



Osteometric and Radiographic Studies of Tarsal Bones in Adult Chinkara (*Gazella bennettii*)

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ABSTRACT

The study is carried out on the gross anatomy, biometry and radiographic analysis of tarsal bones in twenty specimens of male and female adult chinkara (*Gazella bennettii*). The tarsus of chinkara comprises of five bones both grossly and radiographically, settled in three transverse rows viz, tibial and fibular tarsal in the proximal, central and fourth fused tarsal in the middle row, while, the first, second and third fused tarsal in the distal row. The fibular tarsal is the largest and longest bone of the hock, situated on the lateral side and had a bulbous tuber calcis "point of the hock" at the proximal extremity which projects upward and backward. The tibial tarsal bone is the 2nd largest bone of the proximal row, lies on the medial side of the tarsus and bears trochlea at either end. The central and the fourth tarsals are joined to form a large bone which is extended across the entire width of the tarsus and articulates with all bones of the tarsus. The first tarsal is a rectangular piece of bone sited on the posteromedial surface of the hock. The second and third fused tarsal bone resembles the central but is smaller and wedge-shaped. It is situated between the central tarsal bone proximally and the large metatarsal bone distally. The average maximum height and breadth for fibular tarsal, tibial tarsal, central and fourth fused tarsal, first tarsal, second and third fused tarsal are (5.61±0.23 cm and 2.06±0.13 cm), (2.79±0.05 cm and 1.74±0.01 cm), (1.51±0.13 cm and 2.08±0.07cm), (0.61±0.01 cm and 1.10±0.06 cm) and (0.98±0.01 cm and 1.49±0.01 cm), respectively.

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Authors' Contribution

SD, SM and HZ conceived and designed the experiments, interpreted the data and wrote the article. All other authors helped in preparation of the manuscript.

Key words

Chinkara, Tarsal bone, Morphology, Morphometry, Radiography

INTRODUCTION

The Indian gazelle or chinkara (*Gazella bennettii*) is an ungulate species of antelopes, native to Iran, Afghanistan, Pakistan, and India. Chinkara is beautiful having a small and slender body. Male weighs about 23 kg and height of 65 cm at the shoulders and female weighs 15 - 18 kg and a height of 58 - 61 cm (Mallon, 2008). Chinkara lives in light forests, dry scrub, deserts, hills, and dry plains. In India, they occupy more than eighty safe zones. They range up to 1500 meters altitude in Pakistan. They occupy the Kavir national park in Iran (Mallon and Kingswood, 2001). In 2001, the population of chinkara was projected 0.1 million along with eighty thousand existing in the desert of Thar. While in Pakistan the population of chinkara was dispersed and has declined as a result of the hunting. In Iran, the population of this species is disjointed. This species is perhaps very rare in Afghanistan

(Mallon and Kingswood, 2001). Among the wild ungulates of Pakistan, only the habitat and feeding ecology of wild Urial in Pakistan were studied in detail by Din *et al.* (2018).

Animal gross morphological features show significant dissimilarity with respect to age, breed, sex, environmental factors and nutritional condition among others. The measurements of these factors are important symbols for comparison. Many biometrical studies have been carried out to obtain a genetic assessment (Kunzel *et al.*, 2003; Brombin *et al.*, 2009). These biometrical data are significant in anthropology (Bokonyi, 1974), regional anaesthesiology (Olopade and Onwuka, 2005), taxonomy, (Habel, 1982) and comparative gross anatomical and histological descriptions between and within breeds (Olopade *et al.*, 2006). The specific identification of the bones of sheep, goat, and wild ungulates viz. chinkara, blackbuck, hog deer, spotted deer and the blue bull has been always a challenge for the veterinary anatomists. There are several morphological criteria used for the distinction, but classical veterinary anatomists (Barone, 1996; Cotofan *et al.*, 1999; Popovici *et al.*, 1995; Sisson and Grossman, 1964) gave little attention to the fine-detailed description.

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Nowadays scientists are facing with a new perception as archaeozoological studies necessitate this clear difference based on fragmentary pieces as well as the legal forensic studies that seem to hold an increasing quota of the facilities and inquiries entreated at the Comparative Anatomy and Pathological Anatomy Departments.

The goal of this study is to thoroughly describe and explore the tarsal bones of chinkara (*G. bennettii*), both gross anatomically and radiographically, to illuminate the osteomorphometrical (gross morphological and morphometric study) features and thereby creating an impact in filling the breach of knowledge in this field. Till date, no comprehensive study and scientific information have been carried out. The study is of great importance from the vetero-legal point of view. This study will also contribute to discriminate the bones of this animal and confuse them with those of some other analogous small ruminants. This study will be helpful to veterinarians as well as zoo veterinarians in many vetero-legal cases, the legal forensic studies and archaeozoological studies.

MATERIALS AND METHODS

Experimental design

In this study, tarsal bones from twenty (20) specimens of an adult male and female chinkara were studied. Tarsal bones specimens for anatomic and osteometric studies were collected after natural mortality from the Manglot Wildlife Park and Ungulate Breeding Center, Nizampur, Khyber Pakhtunkhwa, Pakistan. After post mortem examination, age and sex were recorded and carcasses were buried in the specific location in park premises to obtain tarsal bones. After elapse of 4 to 5 months specimens of the tarsal bones of each male and female chinkara were unearthed. After collection, the bone specimens were put into clean, hot water for maceration and softening in a large aluminium container and for better collection of small bones, a net was wrapped around. These bones were washed and cleaned with bleaching powder to get rid of the unpleasant odour and were sun-dried subsequently for two to three days. The gross morphological, osteometric and radiographic studies were carried out at the University of Veterinary and Animal Sciences (UVAS), Lahore, Pakistan. Each measurement was repeated three times by two independent observers, and the mean values were recorded. The bones were described using the terminology given in *Nomina Anatomica Veterinaria* (2012). For radiographic investigations, twenty intact limb specimens were obtained instantly after the animals had expired unrelated to skeletal involvement and kept on -20°C. The limbs were thawed, and the radiographic images were acquired in palanto-dorsal, dorso-palantar

and mediolateral views. Digital radiographic system (EZy-Rad Pro X-ray system, Shimadzu; Console Advance, DR-ID 300CL, Fujifilm) with a focus - film distance of 80cm and an exposure of 80kV, 200mA, 6.4mAs placed in pet center UVAS, Lahore, was used for radiographic studies.

Analysis of anatomic values data was conducted with SPSS version 20.0 and was expressed as the mean \pm standard deviation (SD).

RESULTS

Tarsus

The tarsus of chinkara comprises of five bones both gross anatomically and radiographically i.e., In the first row, tibial tarsal, fibular tarsal, 2nd row, fused central and fourth tarsal, and the third row, first tarsal, second and third tarsal fused (Fig. 1).

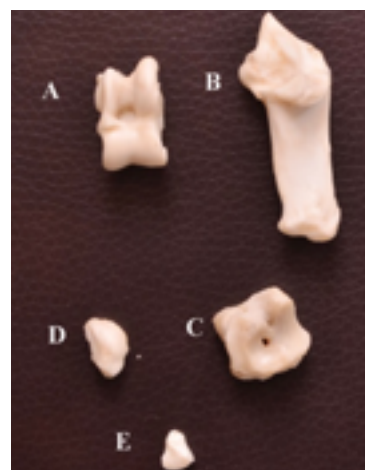


Fig. 1. Tarsal bones of adult chinkara Talus (A); Calcaneous bone (B); Central tarsal bone (C); fused 2nd and 3rd tarsal bone (D); first tarsal (E).

Fibular tarsal bone (calcaneous bone)

The fibular tarsal bone is the biggest and longest of the hock, situated on the lateral side and had a bulbous tuber calcis at the proximal extremity, which projects upward and backward “point of the hock.” (Figs. 7 and 8). It is elongated and distally flattened from side to side. The proximal end of the plantar aspect is enlarged, rounded and centrally slightly grooved (Fig. 2). The medial and lateral surface is slightly concave and convex, respectively (Fig. 2). The distal extremity of the body is flattened laterally and has a strong projection on its distal part, the sustentaculum tali, on the dorsal surface which projects medially. The calcaneus sulcus is present between the middle and the distal articular surfaces. The average maximum height and breadth for fibular tarsal bone, in the current study, is 5.61 ± 0.23 cm and 2.06 ± 0.13 cm, respectively (Table I).

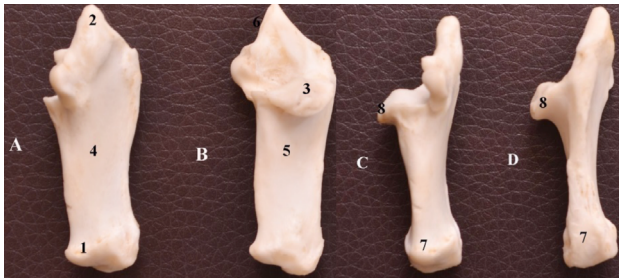


Fig. 2. Different aspects (A, B, C, D) of adult chinkara fibular tarsal bone showing tuber calcis (1,7), facet for articulation with central and fourth fused tarsal (2), sustentaculum tali (3&8), lateral surface (4), medial surface.

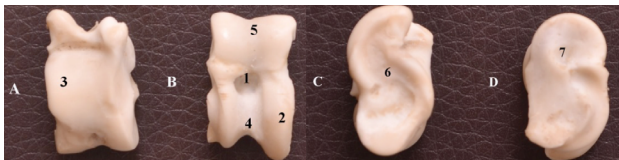


Fig. 3. Surfaces of the tibial tarsal (A, B, C, D) of adult chinkara showing synovial fossa (1), condyles (2), planter surface bearing large oval facet (3), distal trochlea (4), proximal trochlea (5), medial surface (6), lateral surface (7).

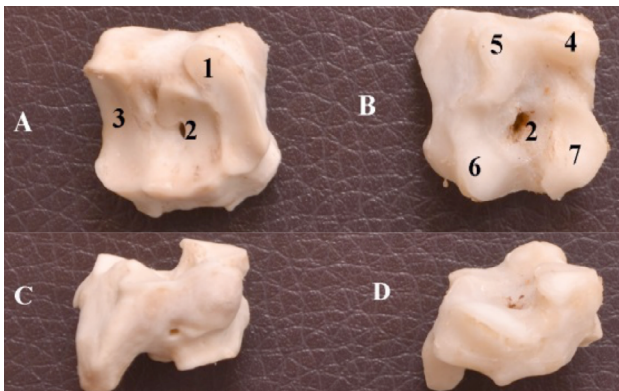


Fig. 4. Surfaces of the central and fourth fused tarsal bones showing proximal (A), ventral (B), medial (C), lateral surface (D), articular facets for calcaneus bones. 1, foramen in the center of the bones more prominent on the ventral surface 2, articular facet for distal trochlea of talus bone 3, articular facet for first, second and third fused tarsal (4,5,6 and 7).

Tibial tarsal bone (talus bone)

It has been observed grossly and radiographically that the tibial tarsal bone is the 2nd largest bone of the first (proximal) row (Table I), lies on the medial side of the tarsus, has trochlea at either end and offered six surfaces for interpretation (Figs. 6 and 8). The proximal extremity of the dorsal surface is continuous with the distal extremity

and has trochlea for the junction with the distal articular surface of the tibia. The trochlea of the tibial tarsal bone consists of two smooth sagittal semicircular ridges with a deep groove between them (Fig. 3). The lateral ridge of the trochlea is thicker than the medial ridge (Fig. 3). A deep rough synovial fossa is notified on the dorsal side on the distal end of the groove (Fig. 3). A prominent rough tuberosity is observed on the medial side of the ridge, on either side of the trochlea and has articular surfaces. The distal extremity of the dorsal surface is composed of two condyles alienated by a shallow groove articulate with center tarsal bone (Figs. 3 and 7). The average maximum height and breadth for tibial tarsal is 2.79 ± 0.05 cm and 1.74 ± 0.01 cm, respectively (Table I).

Central and fourth fused tarsals (centroquartal bone)

It has been seen that the central and fourth tarsals bone are merged to form a comparatively large bone (Figs. 4 and 5) and larger part of the proximal surface of this bones is cast on the distal trochlea of the tibial tarsal bone (Figs. 7 and 8), two concave articular facets are present on the proximal surface, in which medial facet is narrower and more concave than the lateral facet (Fig. 4). A small non-articular area is present between the two articular facets; medial edge of the proximal surface rises proximally above the rest posteriorly (Fig. 4). Laterally, undulating and narrow surface for the junction with the distal end of the fibular tarsal bone is noted (Fig. 4). The planter surface bears two tuberosities, of which the lateral one is rounded, the medial is more prominent and narrower and the area between tuberosities, is excavated and rough, and there is a smooth facet laterally centrally concave for the fibular tarsal bone on the posterior angle. The dorsal surface and the medial border are continuous, convex, and rough and are divided into two lateral and medial articular facets by a dorsoplantar ridge. The ventral surface is convex, and have four articular facets, the dorsal articular facets are wider than planter articular facets and the articular facets on the lateral side is slightly above from the articular facets of the medial side and is crossed by a non-articular groove. The nutrient foramen is present in the center of the non-articular area, more prominent on the ventral surface (Fig. 4). The mean maximum height and breadth for central and fourth fused tarsal are 1.51 ± 0.13 cm and 2.08 ± 0.07 cm, respectively (Table I).

First tarsal bone

The first tarsal bone is a trapezoidal shaped bone and positioned on the posteromedial surface of the hock. The first tarsal is joined with the central tarsal bone proximally, the metatarsus distally, and the second and third fused tarsal laterally (Fig. 8). The mean greatest length and maximum breadth of the first tarsal is 0.61 ± 0.01 cm and 1.10 ± 0.006 cm, respectively (Table I).

Table I.- Measurements of the tarsal bones in adult chinkara.

S.no	Bone	Variables	Female (Mean)	Male (Mean)	Mean (Male + Female)	Range
1	Tibial tarsal	Maximum height (Hm)	2.76±0.04	2.81±0.06	2.79±0.05	2.75-2.90
		Maximum breadth (Bm)	1.75±0.02	1.73±0.03	1.74±0.01	1.73-1.75
2	Fibular tarsal(calcanious)	Maximum height (Hm)	5.44±0.09	5.78±0.11	5.61±0.13	5.37-5.89
		Maximum breadth (Bm)	1.94±0.09	2.18±0.08	2.06±0.13	1.74-2.24
3	Central and fourth fused tarsal	Maximum height (Hm)	1.45±0.05	1.57±0.06	1.51±0.07	1.41-1.62
		Maximum breadth (Bm)	2.05±0.04	2.11±0.07	2.08±0.06	2.00-2.21
4	First tarsal bone	Maximum height (Hm)	0.59±0.01	0.62±0.02	.61 ±0.01	0.54-0.64
		Maximum breadth (Bm)	1.09±0.03	1.11±0.05	1.10±0.06	0.98-1.15
5	2nd and 3rd tarsal bone	Maximum height (Hm)	0.98±0.01	0.98±0.01	0.98±0.01	0.97-0.99
		Maximum breadth (Bm)	1.48±0.01	1.49±0.02	1.49±0.01	1.48-1.50

Table II.- The measurements of the tarsal bones of adult chinkara compared to chital, blue bull, blackbuck and camel ((Yadav *et al.*, 2015; Bharti, 2016; Choudhary *et al.*, 2015; Vukovic and Bogdanovi, 2013).

S.no	Bone	Variables	Chinkara	Chital	Blue bull	Black buck	Camel
1	Tibial tarsal	Maximum height (Hm)	2.79±0.05	3.08±0.03	6.81±0.02	2.81± 0.01	8.18
		Maximum breadth (Bm)	1.74±0.01	2.13±0.02	3.84±0.03	1.82±0.01	—
2	Fibular tarsal	Maximum height (Hm)	5.61±0.13	8.05±0.04	12.00±0.02	5.99±0.02	15.42
		Maximum breadth (Bm)	2.06±0.13	1.75±0.02	3.72±0.02	1.71±0.02	7.06
3	Central and fourth fused tarsal	Maximum height (Hm)	1.51±0.07	1.73±0.03	2.54±0.02	0.83±0.02	3.61
		Maximum breadth (Bm)	2.08±0.06	3.05±0.02	5.11±0.02	2.10±0.02	5.1
4	First tarsal bone	Maximum height (Hm)	.61 ±0.01	0.75±0.08	2.14±0.02	1.13±0.02	
		Maximum breadth (Bm)	1.10±0.06	0.53±0.01	3.32±0.04	1.23±0.02	
5	2nd and 3rd tarsal bone	Maximum height (Hm)	0.98±0.01	1.95±0.04	1.68±0.03	0.59±0.02	2.15
		Maximum breadth (Bm)	1.49±0.01	1.60±0.03	3.34±0.03	1.20±0.02	3.38

Second and third fused tarsal

This tarsal bone is similar to the central but is reduced and wedge-shaped in outline. It is positioned between the central proximally and the large metatarsal bone distally (Figs. 6, 7 and 8). These bones possess two borders and two surfaces. The proximal surface is concave, while the distal surface is slightly convex. The dorsal border is convex and rough. The planter border is rough and contains small tubercles. The mean greatest length and maximum breadth of second and third fused tarsal is 0.98±0.01 cm and 1.49±0.01 cm, respectively in the adult chinkara (Table I).

Radiographic examination

The radiographic studies certified the visualization of all tarsal bones: the talus, calcaneus, central and fourth fused tarsal bones, and the first, second and third fused

tarsal bones (Figs. 6, 7 and 8). Through radiographic studies tarsus in chinkara are formed of the distal extremity of the tibia and malleolar bone and the proximal extremity of the third and fourth fused metatarsal bones in addition to 5 tarsal bones; talus (tibial-tarsal bone) and calcaneus (fibular-tarsal bone) in the proximal row, central and fourth fuse (Fig. 7) tarsal bone in the middle row, first, second and third fused in the distal row (Figs. 6, 7 and 8). Radiographically (dorsoplantar and plantodorsal view) four tarsal joints are identified; tibiotarsal, proximal intertarsal, distal intertarsal and tarsometatarsal joints (Figs. 6 and 7). The plantar surface of the talus is superimposed and articulates with the distal dorsal surface of the fibular-tarsal bone and proximally articulates with the distal extremity of the tibia and malleolar bone forming tibiotarsal joint. Condyles on the distal border of the talus

bone are radiographically easily visible (dorsoplantar view), articulated with the central and fourth fused tarsal bone (Figs. 6 and 8). The dorsal surface of the talus bone has no superimposition, therefore proximal and distal trochlea was easily identifiable (Fig. 6).

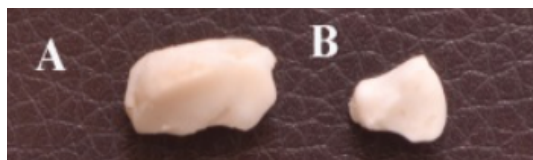


Fig. 5. 2nd and 3rd fused and first tarsal bone.



Fig. 6. Dorso-palantar radiograph of the tarsal bones in adult chinkara proximal intertarsal (calcaneoquartal) joint. 1, distal inter tarsal joint; 2, tarsometatarsal joints; 3, articulation of calcaneus and central and fourth tarsal bone (on the lateral side of the hock); 4, articulation of central and fourth tarsal bone and large metatarsal (on the lateral side of the hock); 5, superimposed first tarsal bone and 6, second tarsal bone.

The fibular-tarsal bone is located on the proximal plantolateral surface of the hock, superimposition only on the lower dorsal surface which is articulated with the tibial-tarsal bone and distally with the central tarsal bone (Figs. 7 and 8). The distal part of the fibular-tarsal bone articulated with the central and fourth fused tarsal bone on the lateral surface (Figs. 6 and 7).

The central and fourth fused tarsal bone. Its proximal part is superimposed dorsally with the talus and the plantar surface with the fibular-tarsal. Its distal part is superimposed with the 2nd and 3rd fused tarsal bone. The lateral part of the ventral surface articulated with the 4th large metatarsal bone (Figs. 6 and 7). The first tarsal bone is regular quadrangular in shape and is completely superimposed with the second 2nd and third fused tarsal bone. The second and third fused tarsal bone a fully superimposed except a small area at its dorsal aspect is visible (Fig. 6).



Fig. 7. Palanto-dorsal radiograph of the tarsal bones in adult chinkara showing tibia (1), calcaneus bone (2), talus bone (3), central tarsal bone (4), second and third fused Tarsal Bone (5), large metatarsal bone (6), tarsocrural joint (7), proximal intertarsal (calcaneoquartal) joint (8), tarsometatarsal joints (9), *Malleolus* (10), sustentaculum tali (11), articulation of central and fourth tarsal bone and large metatarsal (12), articulation of calcaneus and central and fourth tarsal bone (on the lateral side of the hock) (13).



Fig. 8. Mediolateral radiograph of the tarsal bones in adult chinkara showing tibia (1), calcaneus bone (2), talus bone (3), central tarsal bone (4), second and third fused Tarsal Bone (5), first tarsal bone (6), large metatarsal bone (7).

DISCUSSION

Good knowledge of the normal anatomical appearance is required for the correct diagnosis of the lesions of a specific area (Raes *et al.*, 2010). The normal gross anatomic and radiographic appearance of the chinkara tarsus have not yet been described. The tarsus

of chinkara comprised of five bones both grossly and radiographically as reported in ruminants (Raghavan, 1964), in cattle (Melania *et al.*, 2009), in Indian muntjac (*Muntiacus muntjak*) (Rajani *et al.*, 2013), in marsh deer (*Blastocerus dichotomus*) (Bruno *et al.*, 2015) and in blue bull (*Boselaphus tragocamelus*) (Bharti, 2016), while, in contrast to this study, the findings of (Melania *et al.*, 2009) in camelids reported six tarsus bones. Miller *et al.* (2013) identified seven tarsal bones in dogs while in pigs and carnivores by Akers and Denbow, (2008). Similarly, six short bones reported in horses by Getty (1975), while, seven tarsal bones in hedgehog are reported by Ozkan (2002b). De Araujo *et al.* (2013) revealed seven bones in Caviomorph Rodents. Seven tarsal bones have been reported in leopard (*Panther pardus*) (Podhade, 2014). It is incurred from the current investigations that the number of bones in the tarsus of chinkara is more like the wild ruminants as Indian muntjac, marsh deer and blue bull are found closely related animals to chinkara.

The gross morphology of the fibular tarsal found in this study is parallel to the reports of Getty (1975) and Konig and Liebich (2006) in horse, Miller *et al.* (2013) in dog, Choudhary *et al.* (2015) in black buck (*Antelope cervicapra*), Yadav *et al.* (2015) in spotted deer and (Bharti, 2016) in blue bull. It is interesting that the fibular tarsal bone is grossly analogous to non-ruminants i.e. horse and dogs. However, the osteometric parameters measured in this study are distinct from previous reports related to wild animals, i.e. Black Buck (Choudhary *et al.*, 2015), spotted deer (Yadav *et al.*, 2015) and blue bull (Bharti, 2016).

The gross anatomic features of tibial tarsal bone witnessed in chinkara are parallel to the studies of Raghavan (1964) in ox, Miller *et al.* (2013) in dogs, while contradiction to the current study is seen in reports of Smuts and Bezuidenhout (1987) in dromedary camels. A deep rough synovial fossa is identified on the dorsal side of the distal end of the groove in this study. Similar findings have been reported by Raghavan (1964) in ox. The current study also notified that the distal extremity of the dorsal surface is comprised of two condyles divided by a shallow groove articulated with central tarsal bone. A similar description is devised by Raghavan (1964) in ox, and Smuts and Bezuidenhout (1987) in dromedary camels. This feature of the chinkara tibial tarsal bone is more related to ruminants.

The average maximum height and breadth for tibial tarsal is 2.79 ± 0.05 cm and 1.74 ± 0.01 cm, respectively. However, higher values from the present study for the same parameters have been reported in Indian black buck by Choudhary *et al.* (2015) i.e. 2.81 ± 0.005 cm and 1.82 ± 0.004 cm while in blue bull by Bharti (2016) i.e. 6.81 ± 0.01 cm and 3.81 ± 0.01 cm, respectively.

The gross shape of central and the fourth tarsal bones identified in the current study are in accordance with reports of Raghavan (1964) in ox and Frandson *et al.* (2009) in ruminants and swine; but these conclusions were in disagreement with the findings of Getty (1975) in horse who publicized the central tarsal bone was square and not fused with fourth tarsal bone. Getty (1975) reported a small non-articular area between the two articular facets in ox. However, the medial edge of the proximal surface was found raised high above the rest posteriorly in his study. This finding is in accordance with the present study in adult chinkara. This study revealed an average maximum height and breadth for central and fourth fused tarsal is 1.51 ± 0.13 cm and 2.08 ± 0.07 cm, while, Choudhary *et al.* (2015) reported similar parameter at 0.83 ± 0.006 cm and 2.10 ± 0.006 cm in black buck, and 2.54 ± 0.01 cm and 5.11 ± 0.01 cm have been reported by Bharti (2016) in blue bulls.

In this study, the first tarsal bone is located at the postero-medial surface of the hock. Similar description has been narrated by Raghavan (1964) in the ox and Smuts and Bezuidenhout (1987) in dromedary camel. However, this finding is in disagreement with Miller *et al.* (2013) in the dog, who stated that the first tarsal bone was fused with distally lying first metatarsal bone. Whereas, the study of Getty (1975) in horse postulated that the first and second tarsal bones are usually fused. The greatest length and maximum breadth of second and third fused tarsal measured in the current study are higher from the reports of Choudhary *et al.* (2015) in black buck and lower from the reports of Bharti (2016) in blue bulls.

CONCLUSIONS

This may be concluded from the current study that tarsal bones of adult chinkara are both grossly and radiographically analogous to the small ruminants. However, Osteomteric differences exist from other ruminants.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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