0.049	0.088
UI1	MD	0.278	0.581	0.457	0.051	-0.341	0.024	0.157	0.347	0.277	0.226
	BL	0.502	0.578	-0.264	-0.358	-0.445	0.048	0.261	-0.113	-0.116	0.277
UI2	MD	0.453	0.506	0.418	0.142	-0.147	0.319	0.120	0.096	-0.060	0.483
	BL	0.376	0.541	-0.187	-0.246	-0.401	0.274	0.093	-0.042	-0.321	0.213
UC	MD	0.591	0.545	0.004	0.247	-0.005	0.302	0.108	-0.350	0.091	-0.043
	BL	0.525	0.668	-0.371	-0.146	-0.398	0.285	-0.077	-0.088	-0.199	0.048
UP3	MD	0.573	0.569	0.237	0.238	-0.143	0.251	-0.301	-0.415	0.269	0.045
	BL	0.575	0.682	-0.278	-0.311	-0.443	0.121	-0.412	-0.329	0.039	0.045
UP4	MD	0.265	0.591	0.228	0.313	0.167	0.208	-0.481	-0.298	0.357	0.013
	BL	0.561	0.761	-0.058	-0.206	-0.269	-0.008	-0.488	-0.302	0.038	0.074
UM1	MD	0.643	0.608	0.387	0.430	0.126	-0.191	0.076	-0.122	-0.026	0.060
	BL	0.681	0.690	0.020	-0.268	-0.231	-0.252	-0.272	-0.140	-0.132	0.144
UM2	MD	0.547	0.408	-0.142	0.312	0.095	-0.148	-0.074	0.272	-0.437	-0.044
	BL	0.703	0.545	-0.161	-0.054	-0.109	-0.384	0.065	0.050	-0.216	0.273
Eigenvalue		8.687	9.996	2.446	2.642	2.055	1.945	1.823	1.587	1.481	1.272
Pct. Var. Expl.		31.026	35.701	8.737	9.436	7.340	6.948	6.510	5.667	5.288	4.544

teeth for both MD and BL dimensions. Among males this component draws a distinction by arcade in which mandibular teeth receive higher loadings than their maxillary isomeres for both MD and BL dimensions. The fourth component distinguishes premolars from all other teeth, regardless of dimension. This distinction is more clearly drawn among males than females. The fifth component also draws different distinctions among Khow females and males. Among females, this component draws a distinction by arcade, in which mandibular teeth tend to receive lower loadings than their maxillary isomeres, regardless of dimension. The only exception is LM1MD. Among males, the fifth component features a dimensional reversal by jaw, in which BL dimensions receive higher loadings than MD dimensions by dental element in the mandible, while the opposite is the case in the maxilla (except for UM2). This component also evinces a general anterior to posterior decline in loadings among mandibular teeth for both MD and BL dimensions.

An examination of Table 7 indicates that sex dimorphism in tooth size ranges from a high of 5.7% for the BL dimension of LI2 to a low of -0.036 for the MD dimension of UP4. Average absolute sex dimorphism by dimension across the 28 variables is 2.48%. Male averages exceed those of females for 25 of the 28 dimensions,

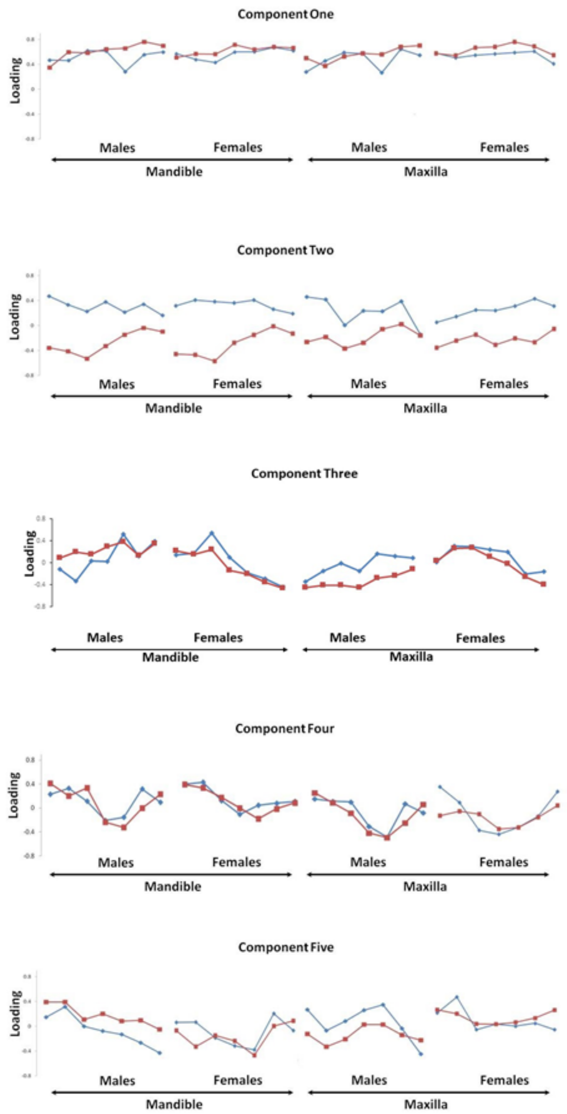

Figure 4. Unrotated component loadings for the first five principal components based on raw measurements after EM estimation from Table 8 among Khow males and females (accounting for 65.0% and 61.8% of the total variance, respectively), plotted to visualize the allocation of tooth size across the dentition as described in the text. Mesiodistal dimensions from I1 to M2 represented by blue diamonds, buccolingual dimensions by red squares.

while three dimensions, all MD dimensions of the premolars (LP3MD, LP4MD, UP4MD), are larger on average among Khow females. The four most highly dimorphic dimensions are LI1BL, UM2BL, LCBL, and UCBL.

Levene's test was used to determine whether Khow females and males are marked by homogeneity of variance for the 28 odontometric variables. Results identify one-fourth as exhibiting significant heterogeneity by sex. Three occur among mandibular teeth (LCMD, LP3MD, LP4MD) and four occur among maxillary teeth (UI1MD, UI2MD, UCBL, UP3MD). All but one (UCBL) involve the mesiodistal dimension and for all but one (LCMD) females exhibit significantly greater variation than males.

Complete and stepwise discriminant function analyses were conducted on sex-specific covariance matrices to determine the strength of sex differences in crown size among the Khow as well as their ability to distinguish females from males. Complete discriminant function analysis correctly identified 86% of females and 79% of males, for an overall classification accuracy of 83% (Table 9). Jackknifing lowered classification accuracies by 10% among females (76%) and 6% (73%) among males, resulting in a reduction of overall classification accuracy of Khow females and males to 74%. Backwards stepwise discriminant function analysis resulted in the elimination of 18 variables. Overall original classification accuracies are somewhat lower (79%) than with complete discriminant function analysis (83%), with females being correctly classified in 83% of cases and males in 75%. Jackknifed classifications with stepwise discriminant function analysis yield less overall decline (-3%) in classification accuracy. This is reflected by less reduction in classification accuracy for both females (-4%, 79%) and males (-1%, 74%). Consequently, the overall accuracy of the jackknifed stepwise model is slightly higher (76%) than that yielded by the jackknifed complete model (74%).

Tooth crown dimensions were geometrically scaled by individual to remove the effects of gross size. The resulting geometrically scaled values were submitted to principal component analysis. As with unscaled dimensions, scree plots indicated that the first five components ought to be retained. Together, these first five components account for 44.5% and 41.8% of the total variance among Khow females and males, respectively (Table 10). Loadings by component, dimension and jaw for Khow males and females are provided in Fig. 5.

An examination of the loadings for the first

Table 9. Classification coefficients and assignment accuracies of discriminant function analysis of Khow females and males from EM estimated data

	Complete		Stepwise	
Variable	Unstd.	Std.	Unstd.	Std.
LI1MD	0.536	0.180	---	---
LI1BL	-0.550	-0.292	-0.369	-0.196
LI2MD	0.758	0.248	1.122	0.367
LI2BL	0.325	0.173	---	---
LCMD	-1.680	-0.507	-1.971	-0.565
LCBL	-0.011	-0.007	---	---
LP3MD	0.943	0.392	0.892	0.371
LP3BL	-0.169	-0.087	---	---
LP4MD	0.884	0.434	0.890	0.437
LP4BL	-0.311	-0.167	---	---
LM1MD	-0.672	-0.379	-0.621	-0.350
LM1BL	-0.271	-0.120	---	---
LM2MD	-0.197	-0.109	---	---
LM2BL	0.739	0.368	---	---
UI1MD	-1.134	-0.443	-1.062	-0.415
UI1BL	0.083	0.043	---	---
UI2MD	0.493	0.268	0.626	0.340
UI2BL	0.032	0.020	---	---
UCMD	-0.098	-0.038	---	---
UCBL	-0.015	-0.009	---	---
UP3MD	-0.493	-0.200	---	---
UP3BL	0.054	0.030	---	---
UP4MD	-0.061	-0.024	---	---
UP4BL	0.660	0.359	---	---
UM1MD	0.323	0.161	---	---
UM1BL	-0.503	-0.267	---	---
UM2MD	-0.516	-0.260	-0.440	-0.440
UM2BL	-0.671	-0.428	-0.652	-0.416
Constant	18.675		18.656	
	$\bar{X}$		$\bar{X}$	
Females	0.828		0.764	
Males	-0.927		-0.855	

Classification Matrix
Complete Analysis - Original

	Females	Males	%Correct
Females	81	13	86
Males	18	66	79
Total	99	79	83

Classification Matrix
Complete Analysis - Jackknifed

	Females	Males	%Correct
Females	71	23	76
Males	23	61	73
Total	94	84	74

Classification Matrix
Stepwise Analysis - Original

	Females	Males	%Correct
Females	78	16	83
Males	21	63	75
Total	99	79	79

Classification Matrix
Stepwise Analysis - Jackknifed

	Females	Males	%Correct
Females	74	20	79
Males	22	62	74
Total	96	82	76

component for both females and males reveals a distinction by dimension in which dental elements receive higher loadings for their MD dimension than for their BL dimension, especially among mandibular non-molar teeth. The second component draws different distinctions among females and males. Among females, apart from UI1, there is a general increase in dimensional loadings from I1 to M2 with BL dimensions receiving higher loadings than MD dimensions among teeth of both jaws. For males there is a double contrast by region and by arcade. Among teeth of both jaws anterior teeth tend to receive lower loadings than posterior teeth; however, when considered by dimension, BL dimensions receive higher loadings than MD dimensions by dental element in the mandible, but in the maxilla this dimensional relationship is reversed. The third component involves the premolars. For females, premolars tend to receive the highest loadings, with P3 showing somewhat higher loadings for the MD dimension and P4 showing higher loadings for the BL dimension. For males the premolars of both jaws receive the lowest loadings, especially for the BL dimension. The fourth component also differs between females and males. For females, mandibular teeth are marked by a reversal of loadings by dimension in which anterior teeth tend to receive higher MD loadings than BL dimensions, while the opposite is the case among the posterior teeth. In addition, apart from the BL dimensions of the molars, maxillary teeth show a general decline in loadings from the front to the back of the arcade. For males the fourth component

Table 10. Unrotated principal component loadings, eigenvalues and percentage of variance explained among Khows by sex based upon geometrically scaled measurements after EM estimation

		Component									
		1		2		3		4		5	
Tooth	Dim.	M	F	M	F	M	F	M	F	M	F
I1	MD	0.505	0.335	-0.098	-0.246	0.266	-0.377	-0.191	-0.015	0.028	-0.086
	BL	-0.400	-0.569	0.116	-0.113	0.407	-0.489	-0.354	-0.131	0.041	-0.176
LI2	MD	0.330	0.505	-0.285	-0.187	0.411	-0.425	-0.293	0.109	0.304	0.104
	BL	-0.588	-0.611	0.316	0.001	0.142	-0.427	-0.407	-0.363	0.153	0.109
LC	MD	0.331	0.440	0.135	-0.369	0.047	-0.232	0.372	0.114	0.609	0.511
	BL	-0.702	-0.709	0.304	-0.007	0.280	-0.302	0.058	-0.018	0.192	0.184
LP3	MD	0.485	0.373	-0.038	-0.249	-0.237	0.187	0.075	-0.412	-0.067	0.129
	BL	-0.357	-0.388	0.413	0.341	-0.489	0.065	-0.225	-0.352	0.072	0.119
LP4	MD	0.304	0.444	0.417	0.034	-0.175	0.074	-0.148	-0.547	-0.430	0.049
	BL	-0.146	-0.150	0.479	0.350	-0.558	0.288	-0.089	-0.520	-0.019	0.335
LM1	MD	0.449	0.507	0.197	0.306	0.369	-0.072	0.201	0.134	-0.228	-0.239
	BL	0.063	0.274	0.303	0.610	-0.147	0.011	-0.176	0.137	0.032	0.278
LM2	MD	0.278	0.416	0.485	0.476	0.045	-0.021	0.488	-0.167	-0.310	-0.159
	BL	-0.011	0.100	0.591	0.685	0.130	-0.040	0.275	0.053	0.208	-0.151
UI1	MD	0.513	0.210	-0.247	0.122	0.152	-0.364	-0.278	0.365	0.048	0.106
	BL	-0.329	-0.315	-0.434	0.177	0.345	0.055	0.096	0.482	-0.069	0.074
UI2	MD	0.408	0.039	-0.180	-0.445	0.226	-0.088	0.092	0.315	0.027	-0.487
	BL	-0.249	-0.389	-0.459	-0.200	0.216	-0.006	0.014	0.187	-0.588	-0.066
UC	MD	0.099	0.296	0.121	-0.236	0.025	0.302	0.212	0.264	0.577	0.579
	BL	-0.451	-0.225	-0.383	-0.207	-0.102	0.093	0.291	0.307	-0.003	0.328
UP3	MD	0.339	0.153	-0.254	-0.444	-0.287	0.567	-0.332	-0.038	0.106	-0.212
	BL	-0.270	-0.483	-0.551	-0.019	-0.510	0.526	-0.011	0.126	0.068	-0.014
UP4	MD	0.362	0.267	0.064	-0.429	-0.394	0.391	-0.366	-0.083	-0.030	-0.155
	BL	0.006	-0.378	-0.401	0.067	-0.571	0.603	0.080	0.058	0.070	-0.228
UM1	MD	0.537	0.620	0.226	0.184	0.082	0.181	-0.031	0.098	-0.053	0.116
	BL	0.197	-0.126	-0.282	0.570	-0.367	0.190	0.426	0.371	0.251	0.155
UM2	MD	-0.008	0.423	0.143	0.072	-0.155	-0.168	0.318	-0.169	-0.445	-0.291
	BL	-0.259	0.141	-0.106	0.450	0.061	0.008	0.538	0.184	-0.016	-0.360
Eigenvalue		3.755	4.291	2.954	3.045	2.563	2.478	2.075	2.075	1.887	1.759
Pct. Var. Expl.		13.411	15.326	10.549	10.874	9.153	8.849	7.411	7.411	6.738	6.282

yields a dimensional reversal in loadings between mandibular and maxillary isomeres in which loadings tend to be higher for MD dimensions among mandibular teeth, while BL loadings tend to be higher among maxillary teeth. Apart from the maxillary teeth among females, the fifth component draws a dimensional contrast between anterior and posterior teeth in which anterior teeth of both jaws receive equivalent or higher loadings than their BL dimensions, while the reverse is the case for posterior teeth. For females, the fifth component also draws a sharp contrast between I2 and C in which both dimensions of the former receive much lower loadings than the latter.

Phase two: Odontometric variation among living South Asian females and males

Paired-samples t-tests indicate few significant differences between antimeres among the three ethnic groups from Gujarat (Lukacs & Hemphill 1993) and the three ethnic groups from Andhra Pradesh (Hemphill *et al.* 1992). Therefore measurements of the left side were used when available, but in cases where the left side member was either missing or not measureable the measurement of its right side antimere was substituted. Descriptive statistics for the 28

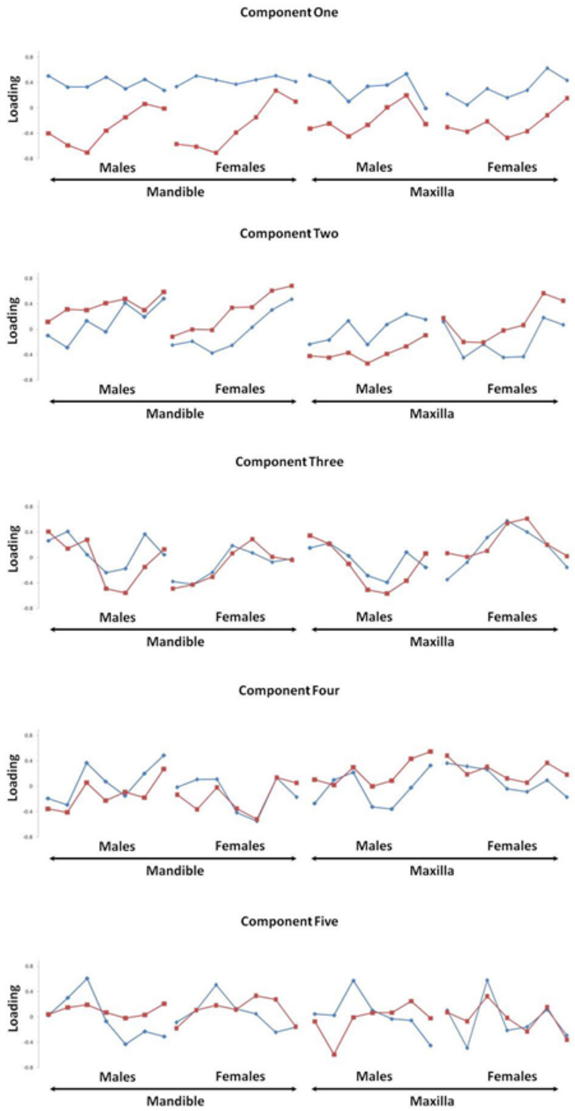

Figure 5. Unrotated component loadings for the first five principal components based on geometrically scaled measurements after EM estimation from Table 10 among Khow males and females (accounting for 44.5% and 41.8% of the total variance, respectively), plotted to visualize the allocation of tooth size across the dentition as described in the text. Mesiodistal dimensions from I1 to M2 represented by blue diamonds, buccolingual dimensions by red squares.

variables among females and males of the six comparative ethnic groups after elimination of outliers and cases missing more than four variables are provided in Table 11. Distributional statistics are provided in Table 12. Inspection of the latter table reveals that statistically significant departures from normality (19/336) are rare (5.7%). Males are more often affected by departures from normality (11/19= 57.9%) than females (8/19= 42.1%), mandibular teeth (12/19= 61.2%) are more often affected than maxillary teeth (7/19= 38.8%), and mesiodistal dimensions are much more often affected (15/19= 78.9%) than buccolingual dimensions (4/19= 21.1%). Overall, Pakanati Reddis are the ethnic group with the greatest number of departures from normality (6), while Vaghela Rajputs are least affected (1). Perhaps most reassuringly, there is no systemic pattern in the departures from normality by individual measurement. Two of the 12 sex-specific samples exhibited significant departures from normality for four measurements (LI1MD, LP4MD, LM2MD, UI1MD), but all other occurrences were single events.

Overall, the proportion of individuals with a complete set of 28 measurements is higher among the six peninsular Indian samples than among the Khow (26.3%), ranging from a low of 30.5% among Gompadhompti Madigas to a high of 56.7% among Bhils. With EM estimation there is a great improvement in the proportion of individuals with compete data sets, even after cases that yield singular matrices or violate Little's (1988) test for multivariate data missing completely at random are eliminated (Table 6). The greatest proportion of individuals with complete data sets after EM estimation occurs among Garasias (91.8%), the lowest occurs among Bhils (76.4%), although Vaghela Rajput females are especially poorly represented (55.1%).

Examination of the descriptive statistics for females and males after EM estimation (Table 13) reveals that EM averages and standard deviations, like those among Khow females and males, tend to be smaller than the original values. These differences are very small, accounting for only a 0.74% difference in variable average values among females and a 0.26% difference among males, coupled with average increases of 1.4% and 1.5% in standard deviations for females and males, respectively. An examination of the distributional statistics for the six comparative groups after EM estimation by sex reveals that the estimation process reduced the number of variables whose distribution departs from normality significantly

Table 11. Descriptive statistics for comparative living samples by sex after elimination of outliers and cases missing more than four variables

							Bhils								**Chenchus**		
	Females (n= 98)				Males (n= 102)				Females (n= 81)				Males (n= 107)			
Variable	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv
LI1MD	92	5.275	0.335	0.064	101	5.363	0.357	0.067	76	5.062	0.388	0.077	100	5.059	0.377	0.074
LI1BL	83	5.655	0.387	0.068	88	5.969	0.408	0.068	69	5.697	0.464	0.081	96	6.103	0.562	0.092
LI2MD	97	5.823	0.395	0.068	99	5.927	0.376	0.063	81	5.665	0.433	0.076	106	5.731	0.406	0.071
LI2BL	88	6.048	0.390	0.065	94	6.302	0.470	0.075	76	6.083	0.499	0.082	101	6.342	0.433	0.068
LCMD	98	6.411	0.365	0.057	101	6.882	0.364	0.053	79	6.280	0.417	0.066	102	6.639	0.412	0.062
LCBL	89	6.822	0.500	0.073	96	7.195	0.619	0.086	79	6.827	0.616	0.090	102	7.370	0.663	0.090
LP3MD	95	6.818	0.363	0.053	101	7.031	0.455	0.065	81	6.500	0.517	0.080	106	6.799	0.470	0.069
LP3BL	97	7.636	0.497	0.065	102	7.809	0.539	0.069	78	7.637	0.556	0.073	107	8.078	0.592	0.073
LP4MD	98	6.990	0.486	0.070	99	7.072	0.441	0.062	79	6.406	0.444	0.069	107	6.573	0.503	0.077
LP4BL	94	8.110	0.459	0.057	100	8.227	0.554	0.067	80	8.038	0.665	0.083	107	8.433	0.634	0.075
LM1MD	98	10.859	0.642	0.059	101	11.216	0.623	0.056	80	10.740	0.555	0.052	106	10.999	0.610	0.055
LM1BL	97	10.443	0.419	0.040	101	10.768	0.482	0.045	81	10.187	0.506	0.050	105	10.545	0.538	0.051
LM2MD	93	10.092	0.543	0.054	98	10.360	0.523	0.050	75	9.361	0.590	0.063	101	9.759	0.702	0.072
LM2BL	98	9.945	0.517	0.052	97	10.309	0.583	0.057	79	9.759	0.590	0.060	103	10.087	0.575	0.057
UI1MD	93	8.205	0.522	0.064	101	8.549	0.482	0.056	78	8.123	0.512	0.063	103	8.383	0.525	0.063
UI1BL	97	6.800	0.494	0.073	102	6.925	0.520	0.075	78	6.850	0.526	0.077	102	7.187	0.574	0.080
UI2MD	96	6.461	0.555	0.086	98	6.714	0.479	0.071	80	6.405	0.791	0.124	105	6.626	0.655	0.099
UI2BL	90	5.751	0.415	0.072	100	5.981	0.487	0.081	80	5.834	0.591	0.101	100	6.157	0.562	0.091
UCMD	96	7.381	0.381	0.052	101	7.780	0.423	0.054	80	7.157	0.390	0.054	105	7.457	0.440	0.059
UCBL	98	7.609	0.516	0.068	102	7.978	0.565	0.071	80	7.512	0.583	0.078	103	8.079	0.668	0.083
UP3MD	97	6.861	0.397	0.058	101	7.010	0.409	0.058	81	6.569	0.385	0.059	107	6.765	0.428	0.063
UP3BL	96	9.097	0.464	0.051	101	9.348	0.499	0.053	78	9.033	0.465	0.052	106	9.458	0.659	0.070
UP4MD	94	6.416	0.338	0.053	100	6.498	0.418	0.064	80	5.992	0.442	0.074	105	6.124	0.444	0.072
UP4BL	97	8.966	0.508	0.057	101	9.258	0.538	0.058	77	8.717	0.589	0.068	105	9.126	0.615	0.067
UM1MD	98	10.050	0.465	0.046	101	10.354	0.512	0.049	81	10.120	0.549	0.054	106	10.310	0.615	0.060
UM1BL	98	11.003	0.485	0.044	100	11.475	0.508	0.044	80	10.971	0.465	0.042	107	11.415	0.642	0.056
UM2MD	81	9.247	0.536	0.058	98	9.576	0.665	0.069	72	9.369	0.628	0.067	99	9.541	0.655	0.069
UM2BL	93	10.932	0.593	0.054	101	11.488	0.634	0.055	77	10.489	0.609	0.058	103	11.081	0.685	0.062

							Garasias								**Gompadhompti Madigas**		
	Females (n= 97)				Males (n= 105)				Females (n= 70)				Males (n= 90)			
Variable	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv
LI1MD	95	5.198	0.391	0.075	98	5.294	0.347	0.066	62	5.102	0.361	0.071	80	5.149	0.311	0.060
LI1BL	90	5.731	0.588	0.103	98	5.896	0.541	0.092	54	5.622	0.510	0.091	69	5.839	0.587	0.101
LI2MD	97	5.767	0.405	0.070	103	5.941	0.413	0.069	65	5.763	0.358	0.062	85	5.846	0.369	0.063
LI2BL	97	5.993	0.570	0.095	98	6.201	0.519	0.084	62	5.965	0.448	0.075	78	6.149	0.597	0.097
LCMD	96	6.382	0.366	0.057	104	6.816	0.441	0.065	70	6.384	0.480	0.075	90	6.664	0.410	0.062
LCBL	96	6.861	0.602	0.088	102	7.171	0.652	0.091	69	6.862	0.638	0.093	89	7.178	0.779	0.108
LP3MD	94	6.767	0.374	0.055	104	6.963	0.524	0.075	70	6.709	0.355	0.053	88	6.893	0.385	0.056
LP3BL	97	7.713	0.523	0.068	105	7.989	0.594	0.074	67	7.575	0.386	0.051	89	7.979	0.559	0.070
LP4MD	96	6.836	0.506	0.074	104	7.004	0.548	0.078	69	6.706	0.373	0.056	85	6.940	0.361	0.052
LP4BL	96	8.295	0.566	0.068	105	8.365	0.630	0.075	67	8.048	0.376	0.047	90	8.371	0.582	0.070
LM1MD	96	10.543	0.490	0.047	104	10.893	0.535	0.049	70	10.696	0.480	0.045	89	11.052	0.534	0.048
LM1BL	95	10.480	0.501	0.048	105	10.734	0.538	0.050	70	9.911	0.471	0.047	89	10.289	0.508	0.049
LM2MD	85	9.774	0.643	0.066	93	10.153	0.564	0.056	65	9.774	0.521	0.053	88	10.019	0.629	0.063
LM2BL	95	10.086	0.580	0.058	100	10.514	0.567	0.054	68	9.651	0.552	0.057	87	10.105	0.618	0.061
UI1MD	95	8.342	0.471	0.056	100	8.506	0.546	0.064	65	8.154	0.439	0.054	87	8.323	0.467	0.056
UI1BL	96	6.875	0.558	0.081	105	7.059	0.617	0.087	63	6.706	0.440	0.066	81	7.068	0.462	0.065
UI2MD	88	6.456	0.488	0.076	102	6.760	0.571	0.084	66	6.502	0.493	0.076	84	6.751	0.436	0.065
UI2BL	96	5.939	0.673	0.113	103	6.090	0.661	0.109	66	5.855	0.570	0.097	89	6.249	0.600	0.096
UCMD	97	7.295	0.427	0.059	105	7.670	0.466	0.061	70	7.199	0.435	0.060	89	7.533	0.436	0.058
UCBL	96	7.716	0.617	0.080	102	8.107	0.694	0.086	70	7.551	0.516	0.068	89	8.031	0.813	0.101
UP3MD	94	6.761	0.390	0.058	104	6.935	0.513	0.074	70	6.684	0.422	0.063	90	6.886	0.435	0.063
UP3BL	96	9.112	0.530	0.058	105	9.353	0.580	0.062	69	8.839	0.437	0.049	89	9.315	0.539	0.058
UP4MD	97	6.261	0.505	0.081	103	6.425	0.550	0.086	69	6.307	0.405	0.064	88	6.491	0.436	0.067
UP4BL	95	9.015	0.544	0.060	103	9.293	0.585	0.063	69	8.774	0.426	0.048	89	9.227	0.546	0.059
UM1MD	96	10.211	0.552	0.054	105	10.451	0.628	0.060	68	9.975	0.393	0.039	90	10.252	0.454	0.044
UM1BL	97	10.932	0.612	0.056	103	11.327	0.519	0.046	69	10.654	0.501	0.047	90	11.131	0.559	0.050
UM2MD	60	9.112	0.556	0.061	81	9.340	0.566	0.061	66	9.556	0.520	0.054	77	9.931	0.556	0.056
UM2BL	89	10.785	0.670	0.062	99	11.308	0.704	0.062	69	10.457	0.639	0.061	89	11.151	0.697	0.063

	Pakanati Reddis								Vaghela Rajputs							
	Females (n= 76)				Males (n= 93)				Females (n= 47)				Males (n= 141)			
Variable	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv	n	$\bar{X}$	sd	cv
LI1MD	70	5.140	0.387	0.075	86	5.229	0.408	0.078	46	5.185	0.384	0.074	137	5.304	0.398	0.075
LI1BL	68	5.765	0.414	0.072	85	5.929	0.450	0.076	45	5.753	0.472	0.082	130	5.954	0.421	0.071
LI2MD	73	5.716	0.446	0.078	90	5.858	0.405	0.069	44	5.707	0.255	0.045	139	5.862	0.423	0.072
LI2BL	73	6.095	0.486	0.080	90	6.208	0.478	0.077	47	6.143	0.401	0.065	130	6.207	0.455	0.073
LCMD	76	6.363	0.444	0.070	93	6.655	0.392	0.059	47	6.419	0.354	0.055	139	6.841	0.442	0.065
LCBL	72	6.865	0.572	0.083	86	7.210	0.619	0.086	44	6.707	0.513	0.077	140	6.946	0.779	0.112
LP3MD	76	6.658	0.443	0.067	93	6.846	0.394	0.058	45	6.689	0.422	0.063	140	6.791	0.425	0.063
LP3BL	76	7.533	0.561	0.074	90	7.733	0.536	0.069	47	7.596	0.464	0.061	136	7.838	0.552	0.070
LP4MD	76	6.728	0.532	0.079	87	6.868	0.324	0.047	47	6.674	0.543	0.081	138	6.887	0.491	0.071
LP4BL	76	8.049	0.572	0.071	92	8.161	0.539	0.066	47	8.100	0.511	0.063	135	8.244	0.531	0.064
LM1MD	76	10.580	0.593	0.056	93	11.078	0.586	0.053	47	10.511	0.665	0.063	138	11.033	0.555	0.050
LM1BL	74	10.154	0.525	0.052	92	10.340	0.558	0.054	47	10.217	0.438	0.043	139	10.581	0.512	0.048
LM2MD	72	9.626	0.588	0.061	90	10.032	0.517	0.051	40	9.495	0.640	0.067	128	9.885	0.760	0.077
LM2BL	75	9.785	0.684	0.070	91	10.082	0.573	0.057	46	9.743	0.532	0.055	134	10.228	0.634	0.062
UI1MD	70	8.344	0.569	0.068	90	8.471	0.563	0.066	44	8.311	0.483	0.058	135	8.624	0.506	0.059
UI1BL	66	6.889	0.583	0.085	89	7.145	0.484	0.068	47	6.798	0.537	0.079	140	7.061	0.519	0.073
UI2MD	72	6.718	0.538	0.080	88	6.748	0.556	0.082	46	6.476	0.437	0.067	139	6.650	0.499	0.075
UI2BL	70	6.034	0.455	0.075	93	6.287	0.579	0.092	47	5.947	0.516	0.087	138	6.188	0.589	0.095
UCMD	75	7.291	0.497	0.068	89	7.547	0.418	0.055	45	7.309	0.409	0.056	137	7.621	0.466	0.061
UCBL	72	7.572	0.588	0.078	93	7.981	0.682	0.085	40	7.458	0.371	0.050	140	7.875	0.808	0.103
UP3MD	74	6.672	0.405	0.061	89	6.854	0.325	0.047	45	6.542	0.396	0.061	140	6.762	0.451	0.067
UP3BL	76	8.816	0.601	0.068	93	9.170	0.518	0.057	47	8.874	0.510	0.057	135	9.187	0.520	0.057
UP4MD	76	6.330	0.467	0.074	90	6.463	0.415	0.064	46	6.215	0.454	0.073	141	6.450	0.459	0.071
UP4BL	76	8.758	0.644	0.073	92	9.067	0.618	0.068	47	8.760	0.589	0.067	139	9.134	0.592	0.065
UM1MD	74	10.046	0.415	0.041	93	10.258	0.528	0.051	47	9.979	0.561	0.056	136	10.355	0.527	0.051
UM1BL	75	10.767	0.601	0.056	91	11.077	0.574	0.052	47	10.817	0.547	0.051	138	11.343	0.529	0.047
UM2MD	67	9.430	0.691	0.073	87	9.813	0.578	0.059	29	9.100	0.696	0.076	110	9.705	0.838	0.086
UM2BL	76	10.500	0.807	0.077	93	11.039	0.726	0.066	43	10.449	0.646	0.062	134	11.021	0.856	0.078

Table 12. Distributional statistics for all comparative living samples by sex after elimination of outliers and cases missing more than four variables[1]

	Bhils										Chenchus									
	Females (n= 98)					Males (n= 102)					Females (n= 81)					Males (n= 107)				
Variable	n	G1	G2	W_{SW}[2]	p_{SW}[3]	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}
LI1MD	92	-0.280	0.435	0.976	0.085	101	0.176	-0.176	0.986	0.375	76	0.140	-0.235	0.975	0.148	100	0.151	-0.382	0.982	0.190
LI1BL	83	-0.220	0.033	0.977	0.143	88	0.258	-0.268	0.980	0.197	69	-0.206	-0.442	0.978	0.265	96	0.076	-0.636	0.984	0.295
LI2MD	97	0.114	0.559	0.984	0.307	99	-0.169	-0.324	0.982	0.207	81	-0.236	0.006	0.965	**0.027**	106	0.076	-0.330	0.986	0.362
LI2BL	88	0.150	-0.058	0.982	0.276	94	-0.325	0.598	0.983	0.253	76	0.162	-0.217	0.978	0.221	101	0.516	0.079	0.976	0.059
LCMD	98	-0.080	0.146	0.984	0.285	101	0.353	-0.188	0.976	0.065	79	-0.114	-0.447	0.986	0.571	102	-0.004	-0.697	0.974	**0.039**
LCBL	89	-0.120	-0.251	0.975	0.084	96	-0.240	-0.566	0.981	0.184	79	-0.283	-0.083	0.981	0.284	102	-0.157	-0.150	0.991	0.726
LP3MD	95	0.160	-0.567	0.975	0.063	101	0.103	-0.104	0.988	0.491	81	0.253	-0.764	0.971	0.061	106	0.027	-0.150	0.991	0.718
LP3BL	97	0.114	-0.457	0.987	0.476	102	0.209	-0.407	0.979	0.109	78	-0.083	-0.104	0.989	0.749	107	-0.038	-0.083	0.993	0.982
LP4MD	98	0.044	-0.473	0.988	0.560	99	0.040	-0.360	0.984	0.278	79	0.096	-0.328	0.992	0.908	107	-0.005	-0.434	0.988	0.455
LP4BL	94	-0.005	-0.471	0.986	0.396	100	-0.242	-0.331	0.986	0.395	80	-0.221	-0.113	0.983	0.368	107	-0.298	0.031	0.988	0.450
LM1MD	98	-0.006	-0.495	0.984	0.299	101	-0.272	-0.264	0.983	0.206	80	-0.096	-0.435	0.978	0.186	106	0.074	-0.455	0.989	0.523
LM1BL	97	-0.010	-0.122	0.985	0.341	101	0.016	-0.253	0.991	0.763	81	-0.160	-0.564	0.987	0.581	105	-0.154	-0.441	0.987	0.416
LM2MD	93	0.280	-0.004	0.984	0.297	98	0.168	-0.375	0.986	0.391	75	0.030	0.659	0.978	0.226	101	0.237	-0.064	0.991	0.763
LM2BL	98	-0.034	0.031	0.992	0.845	97	-0.379	0.953	0.978	0.100	79	-0.256	0.352	0.982	0.319	103	-0.051	-0.712	0.981	0.156
UI1MD	93	-0.175	-0.271	0.983	0.257	101	-0.454	-0.199	0.971	**0.025**	78	-0.250	-0.489	0.983	0.367	103	0.275	-0.818	0.966	**0.010**
UI1BL	97	-0.173	0.091	0.986	0.410	102	0.279	-0.450	0.978	0.087	78	-0.250	-0.512	0.979	0.234	102	-0.264	-0.067	0.981	0.144
UI2MD	92	0.106	0.044	0.992	0.836	98	-0.321	0.138	0.972	**0.032**	80	-0.038	-0.414	0.986	0.550	105	-0.085	0.007	0.992	0.828
UI2BL	90	-0.186	-0.510	0.975	0.084	100	0.123	-0.745	0.975	0.059	80	-0.385	0.354	0.984	0.412	100	-0.268	-0.105	0.985	0.338
UCMD	96	0.094	-0.414	0.982	0.205	101	0.038	-0.572	0.984	0.269	80	-0.271	-0.278	0.986	0.562	105	0.007	0.084	0.991	0.708
UCBL	98	0.315	-0.514	0.975	0.053	102	-0.122	-0.229	0.989	0.538	80	-0.131	-0.537	0.980	0.229	103	0.028	-0.426	0.985	0.279
UP3MD	97	-0.101	-0.372	0.986	0.388	101	-0.060	-0.480	0.984	0.248	81	0.107	-0.296	0.987	0.608	107	-0.086	-0.225	0.992	0.818
UP3BL	96	0.114	-0.302	0.988	0.523	101	-0.131	0.216	0.979	0.106	78	0.230	0.040	0.988	0.686	106	0.136	-0.245	0.987	0.377
UP4MD	94	-0.098	-0.177	0.987	0.457	100	0.028	-0.344	0.983	0.232	80	0.193	-0.684	0.970	0.054	105	0.141	-0.415	0.987	0.426
UP4BL	97	0.083	-0.142	0.987	0.472	101	-0.406	-0.099	0.979	0.109	77	-0.152	-0.125	0.992	0.930	105	0.305	-0.348	0.981	0.141
UM1MD	98	0.012	-0.470	0.982	0.211	101	-0.101	-0.013	0.985	0.310	81	-0.150	-0.516	0.988	0.677	106	-0.119	-0.345	0.982	0.154
UM1BL	98	0.168	-0.273	0.987	0.482	100	-0.127	0.197	0.990	0.629	80	0.198	0.188	0.976	0.146	107	0.161	-0.347	0.990	0.585
UM2MD	81	0.371	-0.081	0.974	0.095	98	-0.047	-0.239	0.990	0.687	72	0.113	-0.145	0.978	0.225	99	0.186	-0.166	0.989	0.588
UM2BL	93	0.006	-0.195	0.991	0.773	101	-0.715	1.317	0.968	**0.014**	77	-0.178	-0.260	0.991	0.853	103	0.228	-0.060	0.979	0.100

	Garasias										Gompadompti Madigas									
	Females (n= 97)					Males (n= 105)					Females (n= 70)					Males (n= 90)				
Variable	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}
LI1MD	95	-0.082	0.141	0.984	0.316	98	-0.231	-0.329	0.982	0.190	62	0.520	-0.261	0.956	**0.026**	80	0.476	-0.384	0.959	**0.011**
LI1BL	90	-0.209	-0.244	0.989	0.638	98	-0.423	0.102	0.980	0.135	54	-0.173	0.154	0.985	0.751	69	0.037	-0.542	0.985	0.575
LI2MD	97	0.071	-0.057	0.986	0.380	103	0.214	-0.167	0.982	0.183	65	0.135	-0.423	0.975	**0.202**	85	0.160	0.178	0.987	0.558
LI2BL	97	-0.136	-0.321	0.987	0.483	98	0.199	0.079	0.982	0.203	62	0.088	-0.427	0.971	0.155	78	0.151	-0.539	0.980	0.277
LCMD	96	-0.047	-0.295	0.981	0.192	104	0.266	-0.365	0.983	0.215	70	0.563	0.115	0.967	0.065	90	-0.051	-0.372	0.988	0.596
LCBL	96	-0.307	0.297	0.980	0.143	102	-0.231	-0.329	0.978	0.083	69	-0.182	-0.659	0.976	0.210	89	-0.330	-0.103	0.981	0.204
LP3MD	94	-0.316	0.225	0.974	0.061	104	0.297	-0.250	0.986	0.334	70	-0.171	0.023	0.986	0.598	88	0.177	0.299	0.982	0.243
LP3BL	97	0.105	-0.557	0.987	0.451	105	0.213	-0.369	0.985	0.303	67	-0.200	-0.120	0.986	0.648	89	-0.021	-0.329	0.984	0.351
LP4MD	96	0.252	-0.485	0.983	0.234	104	0.333	-0.489	0.975	**0.049**	69	-0.182	-0.261	0.979	0.309	85	0.029	-0.231	0.984	0.373
LP4BL	96	-0.352	-0.197	0.978	0.115	105	-0.160	-0.228	0.990	0.630	67	0.237	-0.468	0.964	0.051	90	0.062	-0.923	0.968	**0.027**
LM1MD	96	0.120	-0.493	0.980	0.157	104	0.002	-0.337	0.987	0.383	70	0.264	0.071	0.976	0.206	89	-0.073	-0.533	0.974	0.065
LM1BL	95	-0.054	-0.098	0.990	0.721	105	-0.103	-0.579	0.988	0.458	70	-0.200	-0.175	0.985	0.573	89	0.109	-0.234	0.986	0.446
LM2MD	85	0.210	-0.775	0.965	**0.020**	93	0.401	-0.103	0.977	0.093	65	0.285	-0.262	0.978	0.307	88	-0.164	0.185	0.987	0.502
LM2BL	95	-0.285	-0.261	0.980	0.159	100	0.054	0.293	0.992	0.796	68	-0.345	0.064	0.977	0.236	87	0.067	-0.517	0.978	0.156
UI1MD	95	-0.222	-0.163	0.989	0.605	100	0.176	-0.257	0.988	0.519	65	-0.022	-0.549	0.975	0.219	87	0.409	0.433	0.980	0.214
UI1BL	96	-0.306	-0.413	0.984	0.282	105	-0.006	-0.475	0.989	0.528	63	-0.083	0.115	0.973	0.181	81	-0.014	-0.198	0.987	0.569
UI2MD	88	-0.025	-0.220	0.991	0.820	102	0.267	0.006	0.988	0.473	66	0.069	-0.410	0.972	0.141	84	-0.013	-0.444	0.981	0.259
UI2BL	96	-0.002	-0.318	0.990	0.699	103	0.087	-0.111	0.985	0.283	66	-0.137	-0.217	0.985	0.609	89	-0.279	-0.052	0.988	0.570
UCMD	97	-0.217	0.238	0.988	0.497	105	-0.197	-0.073	0.989	0.557	70	0.383	-0.444	0.971	0.103	89	0.173	-0.522	0.973	0.059
UCBL	96	-0.149	0.105	0.983	0.257	102	-0.162	-0.321	0.987	0.394	70	-0.099	-0.420	0.986	0.614	89	-0.050	-0.061	0.990	0.713
UP3MD	94	0.048	-0.043	0.989	0.598	104	0.278	-0.350	0.984	0.233	70	0.220	-0.475	0.978	0.261	90	-0.097	0.282	0.990	0.704
UP3BL	96	-0.099	-0.258	0.990	0.706	105	0.192	-0.535	0.983	0.191	69	0.071	-0.287	0.981	0.356	89	0.033	-0.260	0.988	0.601
UP4MD	97	-0.055	-0.361	0.986	0.399	103	0.430	0.362	0.977	0.070	69	-0.164	-0.590	0.973	0.144	88	0.211	-0.440	0.982	0.258
UP4BL	95	-0.252	-0.508	0.978	0.103	103	0.039	-0.513	0.988	0.495	69	0.043	-0.543	0.980	0.353	89	0.114	-0.136	0.984	0.358
UM1MD	96	0.059	-0.286	0.986	0.417	105	0.295	-0.491	0.980	0.109	68	-0.037	-0.132	0.983	0.505	90	0.235	0.044	0.976	0.090
UM1BL	97	-0.111	-0.040	0.988	0.564	103	0.086	-0.286	0.988	0.457	69	0.267	-0.326	0.982	0.435	90	-0.216	-0.540	0.977	0.112
UM2MD	60	-0.143	-0.683	0.974	0.232	81	0.188	-0.581	0.978	0.176	66	0.140	0.144	0.985	0.614	77	0.165	-0.030	0.984	0.459
UM2BL	89	-0.276	-0.686	0.973	0.063	99	0.053	-0.325	0.982	0.209	69	-0.223	-0.655	0.981	0.372	89	-0.004	-0.547	0.984	0.339

	Pakanati Reddis										Vaghelia Rajputs									
	Females (n= 76)					Males (n= 93)					Females (n= 47)					Males (n= 141)				
Variable	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}	n	G1	G2	W_{SW}	p_{SW}
LI1MD	70	0.211	-0.295	0.976	0.209	86	0.130	-0.430	0.981	0.243	46	-0.575	0.179	0.951	0.053	137	-0.195	-0.453	0.984	0.122
LI1BL	68	0.275	-0.480	0.973	0.139	85	-0.395	-0.022	0.982	0.277	45	-0.095	-1.217	0.951	0.056	130	0.331	-0.348	0.982	0.077
LI2MD	73	0.198	-0.692	0.976	0.188	90	-0.324	-0.101	0.979	0.162	44	0.496	-0.367	0.952	0.068	139	-0.008	-0.293	0.988	0.290
LI2BL	73	0.221	-0.604	0.981	0.352	90	0.223	-0.620	0.977	0.120	47	-0.422	-0.268	0.957	0.080	130	0.137	0.234	0.987	0.282
LCMD	76	0.294	-0.501	0.975	0.147	93	-0.154	-0.237	0.979	0.139	47	0.017	-0.206	0.984	0.759	139	0.012	-0.405	0.989	0.358
LCBL	72	0.015	-0.192	0.988	0.722	86	0.347	-0.630	0.963	**0.014**	44	0.113	-0.376	0.978	0.548	140	-0.103	-0.487	0.988	0.269
LP3MD	76	-0.274	-0.217	0.983	0.428	93	0.058	0.666	0.977	0.105	45	-0.016	-0.173	0.975	0.438	140	-0.004	0.382	0.989	0.309
LP3BL	76	-0.116	-0.745	0.980	0.291	90	0.112	-0.178	0.981	0.222	47	0.038	-0.538	0.983	0.699	136	-0.168	-0.157	0.985	0.133
LP4MD	76	0.135	-0.231	0.988	0.699	87	-0.207	-0.445	0.975	0.085	47	-0.054	-0.133	0.988	0.918	138	0.325	-0.296	0.973	**0.007**
LP4BL	76	-0.097	-0.572	0.980	0.288	92	-0.210	-0.651	0.977	0.111	47	0.005	-0.744	0.968	0.225	135	-0.266	-0.163	0.986	0.192
LM1MD	76	-0.357	-0.427	0.967	**0.043**	93	-0.186	-0.691	0.979	0.145	47	-0.191	-0.102	0.988	0.914	138	0.097	-0.280	0.990	0.455
LM1BL	74	-0.432	-0.094	0.977	0.197	92	-0.093	-0.369	0.992	0.884	47	0.461	-0.105	0.965	0.175	139	0.195	-0.545	0.984	0.103
LM2MD	72	-0.589	-0.159	0.961	**0.024**	90	-0.119	0.047	0.988	0.580	40	-0.247	-0.199	0.972	0.415	128	0.113	-0.425	0.991	0.532
LM2BL	75	-0.075	-0.108	0.992	0.912	91	-0.037	-0.265	0.991	0.816	46	0.237	-0.669	0.976	0.441	134	-0.047	-0.371	0.988	0.313
UI1MD	70	0.242	-0.335	0.977	0.231	90	0.313	-0.537	0.979	0.144	44	-0.042	-0.061	0.969	0.277	135	-0.096	-0.442	0.981	0.055
UI1BL	66	-0.108	-0.173	0.990	0.868	89	-0.022	-0.291	0.986	0.439	47	0.079	-0.621	0.980	0.583	140	0.112	-0.152	0.992	0.569
UI2MD	72	0.156	0.036	0.984	0.474	88	0.229	-0.430	0.984	0.333	46	0.338	-0.343	0.969	0.253	139	-0.169	-0.103	0.989	0.338
UI2BL	70	-0.402	-0.223	0.968	**0.048**	93	-0.149	-0.102	0.985	0.348	47	-0.277	-0.478	0.969	0.247	138	-0.114	-0.236	0.990	0.400
UCMD	75	-0.126	-0.615	0.979	0.250	89	-0.192	0.560	0.975	0.089	45	0.220	-0.231	0.977	0.491	137	-0.228	-0.197	0.984	0.113
UCBL	72	-0.297	-0.167	0.974	0.139	93	-0.288	-0.061	0.983	0.265	40	-0.165	-0.307	0.968	0.318	140	-0.139	-0.351	0.988	0.287
UP3MD	74	0.183	-0.418	0.977	0.185	89	-0.426	0.127	0.966	**0.019**	45	-0.565	0.300	0.968	0.246	140	0.125	-0.060	0.991	0.543
UP3BL	76	0.111	-0.483	0.988	0.700	93	-0.229	0.303	0.981	0.180	47	0.173	-0.723	0.963	0.147	135	-0.053	0.056	0.985	0.130
UP4MD	76	0.055	-0.328	0.988	0.670	90	0.112	0.003	0.985	0.388	46	0.115	-0.279	0.985	0.816	141	-0.098	-0.323	0.990	0.384
UP4BL	76	-0.294	-0.239	0.986	0.572	92	-0.008	-0.519	0.979	0.150	47	-0.163	-0.254	0.979	0.534	139	-0.044	-0.466	0.985	0.138
UM1MD	74	0.076	-0.506	0.980	0.297	93	-0.079	-0.221	0.992	0.879	47	-0.226	-0.018	0.979	0.566	136	0.089	-0.678	0.984	0.117
UM1BL	75	-0.097	-0.199	0.989	0.762	91	0.174	-0.337	0.984	0.344	47	0.105	-0.210	0.985	0.815	138	0.337	-0.245	0.982	0.061
UM2MD	67	-0.570	-0.263	0.957	**0.021**	87	0.110	0.358	0.982	0.262	29	0.360	-0.636	0.963	0.396	110	0.041	-0.220	0.993	0.840
UM2BL	76	-0.042	0.082	0.990	0.803	93	-0.088	-0.538	0.986	0.414	43	0.003	-0.730	0.970	0.322	134	0.097	-0.347	0.986	0.201

1. Significant p-values in bold.
2. W_{SW}= W statistic of the Shapiro-Wilks (1965) test for normality.
3. p_{SW}= p-value associated with the Shapiro-Wilks test for normality.

Table 13. Descriptive statistics for comparative living samples by sex after EM estimation

	Bhils						**Chenchus**					
	Females (n= 69)			Males (n= 90)			Females (n= 68)			Males (n= 103)		
Variable	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv	X	sd	cv
LI1MD	5.280	0.325	0.062	5.312	0.330	0.055	5.023	0.382	0.076	5.055	0.371	0.073
LI1BL	5.662	0.354	0.063	5.940	0.367	0.062	5.627	0.440	0.078	6.095	0.541	0.089
LI2MD	5.793	0.406	0.070	5.885	0.354	0.060	5.610	0.440	0.078	5.725	0.408	0.071
LI2BL	6.003	0.356	0.059	6.282	0.400	0.064	6.087	0.520	0.085	6.336	0.419	0.066
LCMD	6.407	0.327	0.051	6.840	0.343	0.050	6.267	0.407	0.065	6.645	0.404	0.061
LCBL	6.787	0.442	0.065	7.198	0.600	0.083	6.824	0.619	0.091	7.386	0.647	0.088
LP3MD	6.820	0.366	0.054	6.967	0.430	0.062	6.503	0.525	0.081	6.801	0.476	0.070
LP3BL	7.623	0.488	0.064	7.753	0.500	0.064	7.620	0.523	0.069	8.075	0.601	0.074
LP4MD	6.986	0.482	0.069	7.030	0.431	0.061	6.412	0.451	0.070	6.569	0.509	0.077
LP4BL	8.107	0.416	0.051	8.196	0.540	0.054	8.036	0.669	0.083	8.434	0.638	0.076
LM1MD	10.800	0.655	0.061	11.147	0.606	0.054	10.742	0.535	0.050	10.990	0.604	0.055
LM1BL	10.434	0.423	0.041	10.708	0.450	0.042	10.192	0.492	0.048	10.533	0.528	0.050
LM2MD	10.036	0.553	0.055	10.309	0.496	0.048	9.427	0.527	0.056	9.776	0.686	0.070
LM2BL	9.941	0.492	0.049	10.239	0.544	0.053	9.809	0.539	0.055	10.106	0.569	0.056
UI1MD	8.171	0.473	0.058	8.514	0.489	0.057	8.081	0.492	0.061	8.365	0.512	0.061
UI1BL	6.733	0.456	0.068	6.897	0.500	0.072	6.806	0.526	0.077	7.197	0.555	0.077
UI2MD	6.365	0.487	0.077	6.690	0.483	0.072	6.301	0.771	0.122	6.604	0.635	0.096
UI2BL	5.770	0.414	0.072	5.956	0.475	0.080	5.821	0.615	0.106	6.170	0.537	0.087
UCMD	7.375	0.374	0.051	7.753	0.411	0.053	7.137	0.386	0.054	7.469	0.433	0.058
UCBL	7.571	0.522	0.069	7.937	0.537	0.068	7.493	0.601	0.080	8.079	0.668	0.083
UP3MD	6.867	0.358	0.052	6.962	0.395	0.057	6.551	0.375	0.057	6.762	0.434	0.064
UP3BL	9.112	0.442	0.049	9.279	0.466	0.050	8.990	0.459	0.051	9.459	0.668	0.071
UP4MD	6.381	0.314	0.049	6.467	0.424	0.066	5.967	0.414	0.069	6.120	0.448	0.073
UP4BL	8.968	0.437	0.049	9.219	0.540	0.059	8.679	0.534	0.062	9.122	0.621	0.068
UM1MD	10.009	0.451	0.045	10.291	0.481	0.047	10.114	0.525	0.052	10.297	0.589	0.057
UM1BL	10.959	0.463	0.042	11.425	0.481	0.042	10.950	0.472	0.043	11.414	0.624	0.032
UM2MD	9.216	0.464	0.050	9.549	0.639	0.067	9.391	0.612	0.065	9.533	0.644	0.068
UM2BL	10.978	0.560	0.051	11.425	0.611	0.053	10.475	0.590	0.056	11.095	0.675	0.061

	Garasias						**Gompadhompti Madigas**					
	Females (n= 89)			Males (n= 101)			Females (n= 70)			Males (n= 68)		
Variable	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv
LI1MD	5.227	0.373	0.071	5.291	0.327	0.062	5.100	0.340	0.067	5.170	0.272	0.053
LI1BL	5.732	0.581	0.101	5.920	0.518	0.088	5.614	0.450	0.080	5.941	0.497	0.084
LI2MD	5.791	0.384	0.066	5.936	0.407	0.069	5.763	0.345	0.060	5.881	0.361	0.061
LI2BL	5.985	0.568	0.095	6.240	0.484	0.078	5.966	0.422	0.071	6.239	0.543	0.087
LCMD	6.406	0.359	0.056	6.837	0.423	0.062	6.384	0.480	0.075	6.672	0.382	0.057
LCBL	6.859	0.576	0.084	7.183	0.649	0.090	6.862	0.633	0.092	7.253	0.768	0.106
LP3MD	6.798	0.357	0.053	6.965	0.528	0.076	6.709	0.355	0.053	6.888	0.393	0.056
LP3BL	7.758	0.513	0.066	8.002	0.586	0.073	7.571	0.380	0.050	8.004	0.552	0.069
LP4MD	6.862	0.489	0.071	6.997	0.540	0.077	6.708	0.371	0.055	6.922	0.326	0.047
LP4BL	8.339	0.539	0.065	8.387	0.619	0.074	8.047	0.368	0.046	8.351	0.564	0.068
LM1MD	10.558	0.471	0.045	10.892	0.534	0.049	10.696	0.480	0.045	11.062	0.487	0.044
LM1BL	10.513	0.470	0.045	10.745	0.527	0.049	9.911	0.471	0.048	10.316	0.498	0.048
LM2MD	9.765	0.592	0.061	10.167	0.546	0.054	9.779	0.508	0.052	10.068	0.501	0.050
LM2BL	10.121	0.524	0.052	10.543	0.536	0.051	9.650	0.544	0.056	10.125	0.599	0.059
UI1MD	8.355	0.470	0.056	8.497	0.532	0.063	8.155	0.425	0.052	8.350	0.478	0.057
UI1BL	6.889	0.562	0.082	7.069	0.617	0.087	6.711	0.420	0.063	6.999	0.421	0.060
UI2MD	6.470	0.442	0.068	6.751	0.563	0.083	6.500	0.479	0.074	6.765	0.417	0.062
UI2BL	5.941	0.646	0.109	6.105	0.645	0.106	5.850	0.554	0.095	6.278	0.601	0.096
UCMD	7.321	0.413	0.056	7.690	0.450	0.059	7.199	0.435	0.060	7.546	0.432	0.057
UCBL	7.724	0.622	0.081	8.108	0.698	0.086	7.551	0.516	0.068	8.085	0.809	0.100
UP3MD	6.767	0.385	0.057	6.941	0.515	0.074	6.684	0.422	0.063	6.865	0.423	0.062
UP3BL	9.142	0.505	0.055	9.362	0.572	0.061	8.837	0.434	0.049	9.348	0.546	0.058
UP4MD	6.301	0.486	0.077	6.422	0.552	0.086	6.308	0.402	0.064	6.461	0.433	0.067
UP4BL	9.065	0.508	0.056	9.292	0.582	0.063	8.778	0.424	0.048	9.224	0.563	0.061
UM1MD	10.214	0.552	0.054	10.454	0.638	0.061	9.972	0.388	0.039	10.265	0.408	0.040
UM1BL	10.951	0.594	0.054	11.340	0.506	0.045	10.565	0.498	0.047	11.166	0.574	0.051
UM2MD	9.124	0.442	0.048	9.369	0.524	0.056	9.560	0.505	0.053	9.946	0.512	0.051
UM2BL	10.842	0.607	0.056	11.322	0.685	0.061	10.457	0.634	0.061	11.268	0.658	0.058

	Pakanati Reddis						**Vaghela Rajputs**					
	Females (n= 60)			Males (n= 93)			Females (n= 27)			Males (n= 127)		
Variable	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv	$\overline{X}$	sd	cv
LI1MD	5.172	0.350	0.068	5.226	0.394	0.075	5.119	0.408	0.080	5.301	0.380	0.072
LI1BL	5.775	0.399	0.069	5.931	0.431	0.073	5.747	0.485	0.084	5.954	0.403	0.068
LI2MD	5.726	0.415	0.072	5.857	0.399	0.068	5.682	0.231	0.041	5.852	0.418	0.071
LI2BL	6.112	0.491	0.080	6.207	0.470	0.076	6.137	0.415	0.068	6.197	0.435	0.070
LCMD	6.357	0.444	0.070	6.655	0.392	0.059	6.348	0.360	0.057	6.828	0.426	0.062
LCBL	6.909	0.568	0.082	7.202	0.599	0.083	6.747	0.469	0.070	6.939	0.772	0.111
LP3MD	6.735	0.406	0.060	6.846	0.394	0.058	6.583	0.318	0.048	6.792	0.395	0.058
LP3BL	7.577	0.582	0.077	7.740	0.531	0.069	7.500	0.460	0.061	7.844	0.530	0.068
LP4MD	6.758	0.568	0.084	6.868	0.315	0.046	6.541	0.518	0.079	6.883	0.485	0.070
LP4BL	8.072	0.565	0.070	8.161	0.536	0.066	8.052	0.441	0.055	8.265	0.502	0.061
LM1MD	10.632	0.584	0.055	11.078	0.586	0.053	10.352	0.685	0.066	11.018	0.552	0.050
LM1BL	10.216	0.494	0.048	10.344	0.556	0.054	10.185	0.504	0.049	10.581	0.494	0.047
LM2MD	9.672	0.525	0.054	10.027	0.511	0.051	9.361	0.653	0.070	9.870	0.728	0.074
LM2BL	9.835	0.683	0.069	10.082	0.567	0.056	9.696	0.574	0.059	10.225	0.606	0.059
UI1MD	8.328	0.573	0.069	8.469	0.554	0.065	8.244	0.506	0.061	8.606	0.498	0.058
UI1BL	6.945	0.552	0.079	7.142	0.474	0.066	6.767	0.531	0.078	7.033	0.498	0.071
UI2MD	6.747	0.506	0.075	6.751	0.552	0.082	6.369	0.450	0.071	6.631	0.479	0.072
UI2BL	6.041	0.443	0.073	6.287	0.579	0.092	5.881	0.530	0.090	6.191	0.571	0.092
UCMD	7.342	0.476	0.065	7.549	0.409	0.054	7.227	0.431	0.060	7.614	0.464	0.061
UCBL	7.642	0.514	0.067	7.981	0.682	0.085	7.504	0.314	0.042	7.831	0.772	0.099
UP3MD	6.731	0.404	0.060	6.860	0.323	0.047	6.474	0.418	0.065	6.761	0.443	0.066
UP3BL	8.892	0.613	0.069	9.170	0.518	0.056	8.807	0.462	0.052	9.166	0.514	0.056
UP4MD	6.387	0.483	0.073	6.461	0.410	0.063	6.037	0.411	0.068	6.449	0.431	0.067
UP4BL	8.825	0.646	0.073	9.064	0.616	0.068	8.633	0.599	0.069	9.139	0.561	0.061
UM1MD	10.068	0.393	0.039	10.258	0.528	0.051	9.826	0.517	0.053	10.353	0.522	0.050
UM1BL	10.828	0.574	0.053	11.080	0.568	0.051	10.759	0.580	0.054	11.351	0.510	0.045
UM2MD	9.560	0.637	0.067	9.813	0.561	0.057	9.085	0.715	0.079	9.754	0.738	0.076
UM2BL	10.600	0.806	0.076	11.039	0.726	0.066	10.322	0.686	0.066	10.999	0.807	0.073

(Table 14). As noted above, some 19 significant departures from normality were observed after the removal of outliers, but after EM estimation only five variables are similarly affected. These include: UM2MD among Chenchu females, LI2BL among Chenchu males, LM2MD and UM2MD among Garasia females, and LP4BL among Gompadhompti males. With only five significant departures from normality among the 336 variables considered (1.5%) among females and males of the six comparative samples, these data may be considered as conforming well to normality.

Assessment of sex dimorphism reveals that differences in tooth size between females and males are expressed to differing degrees and with different allocation patterns across the dentition among members of the six comparative living ethnic groups (Table 15). Average sex dimorphism ranged from a high of 4.71% among Vaghela Rajputs to a low of 2.5% among Pakanati Reddis. All six peninsular Indian groups are marked by a greater degree of sex dimorphism than observed among the Khow (2.48%). In fact, while the Khow are marked by three dimensions in which females possess larger dimensions on average than males, none of the dimensions among any of the six peninsular Indian ethnic groups were larger on average among females than males.

While sex differences tend to be greatest for LCMD, this was not the case among Chenchus or Gompadhomptis. While the BL dimension of this same tooth is the second most dimorphic dimension among Bhils and Chenchus, this was not the case for the remaining four groups; in fact, among Vaghela Rajputs this dimension was the third *least* dimorphic. Instead, the second most dimorphic dimension among Garasias is UCMD, among Gompadhomptis is it UI2BL, among Pakanatis it is UCBL, while among Vaghela Rajputs the second most dimorphic dimension is UM2MD. Greater agreement across groups occurs for the third most dimorphic dimension, which is UCBL among members of three groups (CHU, GRS, GPD), while it is the second most dimorphic dimension among Pakanati Reddis.

Table 14. Distributional statistics for all comparative living samples by sex after EM estimation[1]

	Bhils								Chenchus							
	Females (n= 69)				Males (n= 90)				Females (n= 68)				Males (n= 103)			
Variable	G1	G2	W_{SW}[2]	p_{SW}[3]	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}
LI1MD	-0.060	0.930	0.970	0.092	0.055	-0.387	0.985	0.408	0.285	0.032	0.968	0.074	0.183	-0.299	0.981	0.149
LI1BL	-0.173	0.195	0.986	0.651	0.261	0.290	0.983	0.302	-0.198	-0.390	0.984	0.513	0.118	-0.433	0.986	0.372
LI2MD	0.264	1.027	0.971	0.107	-0.298	-0.401	0.976	0.091	-0.027	0.089	0.969	0.089	0.109	-0.321	0.986	0.363
LI2BL	0.095	0.550	0.981	0.374	-0.204	1.031	0.979	0.144	0.142	-0.372	0.976	0.222	0.553	0.355	0.974	**0.042**
LCMD	-0.311	0.651	0.971	0.106	0.300	-0.304	0.977	0.108	-0.242	-0.254	0.988	0.747	0.086	-0.491	0.975	0.051
LCBL	-0.173	0.352	0.972	0.126	-0.166	-0.384	0.987	0.540	-0.335	-0.019	0.980	0.341	-0.190	0.036	0.989	0.597
LP3MD	0.226	-0.470	0.975	0.189	0.141	0.054	0.985	0.385	0.289	-0.789	0.968	0.077	0.013	-0.218	0.991	0.758
LP3BL	-0.004	-0.476	0.983	0.491	0.053	-0.527	0.985	0.373	0.144	-0.160	0.988	0.750	-0.021	-0.145	0.992	0.824
LP4MD	0.208	-0.286	0.988	0.760	0.088	-0.282	0.981	0.221	0.149	-0.347	0.991	0.909	0.002	-0.464	0.988	0.497
LP4BL	-0.229	-0.139	0.981	0.397	-0.338	-0.347	0.979	0.151	-0.129	-0.054	0.988	0.742	-0.330	0.047	0.986	0.383
LM1MD	0.151	-0.506	0.981	0.380	-0.309	-0.413	0.980	0.174	0.167	-0.356	0.981	0.404	0.049	-0.438	0.989	0.549
LM1BL	0.104	-0.059	0.984	0.517	-0.104	-0.251	0.992	0.855	-0.093	-0.624	0.987	0.700	-0.205	-0.437	0.984	0.250
LM2MD	0.392	0.186	0.975	0.187	0.111	-0.429	0.983	0.277	0.406	0.681	0.976	0.202	0.176	0.074	0.993	0.863
LM2BL	0.436	-0.165	0.976	0.210	-0.506	1.562	0.974	0.065	0.081	0.103	0.984	0.560	-0.122	-0.635	0.983	0.194
UI1MD	-0.170	-0.069	0.983	0.451	-0.389	-0.353	0.974	0.073	-0.211	-0.251	0.985	0.612	-0.020	-0.571	0.978	0.087
UI1BL	-0.241	0.331	0.983	0.465	0.257	-0.350	0.981	0.214	-0.146	-0.435	0.984	0.514	-0.226	0.033	0.983	0.214
UI2MD	-0.286	0.201	0.988	0.726	-0.284	0.097	0.974	0.064	0.039	-0.238	0.987	0.700	-0.187	-0.054	0.992	0.774
UI2BL	-0.177	-0.423	0.974	0.162	0.211	-0.624	0.976	0.098	-0.368	0.234	0.983	0.498	-0.200	-0.029	0.988	0.494
UCMD	0.079	-0.367	0.979	0.309	0.114	-0.459	0.982	0.254	-0.131	-0.082	0.988	0.780	0.034	0.100	0.990	0.679
UCBL	0.368	-0.433	0.971	0.107	-0.102	-0.270	0.989	0.633	-0.059	-0.525	0.979	0.291	0.028	-0.426	0.985	0.279
UP3MD	0.083	-0.170	0.989	0.796	0.005	-0.296	0.986	0.478	0.181	-0.342	0.984	0.537	-0.069	-0.284	0.991	0.741
UP3BL	-0.060	-0.170	0.986	0.628	-0.270	0.241	0.973	0.059	0.335	0.272	0.983	0.499	0.127	-0.315	0.986	0.377
UP4MD	-0.408	-0.026	0.975	0.189	0.168	-0.281	0.978	0.126	0.097	-0.793	0.969	0.090	0.162	-0.456	0.986	0.379
UP4BL	-0.042	-0.221	0.984	0.515	-0.377	-0.150	0.979	0.152	-0.147	-0.493	0.985	0.617	0.312	-0.388	0.980	0.125
UM1MD	0.121	-0.286	0.984	0.515	0.019	0.061	0.986	0.479	-0.181	-0.272	0.988	0.787	-0.150	-0.293	0.983	0.209
UM1BL	0.208	-0.101	0.988	0.768	-0.305	0.176	0.987	0.524	0.169	0.084	0.976	0.214	0.032	-0.510	0.989	0.567
UM2MD	0.184	-0.106	0.986	0.618	-0.163	-0.265	0.987	0.527	0.095	-0.836	0.960	**0.027**	0.223	-0.058	0.989	0.552
UM2BL	-0.007	-0.414	0.978	0.268	-0.530	0.510	0.976	0.095	-0.164	-0.080	0.992	0.943	0.214	0.027	0.978	0.079

	Garasias								Gompadhompti Madigas							
	Females (n= 89)				Males (n= 101)				Females (n= 70)				Males (n= 68)			
Variable	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}
LI1MD	-0.041	0.345	0.979	0.166	0.125	-0.187	0.982	0.191	-0.093	-0.291	0.965	0.451	0.211	0.285	0.984	0.550
LI1BL	-0.217	-0.121	0.989	0.697	-0.476	0.372	0.979	0.099	-0.140	0.982	0.971	0.099	0.056	0.061	0.981	0.399
LI2MD	0.127	0.306	0.980	0.191	0.169	-0.147	0.985	0.317	0.142	-0.232	0.974	0.156	0.247	0.188	0.982	0.434
LI2BL	-0.316	-0.643	0.974	0.066	0.243	0.295	0.979	0.105	0.085	-0.102	0.966	0.057	0.171	-0.068	0.976	0.219
LCMD	-0.072	-0.201	0.982	0.252	0.036	-0.610	0.985	0.322	0.563	0.115	0.967	0.065	-0.034	-0.547	0.982	0.454
LCBL	-0.392	0.140	0.979	0.154	-0.271	-0.262	0.976	0.064	-0.180	-0.624	0.977	0.218	-0.359	0.208	0.980	0.350
LP3MD	-0.332	0.474	0.974	0.074	0.299	-0.271	0.985	0.330	-0.171	0.023	0.986	0.598	0.146	0.352	0.979	0.318
LP3BL	0.065	-0.559	0.986	0.463	0.292	-0.471	0.980	0.133	-0.179	-0.066	0.987	0.690	0.130	-0.201	0.982	0.454
LP4MD	0.212	-0.279	0.987	0.547	0.351	-0.386	0.975	0.055	-0.201	-0.232	0.979	0.286	-0.068	-0.202	0.981	0.395
LP4BL	-0.268	-0.259	0.980	0.201	-0.131	-0.248	0.991	0.730	-0.093	-0.157	0.965	0.104	0.135	-0.649	0.961	**0.032**
LM1MD	0.113	-0.530	0.977	0.108	0.025	-0.302	0.986	0.369	0.264	0.071	0.976	0.206	0.153	-0.173	0.973	0.139
LM1BL	0.021	-0.015	0.990	0.713	-0.068	-0.620	0.986	0.369	-0.200	-0.175	0.985	0.573	0.302	-0.054	0.983	0.489
LM2MD	0.133	-0.845	0.970	**0.038**	-0.050	-0.146	0.974	0.189	0.257	-0.192	0.982	0.408	0.159	-0.523	0.980	0.360
LM2BL	-0.069	-0.740	0.983	0.284	0.118	0.563	0.990	0.636	-0.338	0.143	0.978	0.240	0.137	-0.389	0.984	0.551
UI1MD	-0.258	-0.068	0.988	0.579	0.129	-0.230	0.991	0.722	-0.028	-0.415	0.980	0.333	0.529	0.287	0.972	0.123
UI1BL	-0.358	-0.340	0.982	0.263	-0.008	-0.444	0.988	0.481	-0.113	0.361	0.970	0.093	-0.014	0.483	0.983	0.485
UI2MD	0.174	-0.263	0.988	0.557	0.307	0.167	0.987	0.399	0.078	-0.262	0.971	0.105	0.004	-0.075	0.982	0.414
UI2BL	-0.015	-0.408	0.988	0.603	0.106	0.035	0.983	0.210	-0.116	-0.066	0.984	0.495	-0.193	0.005	0.989	0.803
UCMD	-0.286	0.537	0.984	0.344	-0.080	-0.260	0.990	0.636	0.383	-0.444	0.971	0.103	0.246	-0.586	0.971	0.116
UCBL	-0.172	0.168	0.982	0.272	-0.166	-0.345	0.986	0.390	-0.099	-0.420	0.986	0.614	0.059	-0.165	0.985	0.595
UP3MD	0.170	-0.174	0.984	0.337	0.256	-0.357	0.984	0.256	0.220	-0.475	0.978	0.261	0.171	0.391	0.985	0.565
UP3BL	0.032	-0.214	0.988	0.564	0.224	-0.480	0.983	0.211	0.086	-0.256	0.981	0.361	-0.013	-0.082	0.986	0.620
UP4MD	-0.079	-0.168	0.988	0.572	0.447	0.391	0.977	0.069	-0.174	-0.555	0.974	0.151	0.310	-0.241	0.982	0.420
UP4BL	-0.203	-0.406	0.986	0.439	0.053	-0.440	0.987	0.458	0.018	-0.539	0.980	0.337	0.181	0.058	0.980	0.356
UM1MD	0.105	-0.238	0.986	0.450	0.279	-0.558	0.978	0.092	-0.012	-0.066	0.983	0.486	0.215	-0.366	0.959	0.102
UM1BL	-0.274	0.025	0.984	0.338	0.130	-0.199	0.987	0.398	0.262	-0.291	0.983	0.443	-0.398	-0.426	0.969	0.088
UM2MD	-0.180	0.684	0.949	**0.002**	0.079	-0.316	0.984	0.273	0.121	0.312	0.984	0.519	0.250	-0.148	0.982	0.423
UM2BL	-0.246	-0.563	0.974	0.076	0.033	-0.128	0.983	0.220	-0.225	-0.619	0.982	0.418	0.047	-0.911	0.972	0.124

	Pakanati Reddis								**Vaghelia Rajputs**							
	Females (n= 60)				Males (n= 93)				Females (n= 27)				Males (n= 127)			
Variable	G1	G2	W_{SW}	p_{SW}		G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}	G1	G2	W_{SW}	p_{SW}
LI1MD	-0.065	-0.492	0.980	0.417	0.156	-0.246	0.983	0.291	-0.388	-0.512	0.924	0.203	-0.140	-0.592	0.980	0.059
LI1BL	0.181	-0.529	0.974	0.234	-0.423	0.254	0.980	0.161	-0.165	-1.239	0.944	0.153	0.396	-0.082	0.982	0.082
LI2MD	0.385	-0.332	0.974	0.234	-0.323	-0.008	0.979	0.144	0.386	-0.001	0.962	0.419	0.002	-0.293	0.987	0.252
LI2BL	0.128	-0.540	0.987	0.762	0.233	-0.539	0.980	0.163	-0.583	-0.248	0.936	0.100	0.013	0.675	0.980	0.053
LCMD	0.203	-0.605	0.974	0.222	-0.154	-0.237	0.979	0.139	0.452	1.134	0.970	0.594	-0.081	-0.393	0.989	0.378
LCBL	-0.035	0.006	0.989	0.852	-0.128	-0.534	0.977	0.100	0.719	0.565	0.960	0.371	-0.156	-0.545	0.982	0.091
LP3MD	-0.362	0.194	0.977	0.302	0.058	0.666	0.977	0.105	0.012	-0.759	0.946	0.175	0.050	0.442	0.986	0.219
LP3BL	-0.215	-0.723	0.976	0.287	0.094	-0.158	0.983	0.257	-0.136	-1.003	0.951	0.228	-0.030	-0.079	0.990	0.462
LP4MD	0.021	-0.375	0.989	0.865	-0.213	-0.342	0.978	0.108	-0.436	-0.526	0.966	0.497	-0.070	0.099	0.981	0.065
LP4BL	-0.303	-0.738	0.968	0.113	-0.212	-0.625	0.979	0.129	0.288	-0.670	0.971	0.618	-0.226	0.119	0.987	0.299
LM1MD	-0.207	-0.166	0.970	0.144	-0.186	-0.691	0.979	0.145	-0.248	-0.248	0.974	0.716	0.062	-0.349	0.989	0.403
LM1BL	-0.403	-0.260	0.970	0.154	-0.112	-0.363	0.992	0.872	0.708	0.708	0.933	0.082	0.230	-0.506	0.982	0.097
LM2MD	-0.394	0.177	0.976	0.281	-0.095	0.070	0.989	0.621	-0.032	-0.032	0.972	0.656	0.102	-0.320	0.992	0.676
LM2BL	-0.122	0.071	0.988	0.843	-0.036	-0.212	0.992	0.861	0.474	0.474	0.926	0.056	-0.073	-0.258	0.987	0.259
UI1MD	0.255	-0.219	0.980	0.410	0.330	-0.458	0.980	0.166	-0.168	-0.168	0.954	0.267	0.025	-0.378	0.985	0.190
UI1BL	-0.020	-0.113	0.989	0.845	-0.003	-0.190	0.986	0.400	-0.009	-0.315	0.981	0.876	-0.031	-0.321	0.991	0.558
UI2MD	0.294	0.136	0.976	0.293	0.206	-0.467	0.985	0.346	0.426	-0.453	0.957	0.320	-0.362	-0.153	0.980	0.054
UI2BL	-0.488	0.039	0.961	0.051	-0.149	-0.102	0.985	0.348	0.343	-0.438	0.963	0.433	-0.206	-0.145	0.988	0.355
UCMD	-0.156	-0.310	0.983	0.580	-0.212	-0.454	0.976	0.085	0.688	0.664	0.961	0.391	-0.289	-0.189	0.982	0.088
UCBL	-0.127	-0.230	0.984	0.602	-0.288	-0.061	0.983	0.265	-0.067	0.548	0.970	0.610	0.082	-0.552	0.985	0.183
UP3MD	0.086	-0.453	0.975	0.267	-0.190	0.014	0.978	0.112	-0.684	0.152	0.937	0.101	0.222	-0.005	0.988	0.340
UP3BL	0.002	-0.506	0.988	0.809	-0.229	-0.303	0.981	0.180	0.153	-0.358	0.974	0.719	-0.098	0.028	0.984	0.155
UP4MD	-0.126	-0.296	0.985	0.673	0.130	0.058	0.985	0.349	0.134	-0.470	0.973	0.691	-0.165	-0.636	0.981	0.066
UP4BL	-0.478	0.193	0.977	0.317	0.006	-0.502	0.980	0.162	-0.016	0.411	0.967	0.514	0.069	-0.437	0.981	0.072
UM1MD	0.230	-0.722	0.967	0.110	-0.079	-0.221	0.992	0.879	-0.267	-0.352	0.981	0.893	0.085	-0.641	0.985	0.173
UM1BL	0.041	-0.454	0.989	0.862	0.161	-0.287	0.985	0.356	-0.454	-0.454	0.984	0.935	0.367	-0.178	0.981	0.080
UM2MD	-0.651	0.269	0.963	0.065	0.110	-0.215	0.982	0.247	-0.688	-0.688	0.954	0.265	0.097	0.362	0.990	0.522
UM2BL	-0.068	0.123	0.988	0.810	-0.088	-0.538	0.986	0.414	-0.968	-0.968	0.942	0.139	0.084	-0.265	0.987	0.247

1. Significant p-values in bold.

2. W_{SW}= W statistic of the Shapiro-Wilks (1965) test for normality.

3. p_{SW}= p-value associated with the Shapiro-Wilks test for normality.

Table 15. Sex dimorphism among comparative living groups after EM estimation

	Bhils		**Chenchus**		**Garasias**		**Gompadhomptis**		**Pakanatis**		**V. Rajputs**	
Variable	%sexd[1]	Rank[2]	%sexd	Rank	%sexd	Rank	%sexd	Rank	%sexd	Rank	%sexd	Rank
LI1MD	0.606	28	0.637	28	1.224	27	1.373	28	1.044	27	3.555	23
LI1BL	4.910	5	8.317	1	3.280	11	5.825	4	2.701	12	3.602	22
LI2MD	1.588	23	2.050	25	2.504	19	2.048	27	2.288	16	2.992	25
LI2BL	4.648	7	4.091	16	4.261	7	4.576	12	1.554	23	0.978	28
LCMD	6.758	1	6.032	4	6.728	1	4.511	13	4.688	1	7.561	1
LCBL	6.056	2	8.236	2	4.724	4	5.698	7	4.241	3	2.846	26
LP3MD	2.155	20	4.583	14	2.457	20	2.668	24	1.648	21	3.175	24
LP3BL	1.705	22	5.971	6	3.145	13	5.719	6	2.151	17	4.587	14
LP4MD	0.630	27	2.449	23	1.967	24	3.190	20	1.628	22	5.229	13
LP4BL	1.098	26	4.953	11	0.576	28	3.778	18	1.103	26	2.645	27
LM1MD	3.213	13	2.309	24	3.163	12	3.422	19	4.195	4	6.434	5
LM1BL	2.626	18	3.346	19	2.207	23	4.086	15	1.253	24	3.888	21
LM2MD	2.720	17	3.702	17	4.117	9	2.955	21	3.670	7	5.437	9
LM2BL	2.998	14	3.028	21	4.170	8	4.922	10	2.511	14	5.456	8
UI1MD	4.198	9	3.514	18	1.700	26	2.391	26	1.693	20	4.391	16
UI1BL	2.436	19	5.745	8	2.613	16	4.291	14	2.837	9	3.931	20
UI2MD	5.106	4	4.809	12	4.343	6	4.077	16	0.059	28	4.114	18
UI2BL	3.224	12	5.996	5	2.760	14	7.316	2	4.072	6	5.271	12
UCMD	5.125	3	4.652	13	5.040	2	4.820	11	2.819	10	5.355	11
UCBL	4.834	6	7.821	3	4.972	3	7.072	3	4.436	2	4.358	17
UP3MD	1.383	24	3.221	20	2.571	17	2.708	23	1.917	18	4.433	15
UP3BL	1.833	21	5.217	9	2.406	21	5.783	5	3.126	8	4.076	19
UP4MD	1.348	25	2.564	22	1.920	25	2.425	25	1.159	25	6.825	3
UP4BL	2.799	16	5.104	10	2.504	18	5.081	9	2.708	11	5.861	6
UM1MD	2.817	15	1.809	26	2.350	22	2.938	22	1.887	19	5.363	10
UM1BL	4.252	8	4.237	15	3.552	10	5.689	8	2.327	15	5.502	7
UM2MD	3.613	11	1.512	27	2.685	15	4.038	17	2.646	13	7.364	2
UM2BL	4.072	10	5.919	7	4.427	5	7.756	1	4.142	5	6.559	4
AVERAGE	3.170		4.351		3.156		4.327		2.518		4.707	

1. %sexd is the percentage of sex dimorphism calculated as $100\left[\frac{\bar{x}_m}{\bar{x}_f} - 1\right]$ in accordance with the procedure of Garn et al. (1964).

2. Ranking is based on the absolute value of the %sexd.

However, among Bhils UCBL is the sixth most dimorphic dimension, while among Vaghela Rajputs it is the 17th most dimorphic dimension. Even greater inter-group heterogeneity occurs for the fourth most dimorphic dimension.

Heterogeneity in the allocation of sex dimorphism across the dentition was assessed with a Kruskal-Wallis H test applied to the ordinally ranked data presented in Table 9. This test revealed that differences in the allocation of sex dimorphism among members of these six ethnic groups from India and the Khow is statistically significant (H= 45.468, p< 0.001). Pairwise post hoc rank sum tests were undertaken to determine which pairwise differences contribute to this overall statistically significant difference. The results are provided in Table 16. A total of 15 of the 21 pairwise comparisons (71.4%) are statistically significant. Five of the groups are significantly separated from four of the six other groups, but two stand apart as exhibiting statistically significant differences from all but one other group. These include Garasias who are separated significantly from all but Bhils, and Khows who are separated significantly from all but Pakanati Reddis.

Two-way analysis of variance was undertaken to evaluate the roles of group membership and sex as main effects, as well as their potential interaction, in the patterning of geometrically scaled tooth size across all seven living ethnic group samples. Results indicate that the two main effects, as well as their interaction are statistically significant (Table 17). All 28 dimensions differ significantly across groups, while 16 differ by sex once group membership is controlled for, thereby reinforcing the results obtained from the ordinally ranked data with Kruskal-Wallis' H test. The interaction between group and sex yielded significant differences for four dimensions. The results provided in Table 17 indicate that across members of these living ethnic groups, ethnic group membership plays the most influential role, followed by differences in tooth size allocation by sex, while the interaction between group membership and group-specific expression of sex dimorphism plays a lesser, but nevertheless significant role.

The 28 variables after EM estimation and geometric scaling were tested for heterogeneity of variance across samples with Levine's test prior to submission to canonical variates analysis with sexes pooled and with sexes considered separately. With sexes pooled eight of 14 dimensions (57.1%) in both the mandible and maxilla are marked by significant heterogeneity of variance across samples (Table 18). Khows stand apart as the exhibiting the greatest heterogeneity among the groups considered for five dimensions, followed by Chenchus with four. Garasias and Vaghela Rajputs depart most in variance for two dimensions, Gompadhomptis and Pakanati Reddis for one, while Bhils are never identified as showing the greatest departure in variance with sexes pooled. Similar results are obtained when sexes are considered separately. Once again, eight of 14 dimensions in both the mandible and maxilla exhibit significant heterogeneity of variance across groups. It is again Khows who stand apart from the others with the greatest number of dimensions (13: 8 among females, 5 among males), followed by Chenchus (7: 5 among females, 2 among males) and Garasias (5: 3 among females, 2 among males). Three groups (GPD, PNT, RAJ) stand apart with only one dimension exhibiting the greatest heterogeneity of variance, while none of the dimensions were found to exhibit greatest heterogeneity among Bhil females and males.

The results of Levene's test indicate substantial heterogeneity of variance across members of the seven living ethnic groups in geometrically scaled tooth dimensions after EM estimation. Because of this, canonical variates analysis was undertaken with separate-groups covariance matrices,

Table 16. Rank sum post hoc tests of sex dimorphism among members of all living samples after EM estimation[1]

	BHI	CHU	GRS	GPD	KHO	PNT	RAJ
BHI	---	0.014	0.467	0.010	0.043	0.064	0.000
CHU	2.196	---	0.001	0.416	0.000	0.000	0.197
GRS	-0.082	2.327	---	0.004	0.005	0.003	0.002
GPD	2.311	-0.213	2.687	---	0.000	0.000	0.171
KHO	-1.721	3.507	-2.573	-3.867	---	0.341	0.000
PNT	-1.524	-3.589	-4.031	-4.031	0.410	---	0.000
RAJ	3.310	0.852	2.868	0.950	4.621	4.687	---

1. z_{obt} below the diagonal, p-values above the diagonal.

Table 17. Two-way analysis of variance across all living samples by group, sex, and the interaction between group and sex after EM estimation and geometric scaling

	Group		Sex		Group * Sex	
Variable	F	p[1]	F	p	F	p
LI1MD	20.192	**0.000**	33.026	**0.000**	0.804	0.567
LI1BL	4.085	**0.000**	8.976	**0.003**	1.927	0.074
LI2MD	11.050	**0.000**	19.013	**0.000**	0.839	0.540
LI2BL	5.094	**0.000**	0.187	0.665	1.864	0.084
LCMD	8.194	**0.000**	50.136	**0.000**	2.441	**0.024**
LCBL	12.182	**0.000**	12.703	**0.000**	1.553	0.158
LP3MD	14.295	**0.000**	15.125	**0.000**	1.754	0.105
LP3BL	11.525	**0.000**	0.511	0.475	1.492	0.177
LP4MD	26.646	**0.000**	19.945	**0.000**	3.121	**0.005**
LP4BL	6.033	**0.000**	14.905	**0.000**	1.945	0.071
LM1MD	9.835	**0.000**	1.006	0.316	3.375	**0.003**
LM1BL	25.658	**0.000**	7.776	**0.005**	0.566	0.758
LM2MD	35.526	**0.000**	0.067	0.795	1.270	0.268
LM2BL	19.741	**0.000**	0.141	0.708	1.392	0.215
UI1MD	4.096	**0.000**	2.511	0.113	1.915	0.075
UI1BL	26.438	**0.000**	0.242	0.623	0.901	0.494
UI2MD	9.910	**0.000**	0.178	0.673	1.987	0.065
UI2BL	13.129	**0.000**	3.479	0.062	0.704	0.647
UCMD	3.412	**0.000**	8.991	**0.003**	1.013	0.415
UCBL	10.608	**0.000**	20.167	**0.000**	0.929	0.473
UP3MD	50.438	**0.000**	11.697	**0.001**	0.522	0.792
UP3BL	15.535	**0.000**	0.009	0.926	1.855	0.086
UP4MD	31.848	**0.000**	9.377	**0.002**	1.537	0.163
UP4BL	3.588	**0.000**	0.049	0.824	1.443	0.195
UM1MD	6.399	**0.000**	7.601	**0.006**	1.715	0.114
UM1BL	33.243	**0.000**	8.346	**0.004**	1.168	0.321
UM2MD	34.805	**0.000**	0.026	0.871	2.726	**0.012**
UM2BL	13.543	**0.000**	39.203	**0.000**	1.289	0.259
Wilks' λ	11.939	**0.000**	8.693	**0.000**	1.323	**0.004**

1. Statistically significant differences in bold.

rather than the usual procedure, which utilizes the total covariance matrix, but which assumes homogeneity of variance across groups (Gittins 1985:76). Complete canonical variates analysis with sexes pooled, which uses all 28 variables, yields six canonical axes, the first three of which combine to account for 81.6% of the total variance (Table 19).

The first canonical axis, which alone accounts for nearly 43% of the variance among samples, draws a distinction between the Khow, which occupy an isolated position on the left side of the array, and all six peninsular Indian samples that occupy positions in the center and on the right side (Fig. 6). Eight variables are especially influential. These include the MD dimensions of six teeth, four of which occur in the mandible (LI1, LI2, LP3, LP4) and two in the maxilla (UP3, UP4), and two BL dimensions both of which occur among the maxillary anterior teeth (UI2, UC). With regard to the MD dimensions, the Khow have smaller geometrically scaled values than their peninsular Indian counterparts, which when coupled with the negative loadings for these variables, makes the canonical values for these variables less negative. By contrast, the Khow have larger geometrically scaled values for the two BL dimensions, which when coupled with the positive loadings for these variables, renders canonical values for these variables more positive. When coupled with the other 20 variables these most influential variables yield a strongly positive composite canonical score for the Khow (1.954) that stands in contrast to the strongly negative scores of Bhils (-1.022) and Garasias (-0.772) and the moderately negative scores of Vaghela Rajputs (-0.212) and

Table 18. Levene's test for univariate heterogeneity of variance across all living samples with sexes pooled and sexes separate after EM estimation and geometric scaling

a) Sexes Pooled

Mandible				Maxilla			
Variable	F	p[1]	Greatest Variation[2]	Variable	F	p	Greatest Variation
LI1MD	1.195	0.306		UI1MD	0.604	0.727	
LI1BL	6.001	**0.000**	KHO	UI1BL	3.162	**0.004**	0.001[3]
LI2MD	1.001	0.423		UI2MD	7.498	**0.000**	CHU
LI2BL	3.805	**0.001**	KHO	UI2BL	4.526	**0.000**	KHO
LCMD	2.555	**0.018**	0.001	UCMD	0.466	0.834	
LCBL	3.185	**0.004**	GPD, RAJ	UCBL	2.667	**0.014**	RAJ
LP3MD	3.691	**0.001**	0.001	UP3MD	2.406	**0.026**	0.001
LP3BL	0.632	0.705		UP3BL	4.091	**0.000**	KHO
LP4MD	4.996	**0.000**	KHO	UP4MD	3.032	**0.006**	GRS
LP4BL	4.514	**0.000**	CHU	UP4BL	2.004	0.062	
LM1MD	1.909	0.076		UM1MD	5.879	**0.000**	CHU
LM1BL	4.310	**0.000**	CHU, GRS, PNT	UM1BL	2.019	0.060	
LM2MD	1.224	0.291		UM2MD	2.094	0.051	
LM2BL	1.029	0.405		UM2BL	1.986	0.065	

b) Sexes Separate

Mandible				Maxilla			
Variable	F	p	Greatest Variation	Variable	F	p	Greatest Variation
LI1MD	1.083	0.370		UI1MD	0.919	0.532	
LI1BL	2.548	**0.002**	GRSF, KHOF, KHOM	UI1BL	1.995	**0.018**	GRSM, KHOM
LI2MD	1.129	0.329		UI2MD	5.328	**0.000**	CHUF
LI2BL	3.590	**0.000**	CHUF, GRSF, KHOF, KHOM	UI2BL	2.257	**0.006**	KHOF
LCMD	2.880	**0.000**	0.001[3]	UCMD	0.940	0.510	
LCBL	2.945	**0.000**	RAJM	UCBL	4.359	**0.000**	KHOM
LP3MD	3.021	**0.000**	CHUF, KHOF	UP3MD	2.288	**0.006**	KHOF
LP3BL	0.604	0.852		UP3BL	2.369	**0.004**	KHOF, KHOM
LP4MD	2.837	**0.001**	KHOF	UP4MD	1.965	**0.021**	GDPM, GRSF, GRSM, PNTF
LP4BL	2.605	**0.001**	CHUF, CHUM, KHOF	UP4BL	1.124	0.334	
LM1MD	1.528	0.101		UM1MD	2.526	**0.002**	CHUF
LM1BL	3.004	**0.000**	CHUM	UM1BL	1.639	0.069	
LM2MD	0.772	0.691		UM2MD	1.138	0.322	
LM2BL	0.945	0.505		UM2BL	1.069	0.383	

1. Significant differences in bold.
2. Greatest Variation= Sample(s) most heterogeneous for the variable under consideration.
3. 0.001= All samples separated by only 0.001mm, precluding any definition of patterning in heterogeneity.

Pakanati Reddis (-0.178). With a moderately positive composite score for this canonical axis (0.333), Chenchus represent somewhat of an anomaly to this overall pattern. This anomaly is largely a consequence of their relatively smaller geometrically scaled MD dimensions for LI1, LI2, and LP3 coupled with a somewhat larger BL dimension for UC.

The second canonical axis, which accounts for 23.7% of the variance, separates the three Dravidian-speaking ethnic groups from southeast India, as well as the high-status Vagehla Rajputs, found in the background of the array with low scores, from the Khow and the two lower-status ethnic groups from Gujarat (BHI, GRS), which possessing high scores occupy the foreground. Canonical variate correlation coefficients identify four variables as especially influential.

Table 19. Standardized coefficients, canonical variate correlation coefficients and assignment accuracies of canonical variates analysis among members of all living groups with sexes pooled after EM estimation and geometric scaling

	Function											
	1		2		3		4		5		6	
Variable	Std.	CVCC[1]	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC
LI1MD	0.802	**-0.324**	0.333	0.027	0.344	-0.066	0.328	-0.238	0.568	-0.018	0.008	-0.204
LI1BL	1.294	0.105	0.083	-0.103	0.591	0.116	0.444	-0.039	0.808	-0.148	0.100	**-0.148**
LI2MD	1.024	**-0.233**	0.081	-0.062	0.255	-0.077	0.658	-0.053	0.977	0.124	0.386	0.184
LI2BL	1.158	0.074	0.031	-0.122	0.425	0.101	0.619	0.071	0.600	**-0.212**	0.005	-0.113
LCMD	0.704	-0.209	0.025	-0.046	0.484	0.088	0.007	**-0.332**	0.451	-0.184	0.448	0.297
LCBL	1.471	0.254	0.236	-0.008	0.317	-0.004	0.999	**0.320**	0.957	0.016	-0.123	-0.123
LP3MD	0.914	**-0.273**	0.127	-0.001	0.377	-0.076	0.568	0.132	0.663	0.072	0.003	0.035
LP3BL	0.855	-0.039	-0.068	-0.179	0.473	0.350	0.390	0.183	0.809	0.111	0.463	**0.391**
LP4MD	0.817	**-0.331**	0.341	0.155	0.198	-0.274	0.320	-0.110	0.824	0.107	0.208	0.132
LP4BL	1.059	0.040	-0.076	-0.037	0.510	0.274	0.538	0.109	0.664	0.173	0.170	**0.332**
LM1MD	0.959	0.113	-0.195	0.027	0.101	-0.066	0.654	-0.238	0.105	**-0.365**	0.140	-0.043
LM1BL	0.597	0.082	0.582	**0.405**	0.357	0.370	0.208	-0.107	0.198	-0.225	-0.222	-0.107
LM2MD	1.048	0.228	0.618	**0.426**	-0.049	-0.417	0.702	0.216	0.628	0.003	0.280	0.266
LM2BL	0.776	0.162	0.169	**0.341**	0.562	0.241	0.044	-0.112	0.967	0.216	0.038	0.057
UI1MD	0.979	0.019	0.115	0.005	0.413	0.022	0.041	**-0.380**	0.593	-0.003	-0.008	-0.139
UI1BL	1.313	0.383	0.172	-0.022	0.459	0.098	0.518	-0.027	0.833	0.112	-0.303	**-0.488**
UI2MD	1.257	-0.126	0.005	-0.183	0.321	-0.136	0.663	-0.036	1.059	0.208	-0.216	**-0.335**
UI2BL	1.604	**0.240**	0.092	-0.120	0.439	-0.069	0.411	-0.170	1.122	0.184	0.140	-0.224
UCMD	0.887	-0.060	0.304	0.129	0.220	-0.070	0.300	**-0.179**	0.412	-0.161	-0.068	-0.054
UCBL	1.207	**0.229**	0.268	0.068	0.449	0.030	0.575	0.135	1.082	0.180	0.183	-0.019
UP3MD	0.597	**-0.520**	0.068	-0.134	0.325	-0.038	0.714	0.237	0.585	-0.018	-0.259	-0.204
UP3BL	0.581	-0.149	-0.068	-0.116	0.591	**0.347**	0.622	0.345	0.285	-0.115	0.148	0.126
UP4MD	0.856	**-0.368**	0.033	-0.090	0.119	-0.350	0.217	-0.205	0.752	0.128	-0.012	-0.059
UP4BL	0.966	0.012	0.397	0.148	0.180	0.050	0.249	0.038	0.780	0.110	0.325	**0.297**
UM1MD	0.642	-0.068	-0.078	-0.105	0.724	**0.250**	0.479	0.000	1.004	0.086	0.020	-0.033
UM1BL	0.972	0.320	0.074	0.201	0.352	0.319	0.118	-0.043	0.010	**-0.480**	0.107	0.102
UM2MD	1.391	0.327	-0.445	-0.287	0.058	**-0.389**	0.196	-0.078	0.641	-0.057	0.210	0.177
UM2BL	0.598	0.079	0.384	**0.306**	0.298	-0.052	0.698	0.219	0.566	-0.124	0.083	0.162
Eigenvalues	0.879		0.487		0.306		0.183		0.153		0.041	
Can. Corr.	0.468		0.327		0.234		0.154		0.132		0.040	
Cum. Disp	0.429		0.667		0.816		0.905		0.980		1.000	

1. CVCC= Canonical Variate Correlation Coefficients (largest absolute correlation between each variable and any discriminant function indicated in bold).

Original Classification Matrix

	BHI	CHU	GPD	GRS	KHO	PNT	RAJ	%Correct
BHI	110	3	4	19	0	14	9	69
CHU	9	90	21	11	12	13	15	53
GPD	9	6	71	7	5	27	13	51
GRS	29	11	9	106	8	11	16	56
KHO	4	11	9	6	129	10	9	72
PNT	12	12	29	19	6	58	17	38
RAJ	10	17	11	20	10	17	69	45
Total	183	150	154	188	170	150	148	55

Jackknifed Classification Matrix

	BHI	CHU	GPD	GRS	KHO	PNT	RAJ	%Correct
BHI	103	3	5	23	0	15	10	65
CHU	11	85	21	11	12	15	16	50
GPD	9	8	66	7	5	29	14	48
GRS	32	11	9	99	9	12	18	52
KHO	5	11	10	6	124	11	11	70
PNT	14	16	35	20	7	40	21	26
RAJ	11	19	12	21	11	16	64	42
Total	185	153	158	187	168	138	154	51

Continued…

Original Classification Matrix

	NW India	SE India	N. Pakistan	% Correct
NW India	388	97	18	77.1
SE India	112	327	23	70.8
N. Pakistan	19	30	129	72.5
TOTAL	519	454	170	73.8

Jackknifed Classification Matrix

	NW India	SW India	N. Pakistan	% Correct
NW India	381	102	20	75.7
SE India	123	315	24	68.2
N. Pakistan	22	32	124	69.7
TOTAL	526	449	168	71.7

These include three of the four dimensions of the mandibular molars (LM1BL, LM2MD, LM2BL) as well as the BL dimension of UM2. These dimensions tend to be relatively large among Khows, Bhis and Garasias, but relatively small among Gompadhomptis, Pakanati Reddis, Garasias, Chenchus and Vaghela Rajputs.

The third canonical axis accounts for nearly 15% (14.9%) of the variance and provides a strong separation between tribal Chenchus and the two Dravidian-speaking caste samples (GDP, PNT) from southeast India. A similar, albeit less marked distinction, separates tribal Bhils from the two Indo-Aryan-speaking caste samples from northwest India (GRS, RAJ). Canonical correlation coefficients identify three variables as particularly influential and all occur among the maxillary posterior teeth (UP3BL, UM1MD, UM2MD). However, LM2MD also yields a fairly strong coefficient (-0.417) on this axis. Chenchus with a high composite score on this axis (0.870), relative to Gompadhomptis (-0.687) and Pakanati Reddis (-0.582) ought to have larger relative dimensions for the two most influential variables with positive correlations (UP3BL: 0.347; UM1MD: 0.250) coupled with smaller relative dimensions for the two most influential variables with negative correlations (LM2MD: -0.417; UM2MD: -0.389). Indeed, this is exactly what may be seen in Table 19. However, the same relationship is weaker among the three samples from Gujarat. As expected, Bhils stand apart from Garasias by possessing relatively larger LM2MD and UM2MD dimensions, coupled with a relatively smaller UP3BL. However, contrary to expectations, Bhils also possess a relatively larger UM1MD. The situation is even more divergent between Bhils and Vaghela Rajputs. Bhils possess a relatively larger LM2MD, but the other three dimensions do not conform to expectations.

Individual classification accuracies by group with the original classification matrix averages 55% overall (Table 19). Accuracies range from a high of 72% among Khows to a low of 38% among Pakanati Reddis. Jackknifing results in a 4% reduction in classification accuracy and this

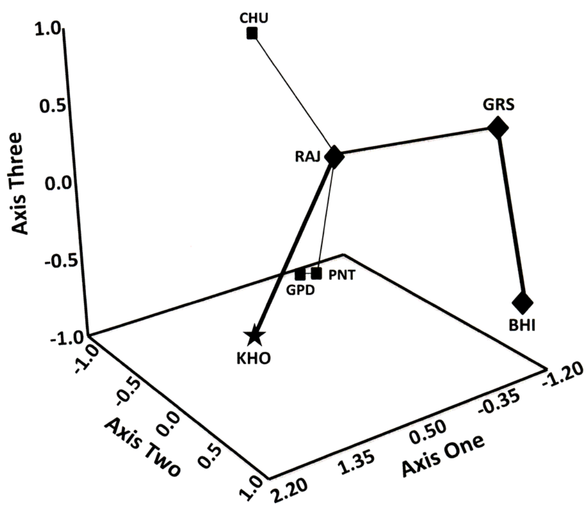

Figure 6. Three-dimensional ordination of group centroids based on scores for the first three canonical axes among all living groups with sexes pooled. Sample abbreviations from Table 1, symbols from figure 2.

reduction, which ranges from 2-4%, is equally apportioned across all groups, except Pakanati Reddis, where the reduction in accuracy was much more marked at 12%. Nevertheless, these assignment accuracy rates based on the original classification matrix and on the jackknifed matrix far exceed the 14.3% accuracy rate expected by chance alone.

Turning to the original classifications, misclassifications of Khow individuals are broadly distributed across the six ethnic groups from peninsular India with no detectable bias in favor of the Bhils and Garasia with whom they share the closest phenetic space in Table 19. Such differences suggest the Khow do not share any specific affinities with any of the peninsular Indian ethnic groups considered here.

At 69%, Bhils represent the second most accurately assigned group by individual. Unlike Khows, there is a distinct patterning in Bhil misassignments. A total of 49 Bhil individuals are misassigned and of these more than half (28, 57.1%) are incorrectly identified as Garasias (19) or Vaghela Rajputs (9). The same is true of Garasias where correct assignments occur in 56% of individuals. Once again, of the 84 Garasia misassignments more than half (45, 53.6%) are incorrectly identified as Bhils (29) or Vaghela Rajputs (16). However, for Vaghela Rajputs, of the 85 misassigned individuals, only 30 (35.3%) were misassigned as Bhils (10) or Garasias (20). Such results suggest a limited pattern of gene flow across ethnic group boundaries among these three ethnic groups of Gujarat that largely concerns the two low-status groups, Bhils and Garasias.

The situation appears different among the three ethnic groups of Andhra Pradesh, for of the 84 missassigned Chenchu individuals, only 34 (42.0%) of those misassignments involved Gompadhomptis (21) or Pakanati Reddis (13). By contrast, among Gompadhomptis, 67 individuals were misassigned and of these nearly half (49.3%) were misassigned as Chenchus (6) or Pakanati Reddis (27), while of the 95 misassigned Pakanati Reddis, 29 were misassigned as Gompadhomptis and 12 were misassigned as Chenchus, accounting for 43.2% of misassignments. Thus, in Andhra Pradesh, gene flow appears to have largely occurred between members of the two Hindu caste groups (GPD, PNT), with involvement of Chenchus limited largely to Gompadhomptis.

This impression of regional effects across ethnic groups is confirmed when individual ethnic groups are pooled into regional samples representing northwestern India, southeast India and northern Pakistan. The original classification matrix yields correct assignment of individuals by region in 73.8% of cases, ranging from a low of 70.8% for members of the three ethnic groups from southeast India (CHU, GPD, PNT) to a high of 77.1% for members of the three ethnic groups of northwest India (BHI, GRS, RAJ). Accuracy rates decrease slightly (2.1%) with the jackknifed classification matrix, ranging from a high of 75.7% for northwest Indian ethnic groups to a low of 68.2% among members of the three ethnic groups from southeast India. As such, these accuracy rates far exceed the expected accuracy rate of 33.3% due to random chance. Such results suggest that both ethnic group membership and geographic region have played meaningful roles in the diversification of these sampled South Asian ethnic groups.

Pairwise Mahalanobis distances (d^2) based upon all six canonical axes (Table 20) were submitted to multidimensional scaling into three dimensions with Kruskal's stress formula 1. The resulting solution was accomplished after 50 iterations, with a stress level of 0.001 (considered near perfect: Kruskal 1964), which accounts for 99.9% of the total variance. The results (Fig. 7) show some similarities and some differences from the three dimensional plot of group centroids for the first three canonical axes (Fig. 6). Once again, the Khow occupy an isolated position on the left side of the array while, with the sole exception of Chenchus, the remaining five peninsular India samples occupy the center and right side of the array. Although Chenchus and Vagelia Rajputs occupy rather isolated positions in the center, the two Dravidian-speaking caste groups (GPD, PNT) and the two low-status Indo-Aryan-speaking ethnic groups from Gujarat (BHI, GRS) occupy unique positions in the upper center and right foreground, respectively. As was the case for the plotting of group centroids for the first three canonical axes in Figure 6, the difference in the phenetic separation between the two caste groups of southeastern India is less than that separating the two low-status groups from northwest India, however the differences are less marked. Perhaps the greatest difference is the identification of Khows as possessing closest affinities to Dravidian-speaking Pakanati Reddis, followed by their low-status counterparts, the Gompadhomptis, and then by the high-status Indo-Aryan-speaking Vaghela Rajputs, while most distant affinities are with the two low-status Indo-Aryan-speaking ethnic groups from Gujarat (BHI, GRS). These results confirm the lack of any specific affinities between the Khow of northern Pakistan and any of the peninsular Indian samples included in this analysis.

A second complete canonical variates analysis was undertaken, but this time the sexes were considered separately to determine whether differential marital mobility leads to differences in the patterning of phenetic affinities among females and males. A total of 13 canonical axes were obtained and the first three combine to account for nearly 70% (69.8%) of the total variance among individuals by ethnic group and sex (Table 21).

The first canonical axis, which accounts for 37.3% of the variance among the 14 samples, draws a distinction between Khow females and males, who occupy an isolated position in the lower left corner of the array, and females and males of all six peninsular Indian samples that occupy positions in the center and on the right (Fig. 8). This axis is strongly influenced by four variables all of which involve MD dimensions. Two occur in the mandible (LI1MD, LP4MD), two in the maxilla (UP3MD, UP4MD), and all but one involve dimensions of the premolars. The Khow have smaller geometrically scaled values than their peninsular Indian counterparts for all four variables, which when coupled with the negative loadings for these variables, makes the canonical values for these variables less negative and the subsequent composite score for this axis more positive. For both Khow females and males greatest differences are with their Bhil counterparts, followed by Gompadhompti females and Garasia females. Least differences occur with Chenchus of both sexes, Vaghela Rajput females, and Gompadhompti males.

The second canonical axis accounts for nearly another 20% (19.6%) of the variance. This axis separates the three Dravidian-speaking ethnic groups from southeast India (CHU, GPD, PNT) from the Khow and the two low-status Indo-Aryan-speaking ethnic groups from Gujarat (BHI, GRS). The high-status Vaghela Rajputs from Gujarat occupy a somewhat intermediate position along this axis that is more proximate to the samples from southeast India than to northwest India. The four greatest contributing variables to this axis are the same as when sexes were pooled (LM1BL, LM2MD, LM2BL, UM2BL) and all receive positive loadings. Not surprisingly, Bhil, Garasia, Khow females and males tend to possess the largest relative values for these variables; in fact, Bhil females have the highest values for all four variables. By contrast Gompadhompti females and males possess the lowest relative values, especially for LM1BL and LM2BL.

The third canonical axis accounts for another 12.9% of the variance and this axis separates Dravidian-speaking tribal Chenchus from their Hindu caste counterparts (GPD, PNT) and, to a lesser degree, tribal Bhils from their low-status

Table 20. Pairwise Mahalanobis distances (d^2) between all living samples based on the six canonical axes obtained with sexes pooled

	BHI	CHU	GPD	GRS	KHO	PNT	RAJ
BHI	---						
CHU	6.266	---					
GPD	4.534	3.375	---				
GRS	2.566	4.491	4.469	---			
KHO	9.450	6.153	7.670	8.316	---		
PNT	3.738	3.097	0.861	3.637	6.438	---	
RAJ	4.166	3.002	3.072	3.225	6.871	1.941	---

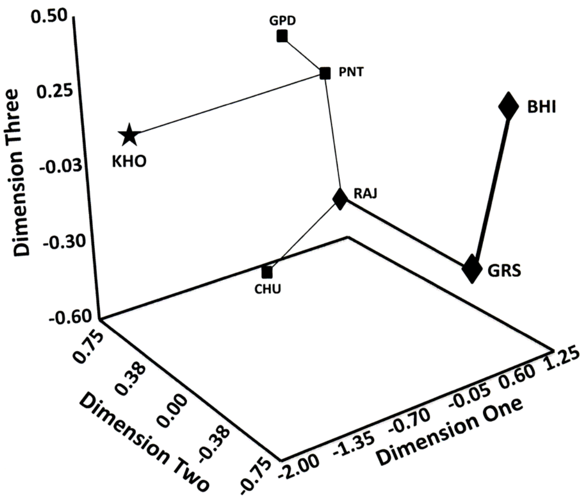

Figure 7. Three-dimensional ordination of multidimensionally scaled pairwise Mahalanobis distances (d^2) for all six canonical axes among all living groups with sexes pooled. Sample abbreviations from Table 1, symbols from figure 2.

Indo-Aryan-speaking caste counterparts, the Garasias. This axis is most influenced by six variables, three of which occur in the mandible (LP3BL, LM1BL, LM2MD) and three in the maxilla (UP3BL, UP4MD, UM1BL). Four of these variables receive positive loadings (LP3BL, LM1BL, UP3BL, UM1BL) and two receive negative loadings (LM2MD, UP4MD). Consequently, high scorers for this axis (CHU, GRS) ought to possess dentitions with relatively large dimensions for those variables receiving positive loadings and relatively small dimensions for those receiving negative loadings, while the reverse ought to be true for those groups that receive low scores (i.e., GPD, PNT). An examination of geometrically scaled values for females and males of these seven living ethnic groups confirms these expectations (Table 13).

As with sexes pooled, a plot of group centroids for the first three canonical axes for the seven living ethnic groups with sexes separate (Fig. 8) indicate

Table 21. Standardized coefficients and canonical variate correlation coefficients among members of all living groups with sexes separate after EM estimation and geometric scaling

	Function													
	1		2		3		4		5		6		7	
Variable	Std.	CVCC[1]	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC
LI1MD	0.785	**-0.347**	0.324	0.003	0.254	-0.101	0.423	0.100	0.133	-0.231	0.466	-0.290	0.408	0.120
LI1BL	1.373	0.131	0.119	-0.095	0.579	0.170	0.202	-0.165	0.248	0.023	1.045	-0.050	0.140	**-0.303**
LI2MD	0.985	-0.254	0.110	-0.071	0.137	-0.113	0.648	0.146	0.416	-0.067	0.947	-0.012	0.523	0.183
LI2BL	1.152	0.078	0.052	-0.117	0.326	0.118	0.488	-0.047	0.350	0.088	0.592	-0.191	0.221	-0.194
LCMD	0.812	-0.156	0.061	-0.037	0.492	0.152	-0.352	**-0.566**	-0.113	-0.288	0.943	0.184	0.368	0.061
LCBL	1.488	0.270	0.267	0.008	0.250	0.038	0.510	-0.059	0.699	**0.338**	1.054	0.147	0.038	-0.295
LP3MD	0.893	-0.294	0.157	0.001	0.300	-0.087	0.513	0.137	0.357	0.110	0.657	0.017	0.025	-0.053
LP3BL	0.907	-0.030	-0.030	-0.165	0.439	0.363	0.212	0.092	0.183	0.154	1.063	0.200	0.489	0.243
LP4MD	0.795	**-0.366**	0.361	0.150	0.101	-0.315	0.387	0.115	0.085	-0.131	0.897	0.005	0.432	0.235
LP4BL	1.049	0.017	-0.064	-0.037	0.437	0.237	0.605	0.358	0.356	0.067	0.521	0.006	0.155	0.177
LM1MD	1.012	0.119	-0.182	-0.126	0.115	-0.122	-0.054	-0.183	0.574	0.174	0.357	-0.303	0.450	**0.355**
LM1BL	0.593	0.069	0.578	0.393	0.312	0.323	0.305	0.154	0.089	-0.151	0.078	**-0.406**	-0.080	0.073
LM2MD	1.046	0.208	0.640	0.421	-0.106	**-0.434**	0.321	-0.004	0.540	0.222	0.710	-0.002	0.315	0.269
LM2BL	0.777	0.150	0.191	**0.340**	0.419	0.170	0.457	0.172	-0.234	-0.203	0.966	0.141	0.354	0.244
UI1MD	1.008	0.017	0.118	-0.012	0.347	-0.005	0.316	0.029	-0.112	-0.365	0.516	-0.178	-0.034	-0.195
UI1BL	1.314	0.367	0.198	-0.015	0.353	0.064	0.584	0.192	0.295	-0.022	0.794	0.008	0.059	-0.304
UI2MD	1.286	-0.125	0.046	-0.178	0.254	-0.127	0.447	0.020	0.335	-0.069	1.188	0.200	-0.179	**-0.480**
UI2BL	1.630	0.234	0.128	-0.110	0.326	-0.080	0.523	0.058	0.130	-0.144	1.228	0.179	0.474	-0.149
UCMD	0.915	-0.037	0.322	0.132	0.190	-0.038	0.142	**-0.291**	0.151	-0.148	0.520	-0.018	0.052	-0.129
UCBL	1.234	0.247	0.301	0.087	0.381	0.062	0.441	-0.049	0.318	0.149	1.186	**0.316**	0.223	-0.181
UP3MD	0.624	**-0.519**	0.083	-0.143	0.302	-0.015	0.294	0.014	0.513	0.218	0.650	-0.042	-0.005	-0.048
UP3BL	0.608	-0.138	-0.046	-0.106	0.576	**0.377**	0.254	0.036	0.489	0.331	0.410	-0.017	0.444	0.217
UP4MD	0.883	**-0.381**	0.044	-0.106	0.077	-0.355	0.229	-0.004	0.040	-0.194	0.814	0.032	0.137	-0.002
UP4BL	0.953	0.004	0.418	0.153	0.061	0.030	0.399	0.086	0.013	-0.001	0.827	0.137	0.392	0.253
UM1MD	0.643	-0.079	-0.060	-0.121	0.608	0.192	0.622	0.198	0.171	-0.093	0.926	-0.069	0.183	0.190
UM1BL	0.995	0.335	0.089	0.200	0.305	0.321	0.048	-0.170	-0.009	-0.046	0.145	**-0.382**	0.221	0.212
UM2MD	1.387	-0.125	-0.434	-0.178	-0.047	-0.127	0.369	0.020	-0.002	-0.069	0.639	0.200	0.401	**-0.480**
UM2BL	0.687	0.118	0.403	0.317	0.376	0.029	-0.047	-0.310	0.574	0.262	0.854	0.114	0.124	0.118
Eigenvalues	0.941		0.496		0.324		0.234		0.202		0.142		0.056	
Can. Corr.	0.484		0.332		0.245		0.189		0.168		0.124		0.053	
Cum. Disp	0.373		0.569		0.698		0.791		0.871		0.927		0.949	

Continued…

	Function											
	8		9		10		11		12		13	
Variable	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC	Std.	CVCC
LI1MD	0.109	-0.078	1.127	0.237	0.313	-0.216	0.639	0.061	0.574	-0.149	0.710	0.142
LI1BL	0.376	-0.225	0.880	-0.104	0.322	0.041	0.706	-0.041	0.986	-0.151	0.672	0.127
LI2MD	-0.159	0.093	0.538	-0.068	0.162	-0.298	0.450	-0.002	0.282	**-0.306**	0.491	0.021
LI2BL	-0.620	0.312	0.828	-0.164	0.347	0.040	0.832	0.023	0.376	**-0.432**	0.597	0.112
LCMD	-0.074	0.204	0.501	-0.202	-0.144	-0.432	0.321	-0.126	0.763	0.036	0.570	0.117
LCBL	-0.151	0.052	1.003	-0.139	0.159	-0.077	0.747	-0.095	1.241	-0.115	0.362	-0.125
LP3MD	-0.144	0.102	0.267	**-0.364**	0.247	-0.043	0.405	-0.055	0.726	0.281	0.439	0.085
LP3BL	0.027	-0.145	0.687	-0.217	0.373	0.127	0.790	0.259	0.622	-0.031	0.952	**0.434**
LP4MD	-0.071	0.004	0.608	-0.147	0.606	0.228	0.451	-0.059	0.889	0.279	0.383	-0.056
LP4BL	0.317	-0.298	0.487	**-0.360**	-0.037	-0.076	0.767	0.299	0.503	0.017	0.394	0.110
LM1MD	-0.015	0.122	0.776	0.321	0.074	-0.223	0.195	-0.130	0.662	0.218	0.259	-0.152
LM1BL	0.137	0.064	0.495	0.137	0.225	0.033	0.475	0.151	0.620	0.128	0.329	-0.001
LM2MD	-0.091	0.081	0.566	0.091	-0.129	-0.320	0.564	0.157	0.594	0.023	0.781	0.169
LM2BL	-0.436	0.263	0.890	0.309	0.234	0.000	0.240	0.002	0.286	-0.130	0.329	-0.046
UI1MD	0.249	-0.193	0.570	0.073	-0.166	**-0.437**	0.615	0.081	0.563	-0.028	0.075	-0.251
UI1BL	0.035	-0.163	0.994	0.182	0.204	0.082	0.125	**-0.567**	0.863	0.024	0.934	0.301
UI2MD	-0.457	0.228	0.975	-0.007	0.526	0.142	1.073	0.184	1.017	0.083	0.678	0.015
UI2BL	0.099	-0.212	1.090	-0.002	0.683	0.378	0.552	**-0.441**	0.860	-0.187	0.516	-0.130
UCMD	-0.187	0.210	0.642	-0.008	0.419	-0.016	0.528	-0.008	0.385	-0.103	0.373	-0.018
UCBL	0.029	-0.098	0.894	-0.073	0.174	0.067	0.748	-0.114	0.548	-0.304	0.619	-0.073
UP3MD	-0.145	0.086	1.024	0.236	0.086	-0.038	0.480	-0.061	0.798	0.344	0.530	0.087
UP3BL	0.027	-0.073	0.564	-0.118	0.396	0.307	0.172	-0.136	0.402	0.135	0.265	-0.107
UP4MD	0.199	-0.206	1.019	0.194	0.321	0.015	0.796	0.140	0.814	0.314	0.803	0.153
UP4BL	-0.156	-0.099	0.319	-0.265	0.129	0.163	0.450	0.075	0.992	**0.390**	0.064	-0.230
UM1MD	-0.227	0.225	0.801	**0.375**	-0.073	-0.281	0.553	0.139	0.673	0.248	-0.018	-0.280
UM1BL	-0.333	0.197	0.298	0.005	0.421	0.238	0.527	0.192	0.625	0.195	0.588	-0.021
UM2MD	-0.077	0.020	0.746	0.176	0.389	0.056	0.799	0.275	0.695	0.037	0.442	-0.144
UM2BL	0.335	-0.201	0.970	0.246	0.417	0.277	0.756	0.303	0.339	-0.150	0.133	**-0.321**
Eigenvalues	0.043		0.030		0.022		0.014		0.011		0.007	
Can. Corr.	0.042		0.030		0.021		0.014		0.011		0.007	
Cum. Disp	0.966		0.978		0.987		0.993		0.997		1.000	

1. CVCC= Canonical Variate Correlation Coefficients (largest absolute correlation between each variable and any discriminant function indicated in bold).

that the Khow occupy an isolated position in the left foreground of the array. The two low-status ethnic groups from northwest India (BHI, GRS) occupy the right side, while the three Dravidian-speaking ethnic groups from southeast India are separated along the third canonical axis in the center back of the array. Once again, Vaghelia Rajputs occupy a position more proximate phenetically to these Dravidian-speaking groups than to their Indo-Aryan-speaking counterparts from northwest India. Of particular importance is the fact that females and males of each ethnic group exhibit closest affinities to one another, in which the amount of phenetic separation by sex within ethnic groups is lowest for Pakanati Reddis and Garasias and greatest among Khows and Gompadhomptis. In addition, which sex appears most unique phenetically varies across ethnic groups. For Gompadhomptis and Bhils, it is females who occupy the relatively more isolated phenetic space, whereas among Chenchus and Khows, this distinction is accorded to males.

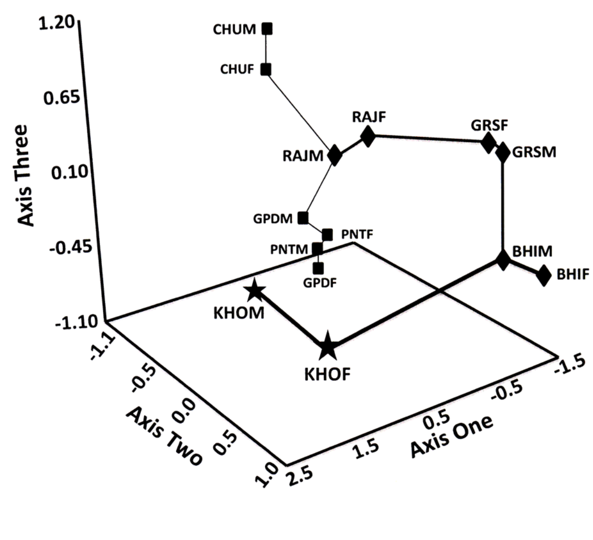

Figure 8. Three-dimensional ordination of group centroids based on scores for the first three canonical axes among all living groups with sexes separate. Sample abbreviations from Table 1, symbols from figure 2.

For two ethnic groups (GRS, RAJ) neither sex appears more phenetically isolated than the other. Such results suggest that marital migration may play different roles depending on the ethnic group under consideration.

Individual classification accuracies by group and by sex with the original classification matrix averages 42% overall (Table 22). Accuracies range from a high of 62% among Bhil females to a low of 16% among Pakanati Reddi males. Jackknifing results in an 8% reduction in classification accuracy and this reduction ranges from a low of 5% for Khow females to 19% among Gompadhompti males. Many of these misassignments are due to misidentifying females as males of the same ethnic group and vice versa. Once these are taken into account, correct assignments by group regardless of sex ranges from a high of 76.8% among Bhil females to a low 28.0% among Pakanati Reddi males. These assignment accuracy rates, based both on the original classification matrix and on the jackknifed matrix, far exceed the 7% accuracy rate expected by chance alone.

The regional effects across ethnic groups initially identified from the sex-pooled analysis are confirmed when individual ethnic groups with sexes considered separately are pooled into regional samples representing northwestern India, southeast India and northern Pakistan. The original classification matrix yields correct assignment of individuals by region in 73.9% of cases, ranging from a low of 71.1% for members of the three ethnic groups from southeast India (CHU, GPD, PNT) to a high of 77.3% for members of the three ethnic groups of northwest India (BHI, GRS, RAJ). Accuracy rates decrease slightly (2.8%) with the jackknifed classification matrix, ranging from a high of 75.1% for northwest Indian ethnic groups to a low of 67.4% among the Khow of northern Pakistan. Nevertheless, despite being considered separately by sex, these accuracy rates far exceed those expected by random chance. Indeed, these results indicate that alongside ethnic group membership and geographic region somewhat differential effects by sex have also played a meaningful role in the diversification of these South Asian ethnic groups.

Pairwise Mahalanobis distances (d^2) based upon the 13 canonical axes (Table 23) were submitted to multidimensional scaling with Kruskal's formula 1 and, as was the case with the sex-pooled analysis, the results (Fig. 9) show close similarities to those obtained with the first three canonical axes (Fig. 8). The overall positioning of the ethnic groups are the same as when sexes are pooled, with Khow females and males occupying an isolated position on the left side with only a very distant connection to Pakanati Reddi females and males. What differences occur involve the relative phenetic separations between females and males of the same ethnic group. Whereas Pakanati Reddi and Garasia females and males were previously identified as showing close phenetic affinities to one another, while greater phenetic distances separated Khowar and Gompadhompti females and males, multidimensionally scaled d^2 values exacerbate sex-based differences across all of the groups and the directional vector of these differences are diverse as well.

This greater sensitivity to sex-based differences within ethnic groups is particularly marked among Pakanati Reddis, Chenchus, and especially Vaghela Rajupts. In fact, in the latter case, the amount of phenetic separation between females and males is equivalent to that which separates Vaghela Rajput females from Chenchu males. These results not only further confirm the lack of affinities between the Khow of northern Pakistan and the peninsular Indian samples included in the analysis, but also indicate: 1) subtle sex-based differences in tooth size allocation occur across members of these ethnic groups, 2) these differences are neither of the same magnitude nor allocational expression across the dentition and, 3) these differences are detected by the canonical axes that account for a lesser proportion of the total variance among samples, as might be expected from the results provided in Tables 12, 15, and 16.

Phase three: Odontometric variation among prehistoric and living Central Asians and South Asians

Sex-pooled average values for the 28 odontometric variables were obtained for 12 prehistoric samples from Central Asia, the Indus Valley of Pakistan and west-central peninsular India that range in antiquity from the early

Table 22. Assignment accuracies of canonical variates analysis among all living groups with sexes separate after EM estimation and geometric scaling

Original Classification Matrix

	BHIF	BHIM	CHUF	CHUM	GPDF	GPDM	GRSF	GRSM	KHOF	KHOM	PNTF	PNTM	RAJF	RAJM	%C[1]
BHIF	43	10	1	0	0	0	4	4	0	0	2	1	3	1	62
BHIM	13	45	2	0	2	3	3	8	1	0	3	4	3	3	50
CHUF	2	1	28	9	4	3	1	2	1	2	7	0	5	3	41
CHUM	2	2	10	45	5	10	3	4	0	6	1	4	8	3	44
GPDF	0	6	2	0	33	6	1	0	2	0	7	3	7	3	47
GPDM	2	2	1	2	1	26	0	4	4	1	5	7	0	4	38
GRSF	9	1	2	5	3	1	38	12	3	0	5	2	5	3	43
GRSM	7	10	0	3	2	2	16	38	4	2	3	2	2	10	38
KHOF	2	2	3	3	4	4	1	3	43	19	2	4	3	1	46
KHOM	0	2	2	5	0	2	0	1	15	51	0	2	4	0	61
PNTF	1	1	2	2	8	3	4	3	2	0	18	8	5	3	30
PNTM	5	6	8	3	7	15	3	7	4	0	11	15	2	7	16
RAJF	2	2	2	0	1	0	3	1	1	0	3	1	8	3	30
RAJM	2	3	10	8	4	8	5	9	5	2	3	8	11	49	39
Total	90	93	73	85	83	83	82	96	85	83	70	61	66	93	42

Jackknifed Classification Matrix

	BHIF	BHIM	CHUF	CHUM	GPDF	GPDM	GRSF	GRSM	KHOF	KHOM	PNTF	PNTM	RAJF	RAJM	%C[1]
BHIF	37	12	2	0	1	0	5	5	0	0	2	1	3	1	54
BHIM	13	40	2	0	3	3	3	8	1	0	4	5	3	5	44
CHUF	2	1	22	14	4	3	1	2	1	2	7	0	6	3	32
CHUM	2	2	13	38	5	11	3	5	0	8	1	5	7	3	37
GPDF	0	6	3	0	26	6	1	1	2	0	11	3	8	3	37
GPDM	2	2	1	5	17	13	0	6	4	1	5	7	0	5	19
GRSF	10	3	2	5	3	1	33	14	3	0	4	3	5	3	37
GRSM	8	12	0	3	2	3	17	31	4	2	3	2	3	11	31
KHOF	2	2	4	3	4	4	1	4	34	22	3	6	3	2	36
KHOM	0	2	3	3	0	3	0	1	17	47	0	3	4	1	56
PNTF	1	2	4	2	8	3	3	4	2	0	13	9	5	4	22
PNTM	5	6	8	3	6	18	3	7	4	0	12	9	2	10	10
RAJF	2	2	2	1	1	0	4	1	1	0	3	1	5	4	19
RAJM	2	4	10	8	5	10	6	10	5	2	4	8	11	42	33
Total	86	96	75	85	85	78	80	99	78	84	72	62	65	97	34

Original Classification Matrix

	BHI	CHU	GPD	GRS	KHO	PNT	RAJ	%Correct
BHI	111	3	5	19	1	10	10	70
CHU	7	92	22	10	9	12	19	54
GPD	10	5	75	5	7	22	14	48
GRS	27	10	8	104	9	12	20	55
KHO	6	13	10	5	128	8	8	72
PNT	13	15	33	17	6	52	17	34
RAJ	9	20	13	18	8	15	71	46
Total	183	158	166	178	168	131	159	55

Jackknifed Classification Matrix

	BHI	CHU	GPD	GRS	KHO	PNT	RAJ	%Correct
BHI	102	4	7	21	1	12	12	64
CHU	7	87	23	11	11	13	19	51
GPD	10	9	62	8	7	26	16	45
GRS	33	10	9	95	9	12	22	50
KHO	6	13	11	6	120	12	10	67
PNT	14	17	35	17	6	43	21	28
RAJ	10	21	16	21	8	16	62	40
Total	182	161	163	179	162	134	162	50

Continued…

Original Classification Matrix

	NW India	SE India	N. Pakistan	TOTAL	% Correct
NW India	389	96	18	503	77
SE India	112	328	22	462	71
N. Pakistan	19	31	128	178	72
TOTAL	520	455	168	1143	74

Jackknifed Classification Matrix

	NW India	SW India	N. Pakistan	TOTAL	% Correct
NW India	378	107	18	503	75
SE India	123	315	24	462	68
N. Pakistan	22	36	120	178	67
TOTAL	523	458	162	1143	71

Neolithic to the last quarter of the 1st millennium B.C. (see Hemphill 2013). The canonical variates obtained from the analysis of living groups with sexes pooled were used to calculate group centroid scores for these sex-pooled prehistoric samples. The resulting plot (Fig. 10) identifies four sample aggregates. The first, located in the lower left, includes the prehistoric sample from west-central India (INM) and all but the latest (SKH) of the prehistoric Indus Valley samples. The second aggregate, found in the upper right, includes the two low-status ethnic groups from Gujarat (BHI, GRS) and the latest prehistoric sample from the Indus Valley (SKH). The third aggregate is located in the center foreground and includes the three living ethnic groups from southeast India (CHU, GPD, PNT) as well as the high-status Vaghela Rajputs (RAJ) from northwest India. The fourth aggregate is composed of the prehistoric samples from southern Central Asia and the Khow are identified as members of this aggregate, possessing closest affinity to the ancient sample from Geoksyur (GKS), located in the Tedjen oasis of southern Turkmenistan.

Multidimensional scaling of pairwise Mahalanobis d^2 pairwise distances (Table 24) for the six canonical axes obtained from the analysis of the seven living ethnic groups with sexes pooled was accomplished in 73 iterations with a good fit (stress= 0.051) that accounts for 98.2% of the variance. Two primary sample aggregates are identified in Figure 11. The first is composed of the prehistoric samples from south-central Asia found on the left side of the array. The Khow are identified as a peripheral member of this aggregate with closest affinities to the ancient sample from Geoksyur. Prehistoric samples from the Indus Valley and west-central peninsular India (INM) form the second aggregate, which is found in the right foreground. These two aggregates are linked by the Protohistoric Grave Complex sample from Timargarha (TMG), which is found in the center of the array. Living samples are divided into two groups. The first includes the three Indo-Aryan-speaking ethnic groups from northwest India. These samples exhibit greatest affinities to one another, except for the tribal Bhils, which are identified as possessing closest affinities to the early Neolithic sample from Mehrgarh. The two Dravidian-speaking caste samples from southeast India are identified as possessing closest affinities to one another in the upper center of the array, and link to the other samples via the prehistoric sample from Timargarha. Tribal Chenchus are identified as an isolate, possessing no close affinities to any of the other samples included in this analysis.

Discussion

Patterning of tooth size

Tooth size allocation among the Khow: When raw measurements are employed principal components analysis identifies the first and most influential component as a general size factor; this is the case both before and after EM estimation. Similar results have been reported by other researchers analyzing samples from other world regions (Harris & Bailit 1988; Harris & Rathbun 1989; Hemphill 2016a; Lukacs & Hemphill 1993; Potter *et al.* 1968; Townsend 1976) and worldwide

Table 23. Pairwise Mahalanobis distances (d^2) between all living samples based on the 13 canonical variate axes obtained with sexes separate

	BHIF	BHIM	CHUF	CHUM	GRSF	GRSM	GPDF	GPDM	KHOF	KHOM	PNTF	PNTM	RAJF	RAJM
BHIF	---													
BHIM	1.938	---												
CHUF	7.428	7.046	---											
CHUM	8.503	6.339	1.906	---										
GRSF	2.868	4.413	5.117	5.655	---									
GRSM	3.785	2.810	6.063	5.165	1.727	---								
GPDF	5.306	5.549	3.921	5.493	5.117	5.866	---							
GPDM	5.923	4.766	3.806	3.531	5.516	4.578	1.449	---						
KHOF	10.024	8.336	6.927	6.969	7.811	7.474	7.607	6.920	---					
KHOM	14.632	10.646	8.742	6.659	12.542	10.851	11.644	9.073	2.385	---				
PNTF	5.254	5.036	3.493	5.139	3.850	4.992	1.767	2.761	6.497	10.555	---			
PNTM	4.848	3.600	3.388	3.712	4.608	4.145	1.193	0.973	5.764	8.102	1.331	---		
RAJF	4.872	4.620	3.030	4.261	2.869	4.441	4.127	4.916	7.266	11.011	2.308	3.374	---	
RAJM	6.329	4.129	3.564	4.060	4.507	3.827	4.100	3.176	6.683	8.636	2.999	2.262	2.427	---

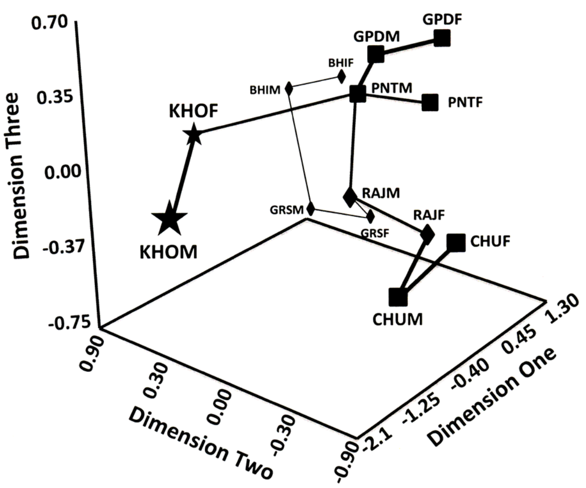

Figure 9. Three-dimensional ordination of multidimensionally scaled pairwise Mahalanobis distances (d^2) for all 13 canonical axes among all living groups with sexes separate. Sample abbreviations from Table 1, symbols from figure 2.

(Hanihara & Ishida 2005; Harris 1998; Harris & Rathbun 1991). One of the few other studies that examined inter-individual differences in tooth size allocation was undertaken among Pima Indians by Potter and coworkers (1968). These researchers found that after a general size factor, the next most influential distinction occurred by region, in which posterior teeth, regardless of dimension, tended to receive higher loadings than anterior teeth. The next distinction was a dimensional contrast among the anterior teeth in which BL dimensions received higher loadings than their complementary MD dimensions. The last identified contrast was the same dimensional distinction, but among posterior teeth.

Another set of studies that examined inter-individual differences in tooth size allocation patterns were based on Harris and Bailit's investigation of Solomon Islanders (Harris & Bailit 1987, 1988; Harris 1998). After identifying a general size factor as accounting for the greatest amount of variation, Harris and Bailit (1988) identified a dimensional contrast (MD vs. BL) as second most important. This was followed by a contrast between anterior and posterior teeth regardless of dimension and then a distinction among posterior teeth between premolars and molars, also regardless of dimension. Harris and Bailit further report that "pole" teeth within dental fields consistently receive higher loadings than distal teeth.

In a subsequent investigation of inter-individual patterns of tooth size allocation among Solomon Islanders, Harris (1998) reported that the first two components feature both dimensional and regional distinctions. In the first, MD dimensions received higher loadings than BL dimensions and there was a general fall-off in loadings from the front to the back of the arcade. In contrast, the second component provided a partial reverse of this pattern in which BL dimensions received higher loadings than their complementary MD dimensions, but the regional pattern of higher loadings among anterior teeth relative to posterior teeth was retained. The third and fourth components were identified as distinguishing premolars and molars from all other teeth, respectively.

Comparison of the results obtained by principal components of raw measurements among Khows to those obtained among Pima Indians and Solomon Islanders reveals both similarities and differences. Like Pima Indians the second most influential factor among females is the distinction by dimension regardless of arcade region. Like Solomon Islanders, Khow males are marked by a more complex pattern that mixes distinctions by dimension and arcade region. However, unlike Solomon Islanders, there is also a contrast by jaw that affects the mandibular anterior teeth and P3. The third component among Khows draws a contrast by dimension (MD vs. BL) regardless of arcade region, just as was found by Harris and Bailit among Solomon Islanders. This stands in marked contrast to Pima Indians where this contrast was confined to the anterior teeth or to Harris' (1998) later findings in which this dimensional distinction was compounded by a regional effect

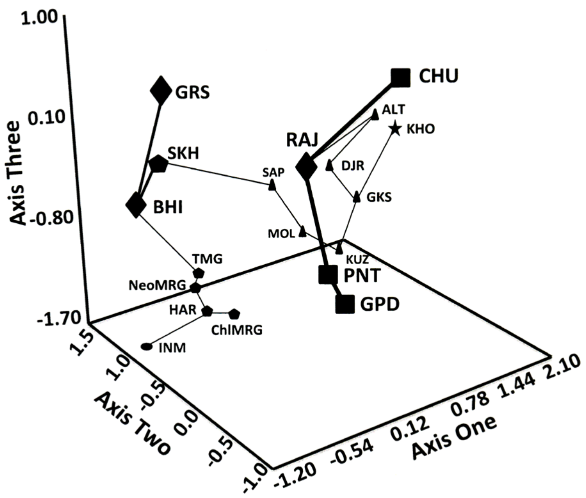

Figure 10. Three-dimensional ordination of group centroids based on scores for the first three canonical axes among all living and prehistoric samples with sexes pooled. Sample abbreviations from Table 1, symbols from figure 2.

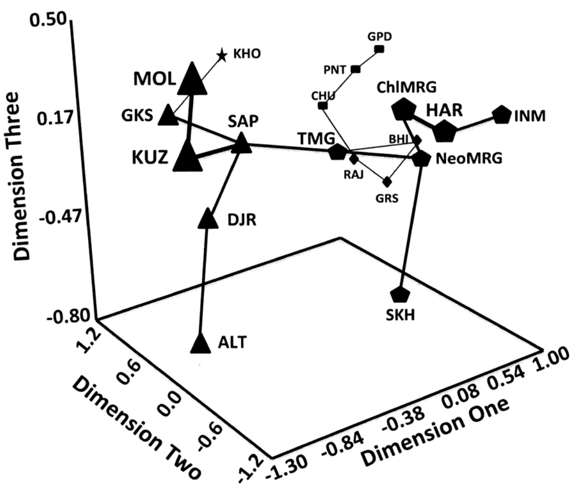

Figure 11. Three-dimensional ordination of multidimensionally scaled pairwise Mahalanobis distances (d^2) among all living and prehistoric samples based on all six canonical axes among all living and prehistoric samples with sexes pooled. Sample abbreviations from Table 1, symbols from figure 2.

Table 24. Pairwise Mahalanobis distances (d^2) between all living and archaeologically derived samples based on the six canonical variate axes obtained from all living samples with sexes pooled

	ALT	BHI	ChlMRG	CHU	DJR	GPD	GKS	GRS	HAR	INM	KHO	KUZ	MOL	NeoMRG	PNT	RAJ	SKH	SAP	TMG
ALT	---																		
BHI	15.955	---																	
ChlMRG	8.759	5.955	---																
CHU	13.079	6.266	11.695	---															
DJR	3.666	10.557	7.597	9.945	---														
GPD	15.546	4.534	6.662	3.375	10.605	---													
GKS	5.476	11.643	9.871	10.533	3.538	9.664	---												
GRS	16.368	2.566	8.413	4.491	9.779	4.469	11.028	---											
HAR	11.091	7.406	2.332	13.484	9.928	10.033	12.203	11.390	---										
INM	13.840	6.275	5.081	14.761	13.213	9.080	14.952	9.816	3.191	---									
KHO	11.879	9.450	10.638	6.153	7.643	7.670	6.455	8.316	14.421	16.039	---								
KUZ	5.462	13.526	7.758	14.379	2.744	13.158	2.115	14.851	10.088	12.839	10.451	---							
MOL	5.713	11.608	8.679	14.445	3.688	12.767	3.947	13.334	10.166	12.916	8.455	2.289	---						
NeoMRG	10.218	3.565	2.137	9.749	9.056	6.409	11.331	6.896	1.497	3.661	9.707	9.216	9.294	---					
PNT	14.600	3.738	6.344	3.097	7.801	0.861	8.461	3.637	8.590	8.133	6.438	10.438	10.434	5.274	---				
RAJ	12.400	4.166	8.249	3.002	9.140	3.072	11.737	3.225	10.777	11.754	6.871	14.437	12.214	7.560	1.941	---			
SKH	9.569	5.271	5.068	11.157	8.407	10.169	10.683	6.852	4.776	6.283	10.764	8.568	8.791	3.598	8.828	8.722	---		
SAP	5.327	7.501	7.269	9.952	3.063	9.697	4.176	8.866	8.112	10.861	6.404	3.061	2.441	7.240	7.451	8.389	6.591	---	
TMG	10.523	6.829	2.393	12.818	9.361	9.929	11.635	10.261	1.117	2.793	13.276	9.521	9.600	1.094	8.563	10.036	3.674	7.545	---

(anterior vs. posterior). The fourth component among Khows draws a distinction by jaw for both females and males. This stands in contrast to the dimensional distinction that is confined to the posterior teeth among Pima Indians, as well as the tooth type distinction between premolars and molars identified among Solomon Islanders by both Harris and Bailit and by Harris. In marked contrast to the findings of Harris and Bailit (1988) among Solomon Islanders, there is no pattern in which "pole" and distal teeth within dental fields tended to receive higher loadings or exhibit higher communalities than distal teeth.

Of "pole" teeth and "distal" teeth: It has been claimed by some researchers that "pole" teeth within dental fields are always more stable than their distal counterparts and the reason often given is that as the earliest-developing member within a specific dental field the "pole" tooth is less affected by environmental factors during development (Alvesalo & Tigerstedt 1974; Dahlberg 1986; Harris & Bailit 1988; Townsend & Brown 1980). Keene (1982) was of the opinion that each of the individual cusps experienced considerable dynamism prior to coalescence at the cap stage at which their final positions were fixed. Recent research in experimental genetics and embryology have indicated that the cap stage is especially crucial for determination of crown shape and size, for it is at this time that the primary enamel knot appears (Jernvall & Thesleff 2012). The primary enamel knot serves as a signaling center that brings cusp formation into tooth development (Jernvall, Åberg, Kettunen, Keränen & Thesleff 1998; Jernvall & Thesleff 2012; Vaahtokari, Åberg, Jernvall, Keränen & Thesleff 1996). Secondary enamel knots form at the site of future cuspal apices during the bell stage (Jernvall, Kettunen, Karavanova, Martin & Thesleff 1994; Thesleff & Nieminen 1996) and cusps form via cell proliferation and mechanical folding (Thesleff & Jernvall 1997; Weiss, Stock & Zhao 1998). Even slight changes that influence the positioning or timing of secondary knots can result in quantifiable differences in crown morphology and hence, shape (Salazar-Ciudad & Jernvall 2002, 2010). Consequently, Townsend and coworkers (2009) suggest that later-developing teeth within a dental field will be marked by greater variation in both size and shape because such teeth spend a relatively longer period in the soft tissue stage.

While this assertion makes intuitive sense and is supported by Harris and Bailit's (1988) finding that commonalities for pole teeth were higher than for distal teeth within dental fields, especially for MD dimensions, the pattern simply does not hold for Khow females and males. Levene's test revealed that one-fourth of the 28 variables are marked by significant heterogeneity of variance between Khow females and males. Logically, the later developing distal field members ought to be disproportionately variable relative to their mesial counterparts. This was not found to be the case. Instead, of the eight variables found to exhibit heterogeneous variance between Khow females and males five are "pole" teeth and only two are distal teeth. Still further, Khow females were found to be more variable than their male counterparts for seven of these eight variables. Such results run counter to claims of greater ontogenetic canalization in females (Dettwyler 1992; Grayson 1990; Hoyenga & Hoyenga 1982; Leonard 1991; Stini 1969, 1972, 1985, Stinson 1985), which ought to provide greater resistance to environmentally induced stress during crown formation.

Sex estimation: Complete discriminant function analysis of tooth size among Khow females and males found that sex could be accurately determined in 79-86% of cases from the original data. Cross-validation through jackknifing lowered accuracy rates somewhat to 73-76%. Backwards stepwise discriminant function analysis yielded correct sex identification in 75-83% of cases from the original data, while cross-validation reduced accuracy rates to 74-79%. Such results fall toward the lower end of accuracy rates when compared to a small sample of similar efforts conducted on other populations. The accuracy rates fall below the 75-85% success rate obtained by Thompson (2013:415) among individuals recovered from Mound 72 at Cahokia, the 88.4-91.0% accuracy rate obtained by Ditch and Rose (1972:63) among individuals recovered from Dickson Mounds, and the 74.5-100% accuracy rate obtained by Viciano and coworkers (2011:103) among those buried by the Mt. Vesuvius eruption in 79 CE. Nevertheless, the accuracy rate obtained among Khows are quite similar to the rate of 69-80.4% obtained by Ateş and coworkers (2006:290) among modern Turks and the rate of 62.9-75.2% obtained by Prabhu and Acharaya (2008:129.e4) among modern Indians.

There are two potential causes behind these differences in the accuracy rates in sex estimation achieved through odontometric measurements. The first is that higher accuracy rates for sex estimation in the skeletal remains of ancient individuals whose actual sex is unknown, is contingent on how well differences in tooth size correlate with skeletal estimators of sex, such as cranial robusticity, pelvic morphology, and various metrical properties of the cranial and postcranial skeleton, which themselves are known to suffer from varying degrees of population specificity (Bidmos & Dayal 2004:4; Bruzek & Murail 2006; Frutos 2005:156; Henke 1977; Işcan, Loth, King, Shihai, & Yoshino 1998:25; Krogman & Işcan 1986; Steyn & Işcan 1997:116; Stojanowski & Seidemann 1999). As such, they do not provide an *independent* estimator of sex; they merely provide a measure of agreement with these other markers. Therefore, if the skeletal estimator proves inaccurate for the estimation of sex for a specific population sample, odontometric agreement with this other indicator is likewise inaccurate. As such, judging odontometric estimators of sex more accurate when applied to ancient skeletal samples is little more than circular reasoning.

A second possibility for the lower accuracy rates among the Khow and among the living samples studied by Ateş and coworkers (2006) and by Prabhu and Acharaya (2009) relative to the ancient remains examined by Thompson (2013) and Viciano *et al.* (2011) has to do with the absolute level of sex dimorphism in tooth size. That is, populations who possess dentitions marked by less sex dimorphism in tooth size are likely to be more difficult to distinguish between females and males than those populations with greater sex dimorphism in tooth size. If such is the case, highest accuracies ought to be associated with populations with greatest sex differences in tooth size. This is exactly the case across these four cases and the Khow individuals of the current study. Greatest average sex dimorphism occurs in the ancient individuals from Mound7 2 at Cahokia (3.679%) and Herculaneum (3.358%) as does average sex estimation accuracy (80% and 87.3%, respectively), while lowest average sex dimorphism (modern Turks: 3.12%, Khows: 2.48%, modern Indians: 2.214%) are associated with lowest sex estimation accuracies (Turks: 73.7%, Khows: 74.5%, modern Indians: 69.1%). However, with only five samples this relationship is only tentative and will require further investigation with a larger number of samples.

Group identification with geometrically scaled odontometric data: When raw measurements are geometrically scaled to partially mitigate the influence of gross size, the allocation of permanent tooth size across the dentition was found to provide a reasonable basis for examination of population relationships among members of living South Asian ethnic groups. Plots of group centroids obtained through multidimensional scaling and complete canonical variates analysis consistently identified the Khow as possessing little affinity to any of the peninsular Indian ethnic groups. Among the latter, a regional effect was observed in which ethnic groups of northwestern India tended to exhibit closest affinities to one another (77.1% accuracy orig., 75.7% jackknifed), and the same was true for the three ethnic groups from southeast India (70.8% accuracy orig., 68.2% jackknifed).

Still further, within these regional aggregates, it was found that in northwest India non-Hindu tribal Bhils and low-status Hindu Garasias shared closer affinities to one another than either did to high-status Vaghela Rajputs. Such results make good sense, given the oral tradition that Garasias represent a separate ethnic group arising from intermarriages between Rajput overseers and Bhil women. The children produced by such marriages, now known as Garasias, often served as *thakurs* who acted as intermediaries between Rajput landowners and Bhil field laborers and domestics (Carstairs 1954; Dave 1960; Deliége 1980). In subsequent years, strong subdivisions arose among Garasias based upon wealth and social status. These include Rajput Garasia, Dungri Garasia, and Bhil Garasia. Among the latter, from which the current sample was obtained, subsequent intermarriages with Bhils have continued, while marriages between Bhil Garasias and Rajputs are unheard of (Mann 1993).

By contrast, in southeast India closer affinities occur between Gompadhompti Madigas and Pakanati Reddis, than either Hindu caste shares with non-Hindu tribal Chenchus. This not only reflects the greater social isolation of tribal and caste Hindu populations in South India, but also the greater amount of genetic drift due to preferences for first cousin or uncle-niece consanguineous marriages (Bittles, 2002; Rao & Inbaraj 1977; Thurston 1909).

With sexes pooled, canonical variates analysis correctly identifies individuals by ethnic group in 55% of cases. With seven groups, this accuracy rate is far greater than by mere chance. Classification accuracy is greatest among Khows (72% orig., 70% jackknifed) with misclassifications scattered widely among the six other ethnic groups, suggesting the Khow have no affinities with any specific ethnic groups from peninsular India included in this analysis. The lowest accuracy rates occur for Pakanati Reddis (38% orig., 26% jackknifed) and Vaghela Rajputs (45% orig., 42% jackknifed). These low accuracy rates may be reflective of economically-based caste mobility among the former (Biswas & Pandey 1996; Dumont 1957), and the practice of hypergamous unions among the latter (Caldwell, Reddy & Caldwell 1983). Clearly, both cases require further investigation.

Ethnicity, Sex dimorphism and permanent tooth size allocation in South Asia: When sexes are considered separately Kho females and males are identified with the second highest accuracy rates (females: 46% orig., 36% jackknifed; males: 61% orig., 56% jackknifed), trailing only their Bhil counterparts (females: 62% orig., 54% jackknifed; males: 50% orig., 44% jackknifed). Misclassifications most often occur because within ethnic groups females tend to be classified as males and vice versa. This makes sense given the results of two-way analysis of variance, which indicated that group membership was the most influential main effect contributing to the patterning of geometrically scaled odontometric variation, followed by sex.

However, misclassification by sex within ethnic groups was not the only source of misclassification. The magnitude (*i.e.,* the relative number) and direction (*i.e.,* misidentified group) differs by both the sex and ethnic group of the specific individual misclassified. This too makes sense from the results of analysis of variance, which indicated that there is a significant interaction effect between ethnic group and sex. This interaction is also evident from the multidimensionally scaled plots of group centroids and Mahalanobis distances. If there was no interaction effect between ethnic group and sex, and if differences in tooth size allocation by ethnic group and by sex were driven purely by ethnic group and by ontogenetic scaling—in which the allocation of tooth size throughout the dentition among females and males of the same group is identical, but inter-group differences are magnified among males—then such plots should show females of each ethnic group as sharing closer affinities to one another, while their male counterparts ought to depart further along the same vector of intergroup differences away from all other males. In other words, female group centroids ought to form a circumplex of intergroup differences of varying magnitude, with their respective male counterpart centroids radiating outward like spokes. This is certainly not the pattern presented in Figures 8 and 9.

Thus, it would appear that sex-based differences in tooth size allocation among the Khow and members of the six other ethnic groups considered here cannot be attributed to a simple model of ontogenetic scaling in which such differences are due solely to male hypermorphosis (Kimmerle, Ross, & Slice 2008; Leigh & Cheverud 1991). Instead, it is likely that sex differences in tooth size allocation are the product of several factors. The first are possible initial, postnatal differences in shape, such as are seen in the mandible (Coquerelle *et al.* 2011:196). The second involves differences in the relationship between size and shape, such as was demonstrated in postnatal growth of the skull in *Calomys expulsus* (Hingst-Zaher, Marcus, & Cerqueira 2000:110) and in postnatal growth the craniofacial complex in extant hominids (Schaefer, Mitteroecker, Gunz, Bernhard, & Bookstein 2004:473). The third is male hypermorphosis, which includes what Shea (1983) termed 'time' and 'rate' hypermorphosis (Schaefer *et al.* 2004), while the fourth involves sex differences in the direction of female and male growth trajectories (Mitteroecker, Gunz, Bernhard, Schaefer, & Bookstein 2004). It is possible that all four of these factors contribute to varying degrees (Bulygina, Mitteroecker, & Aiello 2006) to sex differences in the allocation of permanent tooth size across ethnic groups. Again, much additional work is needed to clarify the nature of these contributions.

Khow origins

Mountain areas, such as that occupied by the Khow, are often considered special habitats because they are largely isolated and secluded from the rest of the world. Like islands they are often considered to foster "ethnographic museums," where archaic cultural traits are preserved because of only extremely limited exchange with members of surrounding lowland communities (Sökefeld 1997:83). It was this very paradigm that led Buddress (1993:39) to call the mountainous region known as Greater Dardistan a "big linguistic museum" (see also Morgenstierne 1961, 1974; Strand 1973).

The proto-historic Indo-Iranian model. In his pioneering work *The Piśāca Languages of Northwestern India*, Grierson (1906) maintained that Dardic languages (among which he included Nuristani languages) were neither of Iranian nor Indian origin, but instead formed a third branch arising from Indo-Iranian stock, thereby yielding Iranian, Dardic and Indic (Indo-Aryan). Some years later in his *Linguistic Survey of India*, Vol. VIII, he modified his view somewhat and considered Dardic (including Nuristani) as forming a separate group within the Indic branch (Grierson 1903-28/1968).

Biddulph (1880/1977) considered the Khow to be of the same race as the Siah Posh Kafirs (the black robes) of eastern Afghanistan, writing "The Kho[w] would seem to have once spread over a much greater extent of the country than they now occupy. The number and diversity of dialects spoken among the Siah Posh points to their having occupied a more extended area from which they have been dislodged and driven into their present narrow limits, and the conversion of surrounding tribes, first to Buddhism and later to Muhammadanism has isolated them from their neighbours" (as quoted in Khan 1975/2013:5). It was similarly surmised by Morgenstierne that the ancestors of the Nuristanis were the first Indo-Europeans to enter the region, and later Indo-Aryans followed, the early Nuristanis were gradually pushed back (*i.e.*, eastwardly displaced) into their present locations (see also Strand 2001:252). "The remarkable archaicism of Kaf. [Nuristani] and its geographical position render it probable that it contains a residuum going back to the language of the tribes which split off from the main body of Aryans and penetrated into the Indian borderland before the invasion of the Indo-Aryans. These later arrivals either assimilated the Kafirs [Nuristanis], or pushed them back into the inaccessible mountain strongholds of Kafiristan" (Morgenstierne 1945: 231). If Biddulph is correct, this would suggest that the biological ancestors of the Khow are to be found to the west and that acquisition of the language Khowar is a more recent development.

As stated in the introduction, all of the languages currently classified as Dardic are of a purely Indic origin, while retaining certain archaic features that have been lost among the Indic languages spoken in the plains (Morgenstierne 1974:6). Nuristani, on the other hand, is characterized by features that cannot be derived from Old Indic. These are mainly of a phonemic nature as the morphology of Old Indic and Old Iranian are so similar that it is difficult to find differences between them. Strand (2001:253) notes that the Nuristani languages are marked by prehistoric Iranian traits that are only distantly related to the Indic languages spoken further east in Chitral and beyond in Gilgit-Baltistan and Kashmir. Given this, Morgenstierne (1974:9) concluded that Nuristani must have branched off in pre-Vedic times and therefore "it seems far more probable that Kafiri [Nuristani] goes back to the language of an advance-guard of the Indo-Iranian invaders."

The notion that the earliest speakers of eastern Indo-European proto-Indo-Iranian had a homeland in the west and subsequently spread eastward is not a new one. In 1896, Ujfalvy called for Iranians emigrating from Aralo-Caspian Sea region, spreading across the Pamirs, to establish themselves in the Tarim Basin of Xinjiang as cultivators. Jettmar (1967:75) reinforces this theme, calling for an influx of Iranian culture into the mountainous region of the Wakhan Corridor, Chitral and Gilgit-Baltistan involving commercial ties and even migrations throughout the whole of the first millennium BCE and beyond into first millennium of the Christian era. A similar view has been taken by Klimberg (1982:2), who maintains that the Chitral Valley likely represented "probably the most important among the ancient trails from the Pamirs down into Gandhara."

If the original formulation of the proto-historic Indo-Iranian Model is true, that Dardic-speaking ethnic groups owe their origins to a migration of Iranian speakers from a homeland located in northwestern Iran or southwestern Central Asia that occurred between the beginning of the 1st millennium BCE and the end of the first millennium CE[2], the impact of this migration among the samples included in the current study ought to be limited to the Khow, for these immigrants are not believed to have spread any further into South Asia. As this migratory event is held to have occurred after the beginning of the 1st millennium BCE, none of the prehistoric samples from Central Asia considered here should demonstrate any affinities to the Khow. In short, the Khow as the descendants of an intrusive migration into South Asia ought to share no affinities with any of the other samples considered in this analysis.

The results of the current analysis yield some weak support for the original formulation of the proto-historic Indo-Iranian model. The Khow do not exhibit any affinities to samples from peninsular India, regardless of whether the data reduction technique is canonical variates analysis or multidimensional scaling, or whether sexes are pooled or considered separately. When prehistoric individuals are considered alongside members of living ethnic groups, the Khow are identified by both canonical variates analysis and multidimensional scaling as possessing closest affinities to the 4th millennium BCE inhabitants of Geoksyur. While this Namazga period III sample is located to the west of the Khow and is found broadly within the Aralo-Caspian and northwestern Iranian/Caucasus region identified as the *Urheimat* for the Indo-Iranian-speakers by Ujfalvy (1896) and Jettmar (1967), its antiquity predates the first millennium BCE by some 2,000-3,000 years. While it could be hypothesized that this region witnessed long-standing population continuity between the 4th and 1st millennia BCE, such continuity stands at odds with the greater biodistance separating the temporally more proximate sample from Altyn-depe (*c.* 2500 BCE) to the Khow (Figs. 10-11). Thus, while suggesting the Khow may have origins outside the Hindu Kush highlands, the pattern of phenetic affinities is incongruous with an eastward migration from the west to Greater Dardistan during the first millennium BCE to the first millennium CE.

Cacopardo and Cacopardo (2001:29) note that although geographically the Chitral Valley route may have been the easiest, but if populations along the way could not be controlled effectively by some form of centralized authority, a long-distance route of commerce through their territories would have been parlous. Indeed, at noted by Stellrecht (1998:12), routes of trade very often depend more on political than geographical considerations. In Chitral, where Buddhism was not firmly established, the presence of centralized political systems of sufficient strength and logistical coordination to guarantee the safety along a route through the Chitral Valley seems highly unlikely. Indeed, the two crucial passages along this route (Lowri road, Kunar trail) are marked by a conspicuous absence of petroglyphs, often indicators of control or possession, and no petroglyphs have been reported by previous researchers along the border tracts of the Chitral-Kunar Valley. It is only with the establishment of first the Rais and then the Kator Islamic dynasties in the 16th century was such authority established.

Contrary to Klimberg's (1982) claim of a prominent role for the Chitral Valley in international trade during prehistoric times, such a route during the first millennium CE remains purely hypothetical (Jettmar 1993:81, 102). Instead, the evidence indicates that at this time an international route did run through Dardistan connecting the populations of the plains of northern India to populations of Central Asia, but the main artery, the famous silk route, passed just north of the Hindu Kush/Karakoram chain. It crossed the Tarim Basin following a northern and a southern route that merged again at Kashgar, which was one of the most important trade centers along the way. From there caravans continued west through Sogdiana towards the Caspian and the Mediterranean, or they turned south into Badakhshan to Balkh, another important junction, from where northwestern India (*i.e.,* Pakistan) could be reached. This southern branch of the silk route led to Laghman in Nuristan and Gandhara in the Vale of Kashmir, joining the main road—the Indus Road—that connected populations of the Indian subcontinent to those of the Iranian Plateau (Rauning 1978: 553-554; Klimburg 1982: 27; Forsyth 1869: 162). Thus, it appears that the main international trade routes skirted as much as possible the mountains passing around Dardistan without crossing it (Cacopardo & Cacopardo 2001:28). Thus, it comes as no surprise that the Khow, as residents of Dardistan, show no affinities to populations of Bactria, but the affinities to Geoksyur and, to a lesser degree, Altyn depe, suggest a far earlier period of interaction than the first millennium BC to the first millennium CE.

As noted in the introduction, Jettmar (1967:75; 1996) asserted that the Gandharan Grave Culture—and by extension the Protohistoric Grave Complex of northern Pakistan (see footnote 1 above)—represented powerful evidence of the presence of Iranian immigrants southeast of the Hindu Kush whose appearance may have been facilitated by the southern route through the Kabul Valley and across the Khyber Pass into the Vale of Peshawar known as the Indus road. However, he also conceded that this evidence occurs in the valleys and foothills rimming the northern border of the Indus Valley and not in Greater Dardistan. However, more recent archaeological surveys and excavations have revealed the presence of the Protohistoric Grave Complex in Chitral (Ali *et al.* 2005a, b; Ali and Zahir 2005; Allchin 1970; Stacul 1969b; Zahir 2012). Yet, the radiocarbon dates obtained from three of the newly excavated sites (Ali *et al.* 2008), which range from 1000 BCE to 1000 CE, are generally more recent than the radiocarbon dates recently obtained from the lowland Protohistoric Grave Complex sites of Gogdara IV and Udegram in the Swat Valley (*c.* 1500/1400 – 800 BCE: Vidale and Micheli 2017:402; Vidale, Micheli, & Olivieri 2016:199), confirming Stacul's (1970:101) suspicion that the highland expressions of this technocomplex represent a subsequent development.

The temporal difference between the more southerly lowland expression of the Protohistoric Grave Complex and its later appearance in the highlands of Chitral raises the possibility that a population movement associated with this culture may have involved populations moving from the south (*i.e.*, Dir, Swat, Vale of Kashmir, Taxila) to the north, either in the late second or the early first millennia BCE. Indeed, Jettmar (1996:84) comments that the great enigma concerning the population of Greater Dardistan is the presence of a large population of non-Dardic speakers, the Burusho, who speak a language that has no known relatives, in the northern portion of this region surrounded by speakers of Dardic and Iranian languages (Tikkanen 1988).

If it is true that the initial entry of Indo-Iranians into South Asia actually occurred somewhat earlier, perhaps in the latter half of the second millennium BCE, that it occurred via a southern route through the Kabul Valley and across the Khyber Pass and is signaled by the presence of the Protohistoric Grave Complex in Lower Dir, Buner and Swat, and was followed by a subsequent movement northward into Chitral after the passage of some 500-1000 years, then the Khow ought to exhibit affinities to the prehistoric inhabitants of Timargarha, which were recovered from a Protohistoric Grave Complex site. However, since these immigrants are held to be Iranian speakers, there should be no affinities between the Khow and earlier samples from the Indus Valley or any of the samples of living ethnic groups from peninsular India.

The results of this study offer no support for this revised proto-historic Indo-Iranian model. None of these analyses identify the Khow as possessing close affinities to the human remains recovered from the Protohistoric Grave Complex site of Timargarha, or even to the temporally more proximate remains from Sarai Khola.

The prehistoric Indo-Aryan model. Grierson's (1906) original trifurcation of the Indo-Iranian languages into three stocks (Iranian, Dardic, Indic) did not hold up to continued scrutiny, for even Grierson (1903-28/1968) himself revised his classification of Dardic to include it as a separate group within the Indic (Indo-Aryan) branch. With this revision, the Indo-Iranian languages were divided into two divisions Iranian and Indic. Within Indic there is a division between Dardic and Aryan (Sanskritic), with the Dardic branch trifurcated into Kafiri (Nuristani), Khowar, and Dard proper (Grierson, 1929:2). Noting the correlation of these divisions with geography, Voegelin and Voegelin (1965) designated them as the western, central, and eastern Dardic languages, respectively.

Perhaps the most outspoken critic of this classificatory scheme for the Indo-Iranian stock of languages has been Morgenstierne (1936, 1961, 1974). Morgenstierne's reservations involve two points, but only the first need be considered here. As noted in reference to the proto-historic Indo-Iranian model, this objection is to the inclusion of the Nuristani languages within Dardic. Morgenstierne (1961:139) contends that these languages occupy a position intermediate between Indic on the one hand and Iranian on the other, but when the isoglosses are examined as a whole, the preponderance fall on the Iranian rather than the Indic side. Further, the Nuristani languages also contain a number of unique archaicisms, which suggest that Nuristani must have split from the other Iranian languages at a very early date, probably soon after the split between Iranian and Indic during the first half of the 2nd millennium BCE.

Grierson (1903-28/1968) contends that Khowar has essential features that link it to the conservative Iranian Galcha languages spoken in the Wakhan Corridor to the north that encompass their own set of achaicisms. Grierson points out that Khowar differs widely from its neighbors, even with regard to a number of the most common words, such as those that denote parts of the body. By contrast in Shina, and even in Kalashwar, these words are of clear Indic derivation, but in Khowar many of these words are either of Iranian origin or their origin remains unknown. Grierson suggests the uniqueness of Khowar relative to the other Dardic languages is no random phenomenon; instead he contends that the originally homogeneous Dardic-speaking population of Nuristan, Chitral, and Gilgit-Baltistan was riven in two by an invasion of Khowar-speakers from north of the Hindu Kush that split the Nuristanis and Kalashas in the west from the Shins, Yashkuns and Kohistanis in the east. Indeed, Grierson considered the Khow to have far greater ties with ethnic groups of the Pamirs and Wakhan Corridor than with "their Dard brethren of Astor and Gurez" to the east (see Dichter 1967:42-3).

Morgenstierne (1932:47, 1936:660, 1938) also suggested that Khow origins were to be found to the north and he emphasized the continued interaction across the Broghal Pass between the Khow of Chitral with populations of Iranian-speaking ethnic groups of the Wakhan Corridor, such as the Wakhi, and beyond to Badakhshan in the west. In a similar vein, Israr-ud-Din (1990:10) notes that long ago the Khow crossed over into the Wakhan Corridor via mountain passes from both the Mulkhow and Torkhow valleys, while Kreutzmann (2005:9, 13) points out the presence of Wakhi communities in Upper Chitral and in the Yasin and Ishkoman Valleys of Gilgit-Baltistan in immediate proximity to Khow communities. Such origins and subsequent interactions may explain Grierson's (1929:3) observation that the Indic element is strongest among those Dardic languages spoken nearest to India, in Kashmir and in southern Gilgit, while the Iranian element is strongest furthest from India, in Nuristan and Chitral.

While no artifacts directly associated with the Bactrian-Margianan Archaeological Complex (BMAC) have been found in Chitral or anywhere in Greater Dardistan, sites attributed to the Protohistoric Grave Complex have been found in Chitral (Ali *et al.* 2005a, b; Ali and Zahir

2005; Allchin 1970; Stacul 1969b). As noted in the introduction, a number of scholars have drawn associations between the Protohistoric Grave Complex with the BMAC and the adjacent Vakhsh/Beshkek cultures of southern Tajikistan (Erdosy 1995; Hiebert & Lamberg-Karlovsky 1992; Parpola 1988, 1993a, 1995). Thus, it would appear that populations living in Chitral during the first millennium BCE, and perhaps earlier, may have had contacts with populations further north across the Hindu Kush (see Francfort 1985:130).

If the prehistoric Indo-Aryan theory is true, that populations from southern Uzbekistan, southern Tajikistan and northern Afghanistan associated with the BMAC and the affiliated Vakhsh/Beshkent cultures crossed the Hindu Kush and established themselves in Chitral and beyond in the foothills and valleys bordering the northern margin of the Indus Valley during the late second or early first millennia BCE, then the Khow ought to represent the living descendants of these Central Asians of the late Bronze Age. Further, since these same Central Asian populations are associated with the Protohistoric Grave Complex found in Chitral, Dir, Buner and Swat, as well as in the Vale of Peshawar and at Taxila, then the prehistoric samples from Timargarha (TMG) and Sarai Khola (SKH) ought to exhibit close affinities to the BMAC samples from southern Central Asia (SAP, DRJ, KUZ, MOL), as well as to the Khow (KHO), while showing no affinities to the prehistoric samples that antedate this hypothesized late 2nd millennium BCE migration (*i.e.*, HAR, ChlMRG, NeoMRG). Still further, since this population movement is also claimed to have led to the establishment of Indic languages (specifically Sanskritic) throughout North India, then secondary affinities ought to be observed between the living samples from Gujarat (BHI, GRS, RAJ), the Khow, Timargarha (TMG), Sarai Khola (SKH), and the prehistoric samples from southern Central Asia (SAP, DJR, KUZ, MOL). Because the spread of Vedic culture to South India is claimed to be the result of elite dominance, there should be no affinities between the three Dravidian-speaking ethnic groups from Andhra Pradesh (CHU, GPD, PNT) and the Khow or any of the samples from either North India, the greater Indus Valley, or Central Asia.

The results of this analysis offer little support for the prehistoric Indo-Aryan model. While canonical variates analysis of living individuals identify the Khow as possessing closer affinities to the Indo-Aryan-speaking ethnic groups of northwestern India (BHI, GRS, RAJ) than to Dravidian-speaking ethnic groups of southeast Asia (CHU, GPD, PNT) when sexes are considered separately (Fig. 8) this relationship is not borne out by any of the other analyses of the living samples. When prehistoric samples are added to the comparative base not only is there no relationship between the Khow and ethnic groups of northwestern peninsular India, but there is no particularly close relationship between Khow and their alleged BMAC-affiliated ancestors. Instead, what affinities occur between the Khow and prehistoric Central Asians occurs with the Namazga III period inhabitants of Geoksyur, which antedates the BMAC by nearly two millennia. As such the location and timing of Khow ancestors as being the populations of the BMAC urban centers is not supported, nor do the Khow appear to share a collateral relationship with Indo-Aryan-speaking North Indian groups as expected if both are descendants of the same migrating population that entered South Asia during the mid- to late-2nd millennium BCE.

Why do the results obtained from tooth size allocation differ from those obtained by recent genome-wide studies? Narasimhan *et al.* (2018) claim that their data rule out a role for BMAC populations in contributing to the ancestry of South Asians, but attribute West Eurasian ancestry to a Late Bronze Age (*Steppe_MLBA*) dispersal that avoided the main body of the BMAC population, but is represented by outliers at Gonur tepe and Shahr-i-Sokhta. BMAC populations are ruled out because they lack the *Steppe_LMBA* component that is so common in South Asia. Instead they suggest there was a greater impact of gene flow in the reverse direction, as the main BMAC genetic cluster is slightly different from preceding Turan populations in possessing about 5% of their ancestry from Ancient Ancestral South Indians (*AASIs*). The authors seek to account for this by noting the presence of a single outlier at the

BMAC site of Gonur tepe, as well as two outliers from Shahr-i Sokhta in eastern Iran, which date to ~2100 – 1700 BCE and who possess an ancestry profile similar to 41 ancient individuals of the Protohistoric Grave Complex in northern Pakistan who lived some 500 – 1000 years later in Swat (*c.* 1400 – 800 BCE). This ancestral profile features a 14-42% contribution from the Ancient Ancestral South Indian-related (*AASI*) ancestry and the rest to early Iranian agriculturalists and *West Siberian_HG*. They further note that, like contemporary and earlier samples from Iran/Turan, there is no evidence of Steppe-pastoralist-related ancestry in these samples (*i.e., Steppe_EMBA* or *Steppe_MLBA* apart from *West Siberian_HG*), but in contrast to all other Iran/Turan samples, evidence of Anatolian agriculturalist-related admixture is negligible among these outliers.

From this, Narasimhan *et al.* conclude that these outlying individuals may be migrants from a population located further east along the cline of decreasing Anatolian agriculturalist ancestry. They continue, noting that while they did not have access to any DNA directly sampled from Indus Valley Civilization (IVC) individuals, based on: a) archaeological evidence of material culture exchange between the IVC both the BMAC to the north and Shah-i Sokhta to the west (Possehl, 2004), b) the similarity of these outlier individuals to post-IVC Swat Valley individuals, and c) the presence of substantial AASI admixture in these samples (suggesting they are migrants from South Asia), and d) the fact that these individuals fit as ancestral populations for present-day Indian groups in *qpAdm* modeling.

There are several problems with the scenario described by the authors. First, the IVC (2600 – 1900 BCE) and the BMAC were not contemporaneous, but largely time successive (2285 – 1520 BCE). The evidence for BMAC artifacts in the Indus Valley post-dates the Mature phase of the civilization and are not found in the Indus Valley itself, but on the margins at such sites as Mehrgarh VIII (Jarrige 1994; Jarrige & Hassan 1989). Second, evidence for direct contacts between the IVC and southern Central Asia are rare, being limited to Dashli 3 in northern Afghanistan, where a seal with unmistakable Harappan influence in the form of mosaic trefoil patterns and bull designs was discovered (Kohl 1992:188; Sarianidi 1977:47). Instead, evidence for contacts between IVC and southern Central Asian populations occurs earlier during the NMG IV-V periods at Altyn depe (Gupta 1979; Gulmuradov 1975, 1978; Kircho 2000; Masson 1988:118-119; Salvatori 2008:79). Third, there is no evidence of a close biological relationship between Mature Phase or even Late Phase Harappans with penecontemporary remains from the Protohistoric Grave Complex site of Timargarha. These discrepancies may reflect two possibilities. The first is that interactions *did* occur between southern Turkmenistan and South Asia, but these interactions occurred prior to the coalescence of the BMAC in the late third and early second millennium BCE. Instead, they may have occurred during the Namazga IV-V periods in which Harappan artifacts appear at sites of the Kopet Dagh piedmont during the third millennium BCE. Second, these contacts may have been facilitated by establishment of the Harappan outpost at Shortughäi (Francfort 1984, 1989), located in eastern Bactria near the BMAC urban centers of Djarkutan and Sapalli tepe, and may signal that the dynamic of dispersal, or admixture, was from the south to the north, rather than from the north to the south, at least during the period in question (*i.e.*, third to mid-third millennia BCE).

The authors estimate that the time of admixture between Iranian agriculturalist-related and AASI ancestry in the three *Indus_Periphery* from Gonur tepe and Shahr-i Sokhta samples was 55 ± 15 generations ago, which they claim corresponds to a 95% confidence interval of about 4700 – 3000 BCE assuming 28 years per generation (Moorjani *et al.* 2016) (p. 10). There are two problems with this estimate. First, how can you get a single estimate of the number of generations required, when the amount of admixture between the two ancestral lines varies from 14-18% for two individuals to 42% in the remaining individual? That is, how can the same amount of time yield three times (3x) the contribution of AASI in one individual relative to another without any *a priori* assumptions coming into play? Second, 53 generations at 28 years per generation (55*28= 1484 years – 1950 CE= 466

CE) does not match with the authors' estimated time range of 4700 – 3000 BCE, even when the upper (53 + 15= 68 generations * 28 years= 1904 years – 1950 CE= 46 CE) and lower estimates are included (53 - 15= 38 generations * 28 years= 1064 years – 1950 CE= 886 CE). Not only do these estimates fall far later in time than their claimed antiquity, but they also fall outside the temporal range for the Swat Valley Protohistoric Grave Complex material (1500/1400 – 800 BCE). Finally, even if the temporal estimates were correct, what archaeological cultures match these dates? In Central Asia, 4700 – 3000 BCE corresponds to NMG I – NMG III. No claims for any significant contacts between Central and South Asia have been advanced by reputable archaeologists until the very end of this range (see Gupta 1979; Hiebert 2002; Kohl 1981, 1984, 1992). For the Greater Indus Valley, 4700 – 3000 BCE corresponds to Periods III-IV at Mehrgarh and the Early Harappan (i.e., Kot Dijian) in the Indus Valley. Again, no claims for extra-subcontinental contacts for this time period have been advanced by reputable archaeologists (Allchin & Allchin 1982; Fairservis 1971).

DeBarros Damgaard *et al.* (2018) conclude that South Asian populations experienced two pulses of West Eurasian admixture. The first was likely broadly associated with the introduction of West Asian cultigens to southern Central Asia and the Indus Valley and is represented by the presence of Anatolian agriculturalist- and Iranian agriculturalist-related ancestry in the Namagza III period individuals from Kara depe and Namazaga depe, as well as among present-day South Indians. The second pulse is held of have been introduced by Late Bronze Age steppe pastoralists who brought the *Steppe_MLBA* ancestry that is ubiquitous among South Asian populations, especially those of Indic-speaking North India. The proposed route of introduction begins in western Kazakhstan and Tajikistan proceeds through the Swat Valley of northern Pakistan and into peninsular India. DeBarros Damgaard *et al.* also claim two additional sources of ancestry to account for the biological history of all South Asia populations: an East Asian source and an indigenous ancestral South Asian source (p. 5). They conclude, "that Early Bronze Age steppe pastoralists did not migrate into South Asia but that genetic evidence fits better with the Indo-Iranian languages being brought to the region by descendants of Late Bronze Age steppe pastoralists" (p. 8).

Their Figure 6 provides a summary of the four *qpAdm* models fitted for South Asian populations. Five, rather than four, sources are identified. These include: *Namazga_CA, Turkmenistan_IA, Onge (as representative of ancestral South Asians), Steppe_MLBA, and Xiongnu_IA* (as representative of ancient East Asians). This figure provides pie charts representing the proportional contributions by the various ancestry sources to 26 selected population samples. Eight come from the extreme northwest (2 are from Uzbekistan, 6 from northern Pakistan), two are Himalayan samples, seven come from West and South India, six are from East India, and three are from Northeast India and Southeast Asia. Running completely counter to their claim of a Late Bronze Age steppe impact on South Asian ethnic groups, this impact appears to be limited to a Kashmiri sample, one sample from Maharashtra in West India, and a sample of Brahmins from Kolkata in East India. Contributions from an ancestral South Asian source are widespread among peninsular Indians, being found in all samples and contributing the greatest proportion of ancestry to all but the Irula, a tribal sample from South India. Indeed, contributions from this ancient South Asian source provide a minority contribution to the two Himalayan samples, to all of the samples from northern Pakistan, and even the Yagnobi of Uzbekistan. The only samples that this ancient South Asian ancestry is not found are the two Tajik samples in southern Central Asia. Not surprisingly, the East Asian ancestry is most common and contributes the greatest proportion among the Southeast Asian samples, the Tharu sample from Nepal (but not the Kashmiri sample) and three of the samples from East India. Perhaps surprisingly, small contributions are also found among the Tajik samples, but this is probably a reflection of the Iron Age Xiongnu source. Finally, and most importantly, the *Namazga_CA* source, representing the admixed Iranian agriculturalist-related with *EHG*-related hunter-gatherers found among the four individuals from Kara depe and Namazga depe, occurs among the Yagnobi, all of the northern Pakistani samples, the two Himalayan samples, all peninsular Indian samples, and even the Northeast Indian and Southeast Asian samples. Thus, it would appear—in direct opposition to the conclusions of deBarros Damgaard *et al.* (2018)—that it was the Late Chalcolithic (Copper Age) populations (and perhaps their ancestors) who migrated to South Asia and it was the Late Bronze Age Steppe pastoralists who did not.

The indigenous model. In his study of the cultural geography of Pakistan, Dichter (1967:40) stated, "although it might be more realistic from a physical and cultural point of view to classify Chitral in a strictly central Asian context as part of adjoining Gilgit, Badakhshan, Nuristan and Wakhan, it nevertheless has to be incorporated in this study. Its inclusion was based on the conviction that both historically and ethnically the state has had far closer ties with the lowlands to the south (including a definite affiliation to 'Pathanism'), in spite of its close proximity to the central Asian highlands." Ali and coworkers (2013:81) comment that this analysis is interesting because it signals Chitral's liminal status and position, such that while it must be considered very much part of the mountains of the Hindu Kush, Nuristan, the Wakhan Corridor and beyond, the population of this region also has strong ties with populations residing to the south and east. Yet despite these assertions, numerous observers have commented on the striking differences in physical appearance, language and culture between the Khow and Pathans found largely to the south (Enriquez 1921:20; Marsden 2005:14). Indeed, Morgenstierne (1936:661-663; 1938) pointed out that while a number of words in Khowar appear to be borrowings from adjacent Eastern Iranian languages, such as Yidgha, Sanglechi-Ishkashmi and Wakhi, borrowings from Pashto (spoken by Pathans) are extremely rare, and they are largely found among the Dardic languages spoken south of Chitral.

As mentioned previously, Morgenstierne (1936, 1961, 1974) has been perhaps the most outspoken critic of Grierson's classificatory scheme for the Indo-Iranian stock of languages. Here we may consider the second of his reservations. Grierson (1903-28/1968) assumed that Dardic languages were a cohesive group because, to a great extent, they have retained Sanskrit phonemic features that had already changed in the Middle Indic languages spoken in the lowlands. Moreover, Morgenstierne observed that the so-called Dardic languages do not contain any fundamental features that cannot be derived from Old Indic. Indeed, there is not one single feature that unifies the Dardic languages as a whole from the rest of the Indic languages. Instead, "Dardic is simply a convenient term to denote a bundle of aberrant Indo-Aryan (Indic) hill languages, which in their relative isolation… have been in a varying degree sheltered against the expanding influences of Indo-Aryan Midland (*Madhyadeśa*) innovations, being left free to develop on their own" (Morgenstierne 1961:139; see also Dupree 1974:12).

If it is true that the Khow represent aboriginal occupants of the Hindu Kush highlands, it should be expected that they ought to share closest affinities to other ethnic groups occupying Greater Dardistan and, depending on how long and to what degree they have been isolated from adjacent lowland populations, they ought to exhibit secondary affinities to the prehistoric samples of southern Central Asia (MOL, KUZ, DJR, SAP, ALT, GKS) as well was to those of the Indus Valley (NeoMRG, ChlMRG, HAR), especially those most proximate geographically and temporally (SKH, TMG), but they ought to possess no affinities to samples from peninsular India (BHI, CHU, GPD, GRS, PNT, RAJ).

The results obtained in the current study offer some support for the Indigenous model. As expected, the Khow share no affinities with ethnic groups of peninsular India, while exhibiting some distant affinities to prehistoric populations of Central Asia. While the fact that these affinities are not closest with the samples from the BMAC urban centers rules out the Indo-Aryan model, the more diffuse affinities with Geoksyur and Altyn-depe may reflect long-standing residence within Chitral District and surrounding environs. Only with additional samples from this region can the indigenous nature of Khow origins within the highlands of Greater Dardistan be identified or refuted definitively.

Conclusions

EM estimation to replace missing values does not introduce systemic bias into within-group variance-covariance matrices. Therefore, missing data for a modest proportion (*c.* 15%) of the data by individual increases effective sample size without compromising data integrity.

It has commonly been assumed that the earlier developing tooth within each dental field—the so-called "pole" tooth—is less variable and hence carries a more faithful phenotypic reflection of the underlying genome than the later members—or "distal" teeth—within each dental field. This was not found to be the case among the Khow, for in many cases the distal tooth proved less variable than its more mesial counterpart. As expected, Khow females were found to be less variable than their male counterparts, reflecting a greater degree of ontogenetic canalization.

Complete discriminant function analysis correctly identified 86% of females and 79% of males, for an overall classification accuracy of 83%. Jackknifing reduced classification accuracies to 74%. Backward stepwise discriminant function analysis resulted in the elimination of 18 variables. The remaining 18 variables yielded a correct classification accuracy of 79%, but jackknifed classification accuracy at 76% is slightly higher than the accuracies yielded by jackknifed complete discriminant function analysis (74%). Consequently, odontometric variables provide a moderately accurate indicator of sex among the Khow.

Geometrically scaled odontometric values permit comparisons across sexes and ethnic groups without the obfuscating effects of sex dimorphism and differential tooth size reduction due to differing histories of agricultural production and ceramic technologies. Individual classification accuracies by group with sexes pooled averages 55% overall and with correct assignment among all groups being highest among the Khow at 72%. The patterning of centroid scores for the first three canonical axes suggests that both ethnic group membership and geographic region have played meaningful roles in the diversification of these sampled South Asian ethnic groups. The results confirm the lack of any specific affinities between the Khow of northern Pakistan and any of the peninsular Indian samples included in this analysis.

Individual classification accuracies by group with sexes separate confirm that the Khow occupy an isolated phenetic position relative to peninsular South Asians. Differences in the relative positioning of males and females among ethnic group samples for northwestern and southeastern India suggest that differences in marital migration patterns have likely played different roles depending on the ethnic group under consideration. These results not only further confirm the lack of affinities between the Khow of northern Pakistan and the peninsular Indian samples included in the analysis, but also indicate: subtle sex-based differences in tooth size allocation occur across members of these ethnic groups, that these differences are neither of the same magnitude nor allocational expression across the dentition and, that these differences are detected by the canonical axes that account for a lesser proportion of the total variance among samples, as might be expected.

Projection of canonical variate scores for the prehistoric samples into the array provided by multidimensional scaling of pairwise Mahalanobis d^2 distances for all six canonical axes obtained from the living samples identifies the Khow as a peripheral member of the aggregate formed by the south-central Asian samples, with closest affinities to the Namazga III period sample from Geoksyur. Prehistoric samples from the Indus Valley and west-central India form a second aggregate linked together by the Protohistoric Grave Complex sample from Timargarha. Samples of living peninsular Indians are only distantly associated with these prehistoric samples, but are distinguished by region. Taken together, these results provide no support for either the protohistoric Indo-Iranian model or the prehistoric Indo-Aryan model. Instead greatest support is for the indigenous model. However, this support comes with two caveats. First, it does not account for the affinity in tooth size allocation between the living Khow and the ancient inhabitants of Geoksyur, yet it is congruent with deBarros Damgard *et al.*'s finding of a distinct *Namazga_CA* genomic signature distinct from that of the Late Bronze Age Steppe pastoralists (*Steppe_LMBA*) as well as their Figure 6, which shows a pervasive impact of the *Namazga_CA* genomic signature in South Asia, including living ethnic groups both to the north and to the south of Dardistan and the Chitral Valley. Second, these results must be confirmed by tooth size allocation analyses of other ethnic groups from Dardistan. *If* such studies show the Khow to have closest affinities to them, then the indigenous model will be confirmed, but if the Khow—even against the background of other ethnic groups from Dardistan—show closer similarities to Geoksyur and Altyn Depe, then a new model, calling for an early entrance of Iranian agriculturalist-related admixture must be considered.

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Notes

1 More recent researchers have emphasized local and temporal diversity in funerary activities and structures once subsumed under the rubric "Gandharan Grave Culture," especially in light of recent discoveries in Chitral (Ali, Batt, Coningham, & Young 2002; Ali, I., Zahir, M., & Qasim, M. 2005b; Ali and Zahir 2005; Zahir 2016), Buner (Stacul 1967), as well as in Bajaur and Mohmand Tribal area (Ali & Rahman 2005; Ali & Zahir 2005; Mohammadzai 2006, 2007, 2008). Further, apart from an upper shaft and a lower burial crypt (Silvi Antonini & Stacul 1972:11-12), there is tremendous variation in the treatment of the dead (primary, secondary, crematory), the number of individuals involved (single, double, multiple, none), furnishings (ceramic wares, semiprecious stones, metal objects) and tomb construction (simple pits, slab stones, packed earth, sealing stones) (Dani 1967:62-65; Silvi Antonini & Stacul 1972:326-328; Vidale 2001; Vidale, Micheli, & Olivieri 2001; Zahir 2012, 2016). No correlations have been found between treatment of the dead, number of individuals involved, furnishings, or tomb construction, with possible parameters reflecting the social identity of the deceased, such as age or sex (Zahir 2012; 2016). Vidale (2001:5) suggests that it is quite likely that different age and/or sex groups were treated differently in light of children being reported as being found only in smaller graves consisting of pits lined with slabs or stone walls, but these differences have been obscured by an extended funerary cycle in which graves were reopened with multiple occurrences of deposition, removal, and manipulation of body parts (Vidale, Agha, Iqbal, Olivieri, & Pulcini 2001:43-44; Vidale and Micheli 2017:396). Therefore, in light of such interregional, intraregional, intra-site and temporal variation for which the type site of Gandharan Grave Culture, Timargarha, is not representative, the more generic term Protohistoric Grave Complex will be used, except in cases of direct quotes.

2 According to Strand (1997-9), the oral traditions of most Nuristani groups place their original homeland around the region of Kama, at the confluence of the Kabul

and Kunar Rivers until about 1,000 years ago. These traditions maintain that they fled from Islamic forces and missionaries from Kandahar to Kabul, from Kabul to Kapisa, and from Kapisa to Kama (Strand 2001:253). However, a recent examination of Y-chromosome variations among four Afghani ethnic groups shows close affinities between Pathans of Afghanistan and Pakistan, distant affinities between Tajiks and Pakistani groups, but no affinities are shared between Hazaras and, Uzbeks and Pakistani groups, and this is especially the case for the Kalasha (Haber *et al.* 2012). Thus it would appear that the Afghan genetic influence on Pakistanis is limited to Pathans and to other ethnic groups residing in the lowland regions of Pakistan.

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