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Study of twenty non-metric dental crown traits using ASUDAS system in NCR (India) population

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Abstract

Background The non-metric dental crown traits (NDCT) can vary within and between the geo-populations. These play a critical role in the ethnicity determination and help in identification of an individual. A commonly used system for scoring these dental traits is "Arizona State University Dental Anthropology System" (ASUDAS).

Aim and objectives Our study aims to evaluate the frequency trend of twenty NDCT traits in the India, National Capital Region population using ASUDAS, and check for any significant sexual dimorphism for each trait.

Methods The maxillary and mandibular dental casts from 200 patients (100 males+100 females, age 18–30 years) reporting to the dental OPD of a Government dental college were evaluated. Twenty dental crown traits were scored as per ASUDAS protocol in each dental cast by three investigators independently. NDCTs were tabulated and the chi-square test was performed for calculation of the *P* value.

Results The results showed that the trait cusp number (83%) and lingual cusp variation (79%) were the two most frequent NDCTs and Y groove pattern (13%) and premolar accessory cusp-4 (12.5%) were the two least frequent traits observed. Shoveling of the upper lateral incisor ($P=0.007$), tuberculum dentale ($P=0.049$), mesial ridge (lingual) ($P=0.034$), and hypocone absence ($P=0.001$) were found to show statistically significant sexual dimorphism ($P < 0.05$). Although grade-wise expression of shoveling in upper lateral had statistically significant sexual dimorphism and the frequency of higher expression grades was found more in females, overall dichotomy of expression was not significant. Similarly, although an expression of grade-wise tuberculum dentale, mesial ridge (lingual) and hypocone absence had statistically significant sexual dimorphism, an overall dichotomy of expression was not significant.

Conclusion The current study shows certain NDCTs like cusp number and lingual cusp variation have a significant association with the NCR population. Sexual dimorphism was not significant; hence, future studies should be planned on a large sample with sex pooled data for each precise location and ethnicity in all the regions of India. This can be further correlated with different facial forms and dental occlusal patterns, for correlation with abnormalities in jaws and teeth.

Keywords Non-metric dental traits, ASUDAS, Cusp of Carabelli, Shoveling, Dental anthropology, Forensic odontology

*FDI tooth-numbering

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Background

Archaeology is a subfield of anthropology, with an exception of a few countries including India where they both are considered two different subjects (Chowdhry and Bablani Popli 2018). Dental anthropology involves analysing, recording and interpreting dental morphological metric and non-metric crown and root traits (Marado and Campanacho 2013). Dental morphological traits are valuable for understanding variations amongst populations, and dental anthropologists have catalogued these diverse dental features (Acharya and Sivapathasundharam n.d.).

The significance of metric and non-metric traits of teeth depends on their frequency of occurrence and distinctiveness in a given population. The non-metric dental crown traits (NDCT) can play a critical role in forensic racial identification and have been used in determining a person's profile, which includes deriving ethnic affiliation (Baby et al. 2017; Simões et al. 2014). Further, since these are inheritable characteristics of an individual, they can also be used to study the evolutionary patterns in dentition with time and can have implications in the determination of dietary and occupational patterns (Kapoor et al. 2021b).

It may have an additional clinical relevance, as the arrangement of jaws and teeth can render certain characteristic traits to the dentition, which may be correlated to the type of malocclusion and the associated abnormalities. Ironically, the long-term implication of the presence of such traits in the stability of dental treatments has not been explored sufficiently (Kapoor et al. 2021a).

Dental traits have been studied by various anthropological systems, including the commonly used method "Arizona State University Dental Anthropology System" (ASUDAS) plaques based on standardized scoring of dental variation on teeth from humans (Baby et al. 2017; Turner et al. 1991).

Globally, various studies have been conducted (Hanihara 2008; Peiris et al. 2011; Tinoco et al. 2016) in search of population patterns for NDCT of teeth using few or all traits of ASUDAS. In the Indian context, very little literature is available on study of NCDT traits including a study comparing Odisha and Kerala populations (Nair et al. 2020). However, India is a vast country with people from different ethnicities and origins; hence, the NDCT data specific to an area, gender and ethnicity in Indian population is the need of the hour. Thus, the present pilot study was designed to use ASUDAS plaques to know the frequency trend of NDCT in the National Capital Region (NCR) population. Further, the objectives were to derive the trend of frequencies of twenty NDCT traits and check for any significant sexual dimorphism for each trait using ASUDAS plaques. NCR region representation has been provided in Fig. 1 (National Capital Region Planning Board n.d.).

Methods

A descriptive cross-sectional pilot study for evaluating the frequency of twenty NCDT on maxillary and mandibular dental casts from 200 NCR residents (100 males + 100 females) was planned and institutional

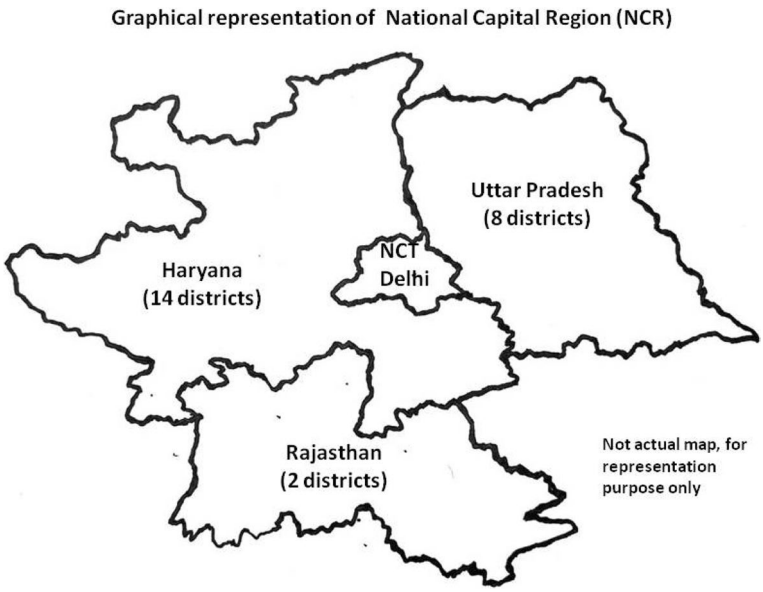

Fig. 1 Graphical representation of National Capital Region (NCR) which includes whole of National Capital Territory (NCT) of Delhi and 24 districts in three neighbouring states of Haryana, Uttar Pradesh and Rajasthan

and university ethical clearance (29/6/116/JMI/IEC) was subsequently taken. All the patient casts were produced from maxillary and mandibular impressions made from volunteered patients recruited at the Department of Oral Pathology and Microbiology of a Dental College in New Delhi after taking informed consent.

It was made sure that all the casts included in the sample belonged to residents of NCR within the age range between 18 and 30 years. This age group was chosen to ensure the presence of fully developed dental arches. The casts with any regressive alterations or congenital defects were excluded.

All observations were carried out under good lighting and using 10X hand lenses. Federation Dentaire Internationale (FDI) tooth notation system was used throughout the study. All three investigators independently examined twenty NDCTs in all casts on the target tooth. Winging (W), shoveling in 21 (SH-UI1), double shoveling (DSH), shoveling in 22 (SH-UI2), interrupted groove (IG), tuberculum dentale, mesial ridge (lingual), premolar accessory cusp in 24 (PAC-4), premolar accessory cusp in 25 (PAC-5), Carabelli cusp (CC), hypocone absence (3-cusp UM2), lingual cusp variation (LC), sixth cusp (C6), seventh cusp (C7), deflecting wrinkle (DW), protostylid (PRS), distal trigonid crest (DTC), hypoconulid absence/ presence of 5th cusp (4-cusp LM2), cusp number and Y groove pattern were the twenty NDCTs studied on the casts. Two authors (DBP and PK) scored the NDCTs independently; all observations were compared and variations in observations if any were resolved by joint evaluation with third author AC. To avoid possible eye strain of the observer which can arise subsequently after taken observations, small breaks of 5 min were taken in between each assessment of single cast data. Plaster replicas of the ASUDAS plaques were used to standardize comparative scoring (Turner et al. 1991). Only the left hemi-arch of each cast was examined, to avoid bias and distortions due to possible asymmetries. The NDCT were identified as "present" or "absent", registered by a dichotomy protocol (Hanihara 2008; Tinoco et al. 2016). When examination of the target left side tooth was not possible due to the presence of a carious lesion, restoration, anomaly, or its absence, then the right quadrant tooth of the same jaw was scored. If even the right element was not possible to be examined, then option "null" was registered and the NDCT was not been examined on that cast. All the observations were entered in "Dental anthropology data collection table" (Table 1). The data obtained was

Table 1 Dental anthropology data collection table

	Trait	Target tooth FDI[a]	Dichotomy expression[b]	Dichotomy score (Tick the correct score observed on cast)										Dichotomy result	
														Yes	No
1	Winging	11, 21	(1A-2) / (1A-4)	1A			1B		2	3		4			
2	Shoveling-1	21	(3-6) / (0-6)	0		1	2	3	4	5		6			
3	Double shoveling	21	(2-6) / (0-6)	0		1	2	3	4	5		6			
4	Shoveling-2	22	(3-7) / (0-7)	0		1	2	3	4	5		6	7		
5	Interrupted groove	22	(M, D, MD, Med) / (0 - Med)	0			M	D		MD		Med			
6	Tuberculum dentale	22	(1-9) / (0-9)	0	1	2	3	4	5	6	7	8	9		
7	Mesial ridge (lingual)	23	(1-3) / (0-3)	0		1			2		3				
8	Premolar accessory cusp-4	24	(1)/ (0-1)	0					1						
9	Premolar accessory cusp-5	25	(1)/ (0-1)	0					1						
10	Cusp of Carabelli	26	(5-7) / (0-7)	0		1	2	3	4	5		6	7		
11	Hypocone absence	27	(0-1) / 0-5)	0		1	2	3		4		5			
12	Lingual cusp variation	35	(1-9) / (0-9)	0	1	2	3	4	5	6	7	8	9		
13	Sixth cusp	36	(1-5) / (0-5)	0		1	2	3		4		5			
14	Seventh cusp	36	(1-4) / (0-4)	0			1		2	3		4			
15	Deflecting wrinkle	36	(3) / (0 – 3)	0			1			2		3			
16	Protostylid	36	(1-7) / (0-7)	0		1	2	3	4	5		6	7		
17	Distal trigonid crest	36	(1)/ (0-1)	0					1						
18	Hypoconulid absence	37	(0) / (4-5)	0			4			5					
19	Cusp number	37	(4) / (4, 5)	4					5						
20	Y groove pattern	37	(y) / (Y, +, X)	Y			+			X					

[a] Fédération Dentaire Internationale (FDI) tooth-numbering

[b] (Present range of grades) / (total range of grades)

Table 2 Overall frequency distribution of each expression grade of all non-metric dental traits

	Count	Column *N* %
Winging		
1A	14	7.0%
1B	6	3.0%
2	13	6.5%
3	157	78.5%
4	10	5.0%
Shoveling-1		
0	40	20.0%
1	58	29.0%
2	69	34.5%
3	29	14.5%
4	4	2.0%
Double shoveling		
0	100	50.0%
1	42	21.0%
2	30	15.0%
3	9	4.5%
4	16	8.0%
5	3	1.5%
Shoveling-2		
0	50	25.0%
1	39	19.5%
2	63	31.5%
3	41	20.5%
4	7	3.5%
Interrupted groove		
0	83	41.5%
D	15	7.5%
M	44	22.0%
MD	7	3.5%
Med	51	25.5%
Tuberculum dentale		
0	87	43.5%
1	48	24.0%
2	40	20.0%
3	19	9.5%
4	4	2.0%
5	2	1.0%
Mesial ridge (lingual)		
0	113	56.5%
1	63	31.5%
2	24	12.0%
Premolar accessory cusp on 24		
0	175	87.5%
1	25	12.5%
Premolar accessory cusp on 25		
0	166	83.0%
1	34	17.0%
Cusp of Carabelli		
0	62	31.0%
1	44	22.0%
2	13	6.5%
3	20	10.0%
4	10	5.0%
5	22	11.0%
6	15	7.5%
7	14	7.0%
Hypocone absence		
0	49	24.5%
1	19	9.5%
2	23	11.5%
3	64	32.0%
4	32	16.0%
5	13	6.5%
Lingual cusp variation		
0	42	21.0%
1	26	13.0%
2	57	28.5%
3	33	16.5%
4	13	6.5%
5	15	7.5%
6	2	1.0%
8	11	5.5%
9	1	0.5%
Sixth cusp		
0	155	77.5%
1	22	11.0%
2	13	6.5%
3	4	2.0%
4	4	2.0%
5	2	1.0%
Seventh cusp		
0	101	50.5%
1	53	26.5%
2	26	13.0%
3	6	3.0%
4	14	7.0%
Deflecting wrinkle		
0	59	29.5%
1	54	27.0%
2	31	15.5%
3	56	28.0%
Protostylid		
0	85	42.5%
1	49	24.5%
2	27	13.5%
3	19	9.5%

Table 2 (continued)

	Count	Column *N* %
4	19	9.5%
5	1	0.5%
Distal trigonid crest		
0	121	60.5%
1	79	39.5%
Hypoconulid absence		
0	154	77.0%
4	37	18.5%
5	9	4.5%
Cusp number		
4	167	83.5%
5	33	16.5%
Y groove pattern		
+	29	14.5%
P	113	56.5%
X	32	16.0%
Y	26	13.0%

entered into an Excel (Registered) and processed with Social Sciences (Registered). The sex pooled frequencies of each NDCT were calculated.

Table 3 Overall dichotomy-based expression of each non-metric dental traits

Traits	Absent	Absent %	Present	Present %
Winging	167	83.50%	33	16.50%
Shoveling-1	167	83.50%	33	16.50%
Double shoveling	142	71.00%	58	29.00%
Shoveling-2	152	76.00%	48	24.00%
Interrupted groove	83	41.50%	117	58.50%
Tuberculum dentale	87	43.50%	113	56.50%
Mesial ridge (lingual)	113	56.50%	87	43.50%
Premolar accessory cusp-4	175	87.50%	25	12.50%
Premolar accessory cusp-5	166	83.00%	34	17.00%
Cusp of Carabelli	149	74.50%	51	25.50%
Hypocone absence	132	66.00%	68	34.00%
Lingual cusp variation	42	21.00%	158	79.00%
Sixth cusp	155	77.50%	45	22.50%
Seventh cusp	101	50.50%	99	49.50%
Deflecting wrinkle	144	72.00%	56	28.00%
Protostylid	85	42.50%	115	57.50%
Distal trigonid crest	121	60.50%	79	39.50%
Hypoconulid absence	46	23.00%	154	77.00%
Cusp number	34	17.00%	166	83.00%
Y groove pattern	174	87.00%	26	13.00%

Results

Overall frequency distribution of each of the 20 NDCTs was carried out on all 200 subjects (100 male and 100 female). The overall frequency distribution of each expression grade of all twenty NDCTs is presented in Table 2, whereas Table 3 depicts the overall dichotomy-based expression of each of 20 NDCTs. The traits Cusp number (83%) and LC (79%) were the 2 most frequent NDCTs, whereas Y groove pattern (13%) and PAC-4 (12.5 %) were the 2 least common NDCTs observed in NCR population. NDCTs showing incidence less than 20% were PAC-4 (12.5 %), Y groove pattern (13%) PAC-5 (17 %), W (16.50%) and SH UI1 (16.50%). Cusp number (83%), LC (79%) and 4-cusp LM2 (77%), tuberculum dentale (56.50%), IG (58.50%) and PRS (57.50%) had more than 50% of incidence.

Table 4 shows the frequency values and percentage of all 20 NDCTs according to sex distribution and sexual dimorphism. Sexually dimorphic frequencies for all 20 NDCTs were tabulated and chi-square test was performed for calculation of *P* value. SH-UI1 (P=0.036), DSH (P=0.029) and DTC (P=0.014) were found to have statistically significant sexual dimorphism ($P < 0.05$) as per dichotomy expression of NDCTs.

Table 5 shows the frequency values and percentage for expression of grade of all 20 NDCTs according to sex distribution and sexual dimorphism. Sexually dimorphic frequencies for expression of grade of all twenty NDCTs were tabulated and chi-square test was performed for calculation of *P* value. SH-UI2 (P=0.007), tuberculum dentale (P=0.049), mesial ridge (lingual) (P=0.034) and 3-cusp UM2 (P=0.001) were found to have statistically significant sexual dimorphism ($P < 0.05$) expression of grades. Although expression of grade-wise SH-UI2 had statistically significant sexual dimorphism and frequency of higher expression grades was found more in females (Table 5), overall dichotomy of expression was not significant (Table 4). Similarly, although expression of grade-wise tuberculum dentale, mesial ridge (lingual) and 3-cusp UM2 had statistically significant sexual dimorphism (Table 5), overall dichotomy of expression was not significant (Table 4).

Discussion

Various authors have highlighted the fact that genetic factors control tooth size and morphology. The process of odontogenesis is controlled by homeobox (HOX) genes, mesenchymal regulatory molecules and their receptors (Cakan et al. 2013). The genome of an individual and population is responsible for morphological dental crown and root traits. It may be of interest to the forensic dental anthropologist that various bioarcheological-based studies have highlighted the differences in the expression and

Table 4 Chi-square test for dichotomy expression of non-metric dental traits

		Categories	*N*	Sex		Chi-square	*P* value*
				Female (*N* (%))	Male (*N* (%))		
1	Winging	Absent	167	85 (85)	82 (82)	0.327	0.568
		Present	33	15 (15)	18 (18)		
2	Shoveling-1	Absent	167	89 (89)	78 (78)	4.391	**0.036**
		Present	33	11 (11)	22 (22)		
3	Double shoveling	Absent	142	64 (64)	78 (78)	4.76	**0.029**
		Present	58	36 (36)	22 (22)		
4	Shoveling-2	Absent	152	78 (78)	74 (74)	0.439	0.508
		Present	48	22 (22)	26 (26)		
5	Interrupted groove	Absent	83	41 (41)	42 (42)	0.021	0.886
		Present	117	59 (59)	58 (58)		
6	Tuberculum dentale	Absent	87	44 (44)	43 (43)	0.02	0.887
		Present	113	56 (56)	57 (57)		
7	Mesial ridge (lingual)	Absent	113	63 (63)	50 (50)	3.438	0.064
		Present	87	37 (37)	50 (50)		
8	Premolar accessory cusp-4	Absent	175	90 (90)	85 (85)	1.143	0.285
		Present	25	10 (10)	15 (15)		
9	Premolar accessory cusp-5	Absent	166	81 (81)	85 (85)	0.567	0.451
		Present	34	19 (19)	15 (15)		
10	Cusp of Carabelli	Absent	149	76 (76)	73 (73)	0.237	0.626
		Present	51	24 (24)	27 (27)		
11	Hypocone absence	Absent	132	61 (61)	71 (71)	2.228	0.136
		Present	68	39 (39)	29 (29)		
12	Lingual cusp variation	Absent	42	17 (17)	25 (25)	1.929	0.165
		Present	158	83 (83)	75 (75)		
13	Sixth cusp	Absent	155	73 (73)	82 (82)	2.323	0.128
		Present	45	27 (27)	18 (18)		
14	Seventh cusp	Absent	101	44 (44)	57 (57)	3.38	0.066
		Present	99	56 (56)	43 (43)		
15	Deflecting wrinkle	Absent	144	71 (71)	73 (73)	0.099	0.753
		Present	56	29 (29)	27 (27)		
16	Protostylid	Absent	85	38 (38)	47 (47)	1.657	0.198
		Present	115	62 (62)	53 (53)		
17	Distal trigonid crest	Absent	121	52 (52)	69 (69)	6.047	**0.014**
		Present	79	48 (48)	31 (31)		
18	Hypoconulid absence	Absent	46	21 (21)	25 (25)	0.452	0.502
		Present	154	79 (79)	75 (75)		
19	Cusp number presence	Absent	34	20 (20)	14 (14)	1.276	0.259
		Present	166	80 (80)	86 (86)		
20	Y groove pattern presence	Absent	174	85 (85)	89 (89)	0.707	0.4
		Present	26	15 (15)	11 (11)		

*Statistically significant sexual dimorphism ($P < 0.005$)

frequency of tooth traits amongst ethnic populations for ancestry identification (Baby et al. 2017).

As per the Clonal model theory, every dental trait is a result of interaction between environmental and genetic factors, which is applicable in the case of NCDT too. The difference in frequencies of NCDTs is likely to be seen in various populations. Thus NDCTs have high taxonomic and forensic significance, and by studying

Table 5 Sexually dimorphic frequencies for expression of grade of non-metric trait and chi test

	Categories	*N*	Sex		Chi-square	*P* value*
			Female (*N* (%))	Male (*N* (%))		
Winging	1A	14	5 (5)	9 (9)	6.108	0.191
	1B	6	5 (5)	1 (1)		
	2	13	5 (5)	8 (8)		
	3	157	78 (78)	79 (79)		
	4	10	7 (7)	3 (3)		
Shoveling-1	0	40	20 (20)	20 (20)	7.682	0.104
	1	58	36 (36)	22 (22)		
	2	69	33 (33)	36 (36)		
	3	29	9 (9)	20 (20)		
	4	4	2 (2)	2 (2)		
Double shoveling	0	100	49 (49)	51 (51)	7.496	0.186
	1	42	15 (15)	27 (27)		
	2	30	20 (20)	10 (10)		
	3	9	5 (5)	4 (4)		
	4	16	9 (9)	7 (7)		
	5	3	2 (2)	1 (1)		
Shoveling-2	0	50	31 (31)	19 (19)	14.194	**0.007**
	1	39	25 (25)	14 (14)		
	2	63	22 (22)	41 (41)		
	3	41	17 (17)	24 (24)		
	4	7	5 (5)	2 (2)		
Interrupted groove	0	83	41 (41)	42 (42)	6.599	0.159
	D	15	6 (6)	9 (9)		
	M	44	18 (18)	26 (26)		
	MD	7	6 (6)	1 (1)		
	Med	51	29 (29)	22 (22)		
Tuberculum dentale	0	87	44 (44)	43 (43)	11.125	**0.049**
	1	48	21 (21)	27 (27)		
	2	40	19 (19)	21 (21)		
	3	19	14 (14)	5 (5)		
	4	4	0 (0)	4 (4)		
	5	2	2 (2)	0 (0)		
Mesial ridge (lingual)	0	113	63 (63)	50 (50)	6.75	**0.034**
	1	63	23 (23)	40 (40)		
	2	24	14 (14)	10 (10)		
Premolar accessory cusp on 24	0	175	90 (90)	85 (85)	1.143	0.285
	1	25	10 (10)	15 (15)		
Premolar accessory cusp on 25	0	166	81 (81)	85 (85)	0.567	0.451
	1	34	19 (19)	15 (15)		
Cusp of Carabelli	0	62	28 (28)	34 (34)	5.698	0.575
	1	44	27 (27)	17 (17)		
	2	13	5 (5)	8 (8)		
	3	20	9 (9)	11 (11)		
	4	10	7 (7)	3 (3)		
	5	22	11 (11)	11 (11)		
	6	15	7 (7)	8 (8)		
	7	14	6 (6)	8 (8)		

Table 5 (continued)

	Categories	*N*	Sex		Chi-square	*P* value*
			Female (*N* (%))	Male (*N* (%))		
Hypocone absence	0	49	25 (25)	24 (24)	21.588	**0.001**
	1	19	14 (14)	5 (5)		
	2	23	18 (18)	5 (5)		
	3	64	31 (31)	33 (33)		
	4	32	9 (9)	23 (23)		
	5	13	3 (3)	10 (10)		
Lingual cusp variation	0	42	17 (17)	25 (25)	9.478	0.304
	1	26	16 (16)	10 (10)		
	2	57	30 (30)	27 (27)		
	3	33	19 (19)	14 (14)		
	4	13	3 (3)	10 (10)		
	5	15	7 (7)	8 (8)		
	6	2	1 (1)	1 (1)		
	8	11	7 (7)	4 (4)		
	9	1	0 (0)	1 (1)		
Sixth cusp	0	155	73 (73)	82 (82)	17.012	**0.004**
	1	22	12 (12)	10 (10)		
	2	13	12 (12)	1 (1)		
	3	4	0 (0)	4 (4)		
	4	4	3 (3)	1 (1)		
	5	2	0 (0)	2 (2)		
Seventh cusp	0	101	44 (44)	57 (57)	6.072	0.194
	1	53	34 (34)	19 (19)		
	2	26	12 (12)	14 (14)		
	3	6	3 (3)	3 (3)		
	4	14	7 (7)	7 (7)		
Deflecting wrinkle	0	59	28 (28)	31 (31)	0.33	0.954
	1	54	28 (28)	26 (26)		
	2	31	15 (15)	16 (16)		
	3	56	29 (29)	27 (27)		
Protostylid	0	85	38 (38)	47 (47)	11.681	**0.039**
	1	49	27 (27)	22 (22)		
	2	27	19 (19)	8 (8)		
	3	19	11 (11)	8 (8)		
	4	19	5 (5)	14 (14)		
	5	1	0 (0)	1 (1)		
Distal trigonid crest	0	121	52 (52)	69 (69)	6.047	**0.014**
	1	79	48 (48)	31 (31)		
Hypoconulid absence	0	154	79 (79)	75 (75)	5.071	0.079
	4	37	14 (14)	23 (23)		
	5	9	7 (7)	2 (2)		
Cusp number	4	167	80 (80)	87 (87)	1.778	0.182
	5	33	20 (20)	13 (13)		
Y groove pattern	+	29	8 (8)	21 (21)	7.16	0.067
	P	113	61 (61)	52 (52)		
	X	32	16 (16)	16 (16)		
	Y	26	15 (15)	11 (11)		

*Statistically significant sexual dimorphism ($P < 0.05$)

these traits, evidence of racial variations credited to the micro-evolutionary process can be obtained. NCDT will have its potential role in forensic dental anthropology once population-based data is available for population (Nair et al. 2020). Hence, the current research had a primary aim to determine frequency of twenty NCDTs in NCR population. For better understanding and applicability, we discuss our NDCT frequency results in global and Indian perspective. Later we have done a comparative discussion of population affinity and sexual dimorphism.

(a) NCDT frequencies in international context:

Various researchers globally have ethnographically classified human populations based on dental morphology (Díaz et al. 2014; Venkatesh et al. 2019). Tsunehiko Hanihara defined the "Mongoloid dental complex" (Hanihara 1992), which was later divided into the Sinodont (Northeast Asian populations) and Sundadont (Southeast Asian populations) dental complexes by Turner (1984). It was suggested that Caucasoid dental complex also exists which is formed by several groups including the one from Western Eurasia (Europe, North Africa, the Middle East, and India) (Venkatesh et al. 2019). Various studies on NDCT have been conducted internationally (Díaz et al. 2014; Hanihara 2008; Peiris et al. 2011; Tinoco et al. 2016) for determining population affinities and placing the study population in a particular dental complex.

In 2015, a web application of ASUDAS (rASUDAS) was produced in R and was based on a naïve Bayes classifier algorithm for analysing twenty one independent traits of crown and root of teeth. rASUDAS application assigns an individual to one or more ancestry groups (rASUDAS n.d.; Scott et al. 2018a; Štamfelj et al. 2019). It is recommended that if a sample received or recovered has the archaeological appearance, rASUDAS analysis can be done (Scott et al. 2018a).

(b) NCDT frequencies in national (Indian) context:

The NCDT frequencies collected in the present study can be compared with a limited number of ASUDAS-based studies. ASUDAS-based studies have been conducted on few Indian geo-population parts including the region of Ajnala (Amritsar) (Acharya and Sehrawat 2021), Bengaluru (Smitha et al. 2018; Venkatesh et al. 2019), Odisha (Nair et al. 2020) and Kerala (Baby and Sunil 2019; Baby et al. 2017; Nair et al. 2020). After careful appraisal of literature, we compiled a comparative analysis table of various ASUDAS-based Indian studies (Table 6). To the best of our knowledge, this study consisted of largest number of NCDT's analysed in any Indian population till date.

Although Indian subcontinent itself is an amalgamation of heterogenous populations, frequency trends form our cross-sectional (observational) study can lay foundation for comparative studies involving various populations of India.

(c) NCDT frequencies comparative discussion:

The frequency distribution of the studied seven of twenty NCDTs in the current study and their comparisons with previously studied data from a non-scientifically exhumed archaeological assemblage of Ajnala (Amritsar, India) (Acharya and Sehrawat 2021) and other sub-divisions of humankind (Western Eurasians, Sub- Saharan Africans and Northeast Asians) has been adopted and compiled in Fig. 2. Although the trends of frequencies of the current study should have matched with Ajnala's evaluation, as they belonged to north Indian origin, only 3-cusp UM2 and Cusp number were the only two features that had frequencies (%) very close to NCDT frequencies of current study. These two traits might have forensic implications and larger resources should be diverted toward morphometric studies. Five out of seven NCDTs namely 3-cusp UM2, Cusp number, C6, C7, and mesial ridge (lingual) had frequencies higher than all four populations compared. Only two NCDT frequencies (CC and Y groove pattern) were in between the four populations compared. Our results revealed that the studied NCDTs were not similar to any of the four populations and this uniqueness should be confirmed with relatively larger sample-sized studies.

"Indodont" a.k.a. South Asian dental pattern has been followed by Sri Lankan aboriginal Vedda population with the exception that SH-UI1 which was not seen in the Vedda (Peiris et al. 2011). Higher frequencies of Cusp number and LC found in our study are consistent with results for the aboriginal Vedda study.

Cusp of Carabelli / Carabelli tubercle (CC): CC is one of the most explored NDCT (Smitha et al. 2018), with many studies from India (Kamatham and Nuvvula 2014; Kirthiga et al. 2016; Smitha et al. 2018) and abroad (Falomo 2002; Mavrodisz et al. 2007). CC's frequency is European> African> American Indians> Mongoloid races (Venkatesh et al. 2019). Current study on NCR (North India) and previous study on Ajnala (Amritsar, North India) (Acharya and Sehrawat 2021) population had CC frequency

Table 6 Comparative analysis table of various ASUDAS-based Indian studies

#	Study year	Target population	Number of traits studied	Sample size (teeth / cast)	Conclusion / inference / important finding	Reference (authors)
1.	2017	Kerala	15	1743 (1259 premolars, 484 molars)	Low prevalence rate of Carabelli trait (11.26% over all)	(Baby et al. 2017)
2.	2018	Bengaluru (Karnataka)	1	400 casts	87% frequency in maxillary first permanent molar	(Smitha et al. 2018)
3.	2019	Bengaluru (Karnataka)	5	400 casts	• Hindus, Muslims and Christians (Indians) belong to Sundonts • Iranians belong to Sinodonts	(Venkatesh et al. 2019)
4.	2019	Kerala	10	1761 teeth	• The most common trait noted was shoveling 11 (69.12%) followed by 21 (62.94%).	(Baby and Sunil 2019)
5.	2020	Odisha And Kerala	11	Odisha (*n*=506) and Kerala (*n*=536)	Cusp of Carabelli (48 %) followed by shovelling of incisors (15%) in frequency	(Nair et al. 2020)
6.	2021	Ajnala (Punjab)	11	1527 teeth	Unique frequency for non-metric dental traits in comparison with major continental ancestries	(Acharya and Sehrawat 2021)
7.	2022	National Capital Region (NCR) population	20	200 upper and lower casts	• Cusp number (83%) and Lingual Cusp Variation (79%) most frequent. • Cusp of Carabelli (frequency 25.5 %) • No sexual dimorphism in traits seen	Present study

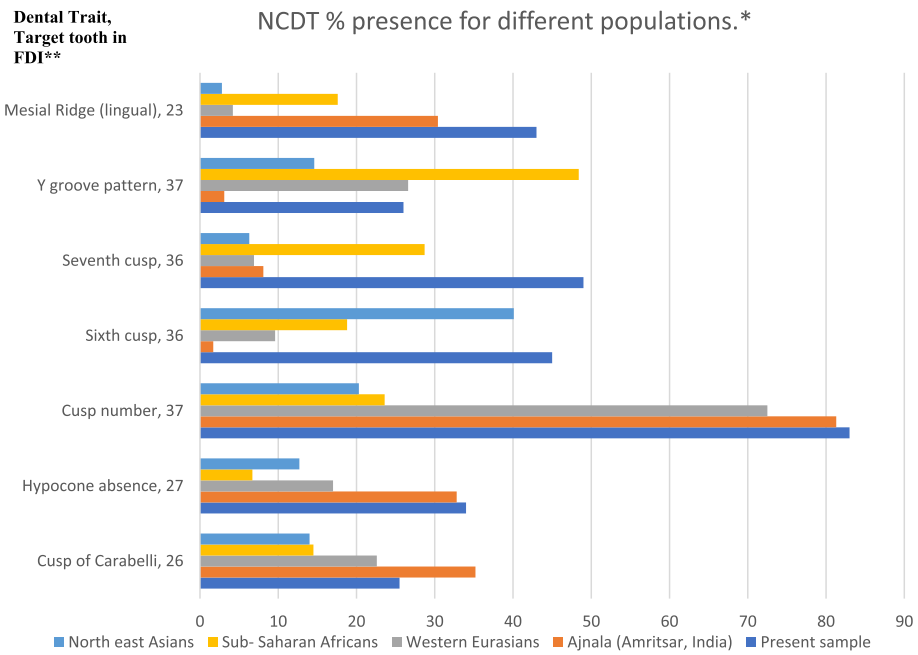

Fig. 2 Comparative frequency distribution (%) of 7 NCDTs in 5 different populations*. *Adopted from Acharya and Sehrawat 2021, **Fédération Dentaire Internationale (FDI) tooth-numbering

of 25.5 and 35.2% respectively, whereas it has been reported much higher (87%) in a south Indian (Bengaluru) population (Smitha et al. 2018).

(d) NCDT sexual dimorphism:

Although it is well known that most of NDCTs which are part of ASUDAS have low or no sexual dimorphism (Scott et al. 2018b; Venkatesh et al. 2019). Contradicting to this, a Brazilian study has found frequencies of CC, 3-cusp UM2, and C6 to be sexually dimorphic (Tinoco et al. 2016). A study to determine NCDT sexual dimorphism in a sample from Odisha and Kerala states of India found that none of the NCDTs show significant sexual dimorphism (Nair et al. 2020). This is in sync with our study where none of NCDTs evaluated showed significant dimorphism in grade expression and dichotomy simultaneously (Tables 4 and 5).

Conclusions

The sample of this study did not have the Western Eurasians pattern, nor the Sub-Saharan Africans, nor the Northeast Asians one. Surprisingly, the derived frequencies are not consistent with the results of many previous studies making current sample unique and it is practically difficult to place the NCR population in a particular "dental complex" anthropologically, based on our results. Our research has found new elements, which have ethnographic value, and we are sure that analysis of NCDTs in heterogenous populations like India will eventually allow scientists to understand diversity of this region of Indian subcontinent.

Since NCDTs do not show sexual dimorphism, sex pooled NCDTs studies should be planned. The uniqueness of our frequencies should be confirmed with relatively larger sample-sized studies, with more dental traits analysed. It is strongly recommended for academicians and researchers to evaluate NCDTs at large and also precisely map the NCDTs in all the regions of India.

Abbreviations

NDCT	Non-metric dental crown traits
ASUDAS	Arizona State University Dental Anthropology System
NCR	National Capital Region
FDI	Fédération Dentaire Internationale
W	Winging between 11* and 21*
SH-UI1	Shoveling in 21*
DSH	Double shoveling in 21*
SH-UI2	Shoveling in 22*
IG	Interrupted groove in 22*
PAC-4	Premolar accessory cusp in 24*
PAC-5	Premolar accessory cusp in 25*
CC	Carabelli cusp in 26*
3-cusp UM2	Hypocone absence in 27*
LC	Lingual cusp variation in 35*
C6	Sixth cusp in 36*
C7	Seventh cusp in 36*
DW	Deflecting wrinkle in 36*
PRS	Protostylid in 36*
DTC	Distal trigonid crest in 36*
4-cusp LM2	Hypoconulid absence/ presence of 5th cusp in 37*

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Authors' contributions

AC, KS, DBP and PK conceived and designed this study. PK and DBP analysed and interpreted the data. AC and KS drafted the manuscript and revised the manuscript. AC, PK and DBP interpreted the data and provided statistical testing expertise and advice and revised the manuscript for important intellectual content. All of the authors reviewed, discussed and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was conducted after Institutional Ethical approval (FILE NO 29/6/116/JMI/IEC). All procedures for data collection were treated with confidentiality according to the Helsinki declarations of biomedical ethics.

Consent for publication

Informed consent taken.

Competing interests

The authors declare that they have no competing interests.

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