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Morphological and Numerical Characteristics of the Southern Chinese Dentitions. Part II: Traits in the Permanent Dentition

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Abstract: *Aim:* To investigate the prevalence of four major dental traits in the southern Chinese permanent dentition and to compare these with studies from different populations.

Materials and Methods: The material used in the study consisted of high quality study models collected from 725 randomly selected 12-year-old children in Hong Kong (358 males and 367 females). The various traits were assessed using standard diagnostic criteria. Literature and data related to dental traits in the permanent dentition were sourced using PubMed and hand searches.

Results: The mouth prevalence of shovelling, lingual tubercle, Carabelli's trait, and protostylid were 80.4%, 38.9%, 50.5% and 37.5% respectively. The prevalence figure for the cusp type of Carabelli's trait in this study (23.7%) was higher than for other Mongoloids. The prevalence figures for semi-shovel shaped maxillary incisors (42.6% to 48.6%) and the cusp type of protostylid trait in mandibular molars (10.1%) were higher than for any other populations.

Conclusion: The higher prevalences of semi-shovel shaped maxillary incisors, and protostylid cusp on the mandibular molars can be considered to be characteristics of the southern Chinese permanent dentition.

Keywords: Dental traits, permanent dentition, southern Chinese.

INTRODUCTION

The term "trait" has been defined as a distinguishing feature, or characteristic of an individual. The frequency of occurrence of a trait may be low in a specific population because that trait is becoming progressively more, or less well developed in that population. Hence, it is not inconceivable that a trait could inadvertently be considered to be an anomaly, even though it may be a characteristic feature of that population. Thus, what may be considered to be an anomaly in one population may be a trait in another population. Furthermore, the dentition of man is changing in form, size and number. Studies have, according to Dahlberg [1], revealed that these changes are not taking place at the same rate in the various geographic and racial groups. This evolutionary tendency is probably the reason why there is so much variation in the number of cusps exhibited by the maxillary first primary molar of Japanese children [2].

The large variation in morphological features and their form may not be easily altered; thus, a trait of the human dentition can be a valuable diagnostic tool for anthropological studies in classifying and characterizing different ethnic

groups. From a skull that was found at Zhoukoudian upper cave in northern China which had shovel-shaped incisors, Weidenreich [3] concluded that there was a close link between the prehistoric homo-erectus and the modern Mongoloid populations; because shovelling of the incisors has always been associated with the Mongoloid samples such as Chinese and Japanese [4-6].

Investigations into racial differences in dental morphology have led to the hypothesis that the common origins of peoples are reflected to a certain degree in their similar phenotypic patterns. For example, studies of fossil material have shown that the ancestors of all native Americans probably originated in northeast Asia [7]. The accumulation of data on the morphological traits of the teeth in different populations has led anthropologists to become more concerned with the evolutionary significance of these data, and to consider the mode of inheritance. The various morphological traits of the dentition are likely to be inherited; however, the mode of inheritance, of most traits, is at present poorly understood, and may well remain so for a long time.

Although teeth have proven to be an extremely valuable fossil material for scientists to study the history of man, unusual anomalous morphological features were mistakenly regarded by some early observers as aberrations and not considered to represent normal biological variation. One of the first traits to be recorded was Carabelli's trait in 1842 [8].

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Shovelling of incisor teeth was first reported by Mühlreiter in 1870 (Mühlreiter 1870), while the number of cusps on maxillary molars was published in 1913 by Keith [9]. The cusps and grooves on mandibular molars were subsequently investigated by Gregory and Hellman in 1926 [10]. The twenty-eight observable dental traits that have been studied in the Mongoloid dentition include shovelling of the incisors teeth, Carabelli's trait, the number and form of cusps, ridges and fissure patterns, and three roots on the mandibular first molar [7, 11-13].

The southern Chinese are a specific group of Chinese who reside in the part of China that is south of the Yangtze river. Research works has indicated that there are differences in the peoples of northern and southern China. The southern Chinese are shorter than their northern Chinese counterparts, speak different dialects and have markedly different eating habits [14]. Since only limited data are available on the prevalence of the dental characteristics of the southern Chinese, there seems to be a need to investigate the major dental traits in this population. The aims of this study were to determine the prevalence of the various dental traits, such as shovelling, lingual tubercle, Carabelli's trait, and protostylid in the permanent dentition of twelve years old southern Chinese children in Hong Kong, and to determine if there were any inter-relationships between these major dental traits. By comparing these data with those on other populations, it was intended to determine if the permanent dentition of the southern Chinese has any features that may be considered to be characteristics of their dentition.

MATERIALS AND METHODS

The prevalence data of dental traits were based on plaster casts of the permanent dentition of 725 children (365 girls and 358 boys), which had been obtained from a randomly selected sample of 12 years old southern Chinese children in Hong Kong. Details of the sampling method were described in Part I of this series of papers.

In the study cast examination, individual teeth on the casts were examined by one calibrated examiner using an illuminated magnifying glass (x2) to diagnose the presence or, absence of a trait. Illustrated versions of the various classifications of the four traits, and a list of the teeth upon which they could be expected to occur, were prepared to enhance the accuracy of the diagnoses and to maintain the level of examiner reliability. The reasons for omitting some teeth from the investigation were: (i) poor quality or of the study cast; (ii) chipped or broken teeth; (iii) wear or attrition; (iv) gross caries; and (v) restorations. The following criteria were employed to diagnose the four dental traits.

Shovelling

An incisor or canine with an extraordinary development of the lateral borders and cingulum of the lingual surface of the crown, a depression in the central and incisal portions of the surface giving the impression of a shovel. Hrdlicka's classification [4] has four variations: (0) no shovel – no perceptible trace of rim and fossa or in which trace of these were so faint or imperfect as no to deserve special characterization; (1) trace of shovel – distinct traces of the enamel rim but which could not be classed yet as semi-shovel; (2) semi-shovel shaped – the enamel rim was distinct but the enclosed fossa was shallow; and (3) pronounced shovel

shape – the enamel rim with the enclosed fossa were well developed.

Lingual Tubercle

A single or double protuberance arising from the cingulum of the lingual surface of the maxillary canine or incisor and extending less than half the distance from the cemento-enamel junction to the incisal edge. Lingual tubercle was classified as either present or absent. The type present was classified as either a single or double tubercle [15].

Carabelli's Trait

Either a tubercle of varying size, or a groove, or even a pit on the lingual surface of the protocone of the permanent maxillary first molar. The classification of Carabelli's trait was based upon Snyder's simplified index [16]; (0) no cusp and smooth – a completely smooth surface; (1) no cusp but small line – a surface having a furrow interrupting its continuity; (2) no cusp but pit – a surface having a pit interrupting its continuity; (3) cusp outline without apex – an eminence without a defining groove; (4) partial cusp without apex – a small cusp with a groove setting it off from the tooth surface; and (5) cusp with apex – a large cusp.

Protostylid

An additional cusp on the buccal surface of the mesiobuccal cusp of a mandibular molar. There were five subdivisions of the classification which was proposed by Snyder and his co-workers [16]; (0) no cusp – completely uninterrupted surface; (1) pit – a pit with a vertical wrinkle or irregular irregularities; (2) eminence – eminence of cusp without groove outline; (3) elevation – a small but positive elevation; (4) cusp – well defined cusp.

Reproducibility examinations were conducted to check the intra-examiner reliability. Approximately 10% of the 725 subjects were randomly chosen for re-examinations. In order to ensure that each trait was present in the reproducibility test, at least 5 subjects were chosen randomly who exhibited each of the traits. The Kappa coefficient (K) was used to determine the intra-examiner reproducibility. To determine if there were any statistical differences between gender and side, the chi-square test was used to test the quantity of the proportions. To determine any association between the various traits, the Pearson correlation coefficients were used.

In order to be able to compare the prevalence data with those of other studies, literature and data from 1930 to 2009, which were related to dental traits in the permanent dentition, were sourced using PubMed and hand searches. The key words used for the PubMed searches were dental traits, permanent dentition, shovelling, lingual tubercle, Carabelli's trait, and protostylid. Reference lists of articles retrieved from the electronic database were then hand searched to identify additional articles that might provide information relevant to the objectives of this paper. It was impractical to perform a systemic review because the methodology used in the published studies varied, thus preventing valid statistical analyses.

RESULTS

The 725 subjects had a gender distribution of 358 males (49%) and 367 females (51%). The mean chronological ages

were 12.5 years and 12.6 years for the males and females respectively. The intra-examiner reproducibility for the diagnosis of each the dental traits was calculated using Kappa coefficients; the values ranged from 0.44 (protostylid) to 0.66 (Carabelli's trait).

The mouth prevalence of the four major types of dental traits in the permanent dentition for southern Chinese boys and girls are shown in Table 1, while the tooth prevalences are displayed in Tables 2 to 5. Since there were no significant differences found between the genders, and between the left and right sides of the arch, the data were pooled for the determination of any associations between the four traits (Tables 6 and 7), and for comparison with those of other studies (Tables 8 to 12).

Shovelling, which was found on the incisors and canines had prevalence rates of 79.0% for the 367 girls and 81.6% for the 358 boys (Table 1). In almost 90% of those affected the shovelling occurred bilaterally. The semi-shovel type of shovelling was found to be the commonest type, with 45.6% of the incisors exhibiting this form. The tooth prevalence showed that the lateral incisors were the most frequently

affected teeth (Table 2). The inter-relationship between shovelling and Carabelli's trait was found to be statistically significant in this study ($p = 0.021$), see Table 7. The semi-shovel type of shovelling was more prevalent in the southern Chinese (42.6% to 68.0%) compared with other populations (up to 47.5%), whereas the pronounced type of shovelling was more prevalent in other Mongoloids (Table 8).

Almost 40% of the children exhibited the lingual tubercle trait (Table 1). The single tubercle form was seen in 85% of the affected children. The tooth prevalence figures in Table 3 show that canines were more commonly affected than incisors. The inter-relationship between lingual tubercle and shovelling was found to be statistically significant in southern Chinese children ($p = 0.008$), see Table 7. The prevalence of lingual tubercle on canines in southern Chinese was comparable to that of other Mongoloids (Table 9).

Carabelli's trait which was found only on the permanent first molars affected 47.1% of the girls and 53.9% of the boys (Table 1). The line form (classification type 1) was the commonest type (Table 4). The inter-relationship between Carabelli's trait and lingual tubercle was found to be statisti-

Table 1. The Mouth Prevalence of the Various Dental Traits in the Permanent Dentition of 725 Twelve Years Old Southern Chinese Girls and Boys in Hong Kong

Dental trait	Girls (N = 367)		Boys (N = 358)		Total	
	n	%	n	%	n	%
Shovelling	290	79.0	292	81.6	582	80.4
Lingual tubercle	145	39.5	137	38.3	282	38.9
Carabelli's trait	173	47.1	193	53.9	366	50.5
Protostylid	144	39.2	128	35.8	272	37.5

Table 2. The Prevalence of Shovelling for the Maxillary Permanent Anterior Teeth of 725 Twelve Years Old Southern Chinese Children in Hong Kong

Tooth type	Number of teeth examined	Number and percentage of different types of shovelling trait		
		trace	semi-shovel	pronounced shovel
11	722	168 (23.3%)	348 (48.2%)	56 (7.8%)
12	721	102 (14.2%)	307 (42.6%)	153 (21.2%)
13	701	154 (22.0%)	105 (15.0%)	26 (3.7%)
21	720	169 (23.5%)	350 (48.6%)	54 (7.5%)
22	721	111 (15.4%)	303 (42.0%)	147 (20.4%)
23	703	157 (22.3%)	102 (14.5%)	23 (3.3%)

Table 3. The Prevalence of Lingual Tubercle for the Maxillary Permanent Anterior Teeth of 725 Twelve Years Old Southern Chinese Children in Hong Kong

Tooth Type	Number of Teeth Examined	Number and Percentage of Different Types of Lingual Tubercle	
		single	double
11	722	93 (12.9%)	59 (8.2%)
12	721	52 (7.2%)	2 (0.3%)
13	701	179 (25.5%)	3 (0.4%)
21	720	94 (13.1%)	55 (7.6%)
22	721	54 (7.5%)	4 (0.6%)
23	703	176 (25.0%)	2 (0.3%)

Table 4. The Prevalence of Carabelli's Trait for the Maxillary First Permanent Molars of 725 Twelve Years Old Southern Chinese Children in Hong Kong

Tooth Type	Number of Teeth Examined	Number and Percentage of Different Types of Carabelli's Trait				
		line	pit	cusp outline	partial cusp	cusp with apex
16	720	137 (19.0%)	31 (4.3%)	103 (14.3%)	27 (3.8%)	40 (5.6%)
26	723	111 (15.4%)	30 (4.2%)	102 (14.1%)	27 (3.7%)	38 (5.3%)

Table 5. The Prevalence of Protostylid for the First and Second Mandibular Permanent Molars of 725 Twelve Years Old Southern Chinese Children in Hong Kong

Tooth Type	Number of Teeth Examined	Number and Percentage of Different Types of Protostylid			
		pit	eminence	elevation	cusp
47	550	23 (4.2%)	6 (1.1%)	4 (0.7%)	3 (0.6%)
46	715	146 (20.4%)	33 (4.6%)	23 (3.2%)	16 (2.2%)
36	708	153 (21.6%)	33 (4.7%)	20 (2.8%)	15 (2.1%)
37	571	30 (5.3%)	7 (1.2%)	2 (0.4%)	2 (0.4%)

Table 6. The Number and Percentage of 725 Twelve Years Old Southern Chinese Children in Hong Kong with Teeth Affected by Combinations of Traits

Combinations of Traits	n	%
Carabelli's trait + Protostylid	163	22.5
Carabelli's trait + Shovelling	306	42.2
Carabelli's trait + Lingual tubercle	172	23.7
Shovelling + Lingual tubercle	271	37.4
Shovelling + Protostylid	226	31.2
Protostylid + Lingual tubercle	98	13.5

Table 7. The Inter-Relationships (Correlation Coefficients) Between Shovelling, Lingual Tubercle, Carabelli's Trait and Protostylid in 725 Twelve Years Old Southern Chinese Children in Hong Kong

	Lingual tubercle	Carabelli's trait	Protostylid
Shovelling	0.33 **	0.19 *	0.03 ns
Lingual tubercle		0.27 **	0.01 ns
Carabelli's trait			0.31 **

** 0.01 < p < 0.05.

** 0.001 < p < 0.01.

ns - not significant.

Table 8. The Prevalence, Expressed as a Percentage, for the Shovelling Trait on the Permanent Maxillary Incisors in Published Studies

Ethnic Group	Author	Tooth Type	Number of Subjects Examined	Shovelling Type			
				0	1	2	3
Southern Chinese	Present study	I ¹	725	20.1	23.5	48.6	7.8
		I ²	725	20.8	15.4	42.6	21.2
	Ling 2008 [27]	I ¹	♂292	1.0	27.0	66.0	7.0
			♀161	1.0	27.0	68.0	3.0
		I ²	♂292	0	12.0	51.0	27.0
			♀161	1.0	12.0	61.0	27.0
Mongoloid							
Chinese	Hrdlicka 1920 [4]	I ¹	♂546	7.8	1.8	23.4	66.2
			♀104	3.8	1.0	12.5	82.7
		I ²	♂547	9.5	1.5	24.0	56.9
			♀104	3.4	1.0	13.5	68.8
Eskimo	Hrdlicka 1920 [4]	I ¹	40	0	15.0	47.5	37.5
Pima Indians	Dahlberg and Mikkelsen 1947 [21]	I ¹	♂101	0	4.0	0	96.0
			♀125	0	1.0	0	99.0
		I ²	♂93	1.0	13.0	0	81.0
			♀119	0	7.0	19.0	81.0
Aleuts	Moorrees 1957 [5]	I ¹	♂45	0	4.5	31.1	64.4
			♀30	0	0	40.0	60.0
		I ²	♂42	0	0	31.0	66.6
			♀28	0	2.4	32.1	64.2
Japanese	Kikuchi 1967 [58]	I ¹	259	2.3	3.1	15.1	76.1
		I ²	259	1.1	2.7	16.2	74.1
Arctic	Turner 1967 [48]	I ¹	110	55.0	45.0	0	0
Taiwanese	Jien 1970 [19]	I ¹	♂278	0	4.0	20.1	75.9
			♀272	0	1.5	13.2	85.3
		I ²	♂213	0	8.0	22.5	69.5
			♀233	0	7.3	21.5	71.2
Alaskan Eskimo	Bang and Hasund 1971 [59]	I ¹ I ²	106	19.8	-	-	-
Navajo Indians	Scott 1973 [60]	I ¹ I ²	383	47.5	-	-	-
Papago Indians	Scott 1973 [60]	I ¹ I ²	171	49.0	-	-	-
Yuma Indians	Scott 1973 [60]	I ¹ I ²	67	36.0	-	-	-

(Table 8). Contd.....

Ethnic group	Author	Tooth type	Number of subjects examined	Shovelling type			
				0	1	2	3
Mohave Indians	Scott 1973 [60]	I ¹ I ²	48	34.5	-	-	-
Lengua Indians in Paraguay	Kieser and Preston 1981 [61]	I ¹ I ²	202	4.5	-	-	-
Pima Indians	Scott et al 1983 [23]	I ¹	♂595	0	23.2	39.9	37.5
			♀659	0	18.8	42.9	38.3
		I ²	♂514	0	58.4	27.2	14.4
			♀563	0.2	52.4	30.9	16.6
Caucasian							
American whites	Hrdlicka 1920 [4]	I ¹	2000	68.4	23.2	6.4	2.0
		I ²	2000	54.8	23.2	8.1	1.2
Finns	Koski and Hantala 1952 [62]	I ¹	423	9.0	76.4	10.9	3.8
		I ²	408	7.1	73.4	16.7	2.9
Southeastern British	Berry 1976 [24]	I ¹	218	90.6	-	-	-
		I ²	210	92.9	-	-	-
Northwestern British	Berry 1976 [24]	I ¹	218	79.4	-	-	-
		I ²	226	84.5	-	-	-
Orkney Islanders	Berry 1976 [24]	I ¹	201	91.3	-	-	-
		I ²	143	82.9	-	-	-
Shetland Islanders	Berry 1976 [24]	I ¹	185	88.1	-	-	-
		I ²	123	74.8	-	-	-
Bonn Germans	Berry 1976 [24]	I ¹	182	47.0	-	-	-
		I ²	152	55.3	-	-	-
Heidelberg Germans	Berry 1976 [24]	I ¹	112	53.1	-	-	-
		I ²	100	57.5	-	-	-
Jats Indians	Kaul and Prakash 1981 [63]	I ¹	♂283	18.0	36.8	26.5	18.7
			♀231	6.9	24.7	46.8	21.4
		I ²	♂251	29.1	29.7	23.1	19.1
			♀202	19.2	40.9	23.7	16.3
Canadian whites	Saunders and Mayhall 1982 [64]	I ¹	827	77.1	19.4	3.0	0.5
		I ²	827	78.9	18.3	2.3	0.5
American whites	Hsu <i>et al.</i> 1997 [65]	I ¹	142	31.7	-	-	-
American whites	Edgar and Lease 2007 [66]	I ¹	53	25.0	53.0	21.0	2.0
		I ²	52	37.0	48.0	15.0	0
Jordanians	Khraisat <i>et al.</i> 2007 [46]	I ¹ I ²	300	47.0	-	-	-
Negroid							
Sub-Saharan Africans	Irish 1997 [25]	I ¹	976	94.7	-	-	-
Others							
Queckchi Indians	Escobar <i>et al.</i> 1977 [67]	I ¹	540	51.5	-	-	-
Taiwan aborigines (Ami)	Liu 1977 [68]	I ¹	♂70	2.5	25.9	14.2	57.3
			♀42	2.4	7.3	19.5	70.7
		I ²	♂70	3.5	14.7	20.8	61.0
			♀42	11.3	11.3	8.5	69.0
Taiwan aborigines (Atayal)	Liu 1977 [68]	I ¹	♂81	2.1	2.1	22.3	73.4
			♀49	1.2	4.8	14.3	79.8
		I ²	♂81	10.5	0	11.6	77.9
			♀49	11.9	2.3	4.8	80.9

⁰ = no shovel, ¹ = trace of shovel, ² = semi-shovel shaped, ³ = pronounced shovel shape.

Table 9. The Prevalence, Expressed as a Percentage, of the Lingual Tubercle Trait on the Permanent Maxillary Incisors and Canines in Published Studies

Ethnic Group	Author	Tooth Type	Number of Subject Examined	Lingual Tubercle Trait	
				Absent	Present
Southern Chinese	Present study	I ¹	725	78.9	21.1
		I ²	725	91.9	8.1
		C ^c	725	74.0	26.0
Mongoloid					
Pima Indians	Scott et al. 1983 [23]	C ^c	695	63.6	36.4
Papago Indians	Scott et al. 1983 [23]	C ^c	153	52.9	47.1
Hopi Indians	Scott et al. 1983 [23]	C ^c	87	79.3	20.7
Tewa Indians	Scott et al. 1983 [23]	C ^c	23	95.7	4.3
Zuni Indians	Scott et al. 1983 [23]	C ^c	11	90.9	9.1
Keams Indians	Scott et al. 1983 [23]	C ^c	138	71.7	28.3
Tuba Indians	Scott et al. 1983 [23]	C ^c	102	68.6	31.4
Ramah Indians	Scott et al. 1983 [23]	C ^c	65	47.7	52.3
San Carlos Apache Indians	Scott et al. 1983 [23]	C ^c	19	73.7	26.3
Yuma Indians	Scott et al. 1983 [23]	C ^c	37	62.2	37.8
Mohave Indians	Scott et al. 1983 [23]	C ^c	19	68.4	31.6
Caucasian					
Southeastern British	Berry 1976 [24]	I ¹	216	99.1	0.9
		I ²	202	89.1	10.9
		C ^c	145	82.1	17.9
Northwestern British	Berry 1976 [24]	I ¹	235	96.6	3.4
		I ²	228	85.1	14.9
		C ^c	219	77.2	22.8
Orkney Islanders	Berry 1976 [24]	I ¹	187	99.5	0.5
		I ²	122	86.9	13.1
		C ^c	60	92.5	7.5
Shetland Islanders	Berry 1976 [24]	I ¹	177	98.3	1.7
		I ²	117	92.3	7.7
		C ^c	62	79.0	21.0
Bonn Germans	Berry 1976 [24]	I ¹	181	100	0
		I ²	150	90.3	9.7
		C ^c	118	71.6	28.4
Heidelberg, Germans	Berry 1976 [24]	I ¹	118	97.0	3.0
		I ²	107	84.1	15.9
		C ^c	58	73.3	26.7
Jats Indians	Kaul & Prakash 1981 [63]	I ²	♂ 258	73.6	26.4
		I ²	♀ 201	78.6	21.4
		C ^c	♂ 159	57.2	42.8
		C ^c	♀ 140	59.3	40.7
Northern American	Edgar and Lease 2007 [66]	I ¹	50	56.0	44.0
		I ²	43	51.0	49.0
		C ^c	43	51.0	49.0
Negroid					
Sub-Saharan African	Irish 1997 [24]	I ¹ I ²	976	38.8	61.2

Table 10. The Prevalence, Expressed as a Percentage, for Carabelli's Trait on the Permanent Maxillary First Molars in Published Studies

Ethnic Group	Author	Number of Subjects Examined	Carabelli's Trait		
			Absent	Line or pit	Cusp
Southern Chinese ^S	Present study	725	49.5	26.8	23.7
	Ling 1992 [69]	435	58.1	6.1	35.8
Mongoloid					
Aleuts	Moorrees 1957 [5]	60	86.7	-	-
Japanese	Tsuji 1958 [47]	678	68.1	-	-
Koniag Eskimo	Turner 1967 [48]	211	65.9	32.2	1.9
Taiwanese	Jien 1970 [19]	♂306 ♀298	61.0 68.0	- -	- -
Chinese in Liverpool	Goose and Lee 1971 [42]	134	71.0	-	-
Lengua Indians in Paraguay ^A	Kieser and Preston 1981 [61]	202	29.9	54.8	15.3
Tibetan in India ^K	Sharma 1983 [70]	♂33 ♀36	93.9 94.4	6.1 5.6	0 0
Pima Indians ^D	Scott <i>et al.</i> 1983 [23]	♂609 ♀633	22.4 31.9	72.3 62.4	5.1 5.7
Chinese	Guo <i>et al.</i> 1995 [71]	♂74 ♀86	71.6 87.2	- -	- -
Japanese	Guo <i>et al.</i> 1995 [71]	♂123 ♀46	65.9 84.8	- -	- -
Japanese	Ooshima <i>et al.</i> 1996 [17]	745	-	-	8.3
Taiwanese ^K	Hsu <i>et al.</i> 1997 [45]	309	63.1	-	-
Caucasian					
American whites	Dietz 1944 [37]	1000	27.7	-	-
American whites ^K	Meredith and Hixon 1954 [72]	100	16.5	-	-
Jews in Yemen ^K	Rosenzweig and Zilberman 1967 [73]	30	7.0	26.0	67.0
Jews in Cochinchina ^K	Rosenzweig and Zilberman 1967 [73]	30	38.0	26.0	26.0
American whites	Keene 1968 [74]	392	40.0	21.8	38.2
British	Goose and Lee 1971 [42]	602	21.2	60.1	18.7
Gujarati Hindu ^K	Joshi <i>et al.</i> 1972 [75]	♂198 ♀291	30.5 38.8	36.8 38.6	32.5 23.1
Skolt Lapps	Kirveskari 1974 [76]	142	22.5	62.7	14.8
Rural Finns	Alvesalo <i>et al.</i> 1975 [43]	233	21.0	59.3	19.7
Southeastern British	Berry 1976 [24]	207	57.7	31.6	10.6
Northwestern British	Berry 1976 [24]	203	43.3	35.0	21.7
Orkney Islanders	Berry 1976 [24]	205	54.1	33.2	12.7
Shetland Islanders	Berry 1976 [24]	174	52.3	23.6	24.1

(Table 10). Contd.....

Ethnic Group	Author	Number of Subjects Examined	Carabelli's Trait		
			Absent	Line or pit	Cusp
Bonn Germans	Berry 1976 [24]	127	39.4	34.6	26.0
Heidelberg Germans	Berry 1976 [24]	163	42.6	37.7	19.6
Jats Indians ^D	Kaul and Prakash 1981 [64]	♂ 304 ♀ 262	34.2 42.7	32.6 31.0	33.2 26.3
Canadian whites ^D	Saunders and Mayhall 1982 [65]	827	16.1	38.2	45.7
South African whites ^A	Thomas <i>et al.</i> 1986 [77]	100	17.5	36.1	46.4
Asian Indians ^D	Townsend and Martin 1992 [78]	♂192 ♀238	13.0 15.1	57.3 58.8	29.7 26.1
American whites	Hsu <i>et al.</i> 1997 [66]	M46 F96	12.5 33.3	- -	- -
Northern American ^D	Edgar and Lease 2007 [67]	53	40.0	-	-
Jordanian	Khraisat <i>et al.</i> 2007 [46]	300	35.0	-	-
Negroid					
South African blacks ^A	Thomas <i>et al.</i> 1986 [77]	100	20.8	38.8	40.4
Sub-Saharan African	Irish 1997 [24]	976	48.8	-	-
Others					
Queckchi Indians	Escobar <i>et al.</i> 1977 [67]	540	45.6	43.7	10.7
Taiwan aborigines (Ami) ^D	Liu 1977 [68]	♂70 ♀42	40.8 46.5	48.2 44.2	11.0 9.3
Taiwan aborigines (Atayal) ^D	Liu 1977 [68]	♂81 ♀49	21.9 32.4	78.1 58.1	0 9.5
Taiwan aborigines (Bunun) ^K	Tsai <i>et al.</i> 1996 [79]	233	51.9	-	-
Taiwan aborigines (Bunun) ^K	Hsu <i>et al.</i> 1997 [45]	229	54.4	-	-

^AAlvesalo's index (Alvesalo *et al.* 1975) was used in the study. The original data were reanalysed for comparison (Absent = 0, Line or pit = 1+2, Cusp = 3+4).

^DDahlberg's index (Dahlberg 1963) was used in the study. The original data were reanalysed for comparison (Absent = 0, Line or pit = 1+2+3+4, Cusp = 5+6+7).

^KKraus's index (Kraus 1951) was used in the study. The original data were reanalysed for comparison (Absent = a, Line or pit = b, Cusp = c).

^SSnyder's simplified index (Snyder *et al.* 1969) was used in the study. The original data were reanalysed for comparison (Absent = 0, Line or pit = 1+2, Cusp = 3+4+5).

cally significant in this study ($p = 0.004$), see Table 7. The prevalence of Carabelli's trait for southern Chinese is comparable with the prevalence for some Caucasian groups. Moreover, the prevalence of Carabelli's cusp in southern Chinese, at between 23.7% and 35.8%, was highest among the Mongoloids (Tables 10 and 12).

There were 37.5% children that were affected by protostylid (Table 1). The buccal pit form is the most commonly seen type (Table 5). The inter-relationship between Carabelli's trait and protostylid was found to be statistically significant in southern Chinese children ($p = 0.005$), see Table 7. The prevalence of cusp type of protostylid in this study (10.1%) was higher than for the other ethnic groups (Table 11).

DISCUSSION

The studying of traits on dental casts is comparable to using fossilized material to diagnose characteristics of the dentition of pre-historic man. Detailed information can usually be successfully obtained from these sources. This may

indeed be more reliable than direct clinical examinations for which instant clinical decisions have to be made and visual access is restricted in the oral cavity [17]. Use of an oral examination may result in information being inadvertently not collected. For example, the line form of Carabelli's trait cannot be easily detected in the clinical environment because the quality and direction of the light can be critical factor. Similarly, a double lingual tubercle of a central or lateral incisor can be very difficult to detect clinically, unless magnifying glasses are used, which is easier to do on a cast than in the mouth. Thus, the studying of dental casts was considered to be superior to the clinical method of examination. However, it is essential that the dental casts are a true and accurate reproduction of the original teeth and that they have not been damaged during preparation or storage.

Diagnostic criteria for the four dental traits were difficult to develop even with the aid of previously published literature because there is not a lack of universally accepted classifications for each trait. So, the different diagnostic criteria used in this study, and those used in the various published

Table 11. The Prevalence, Expressed as a Percentage, for the Protostylid Trait on the Permanent Mandibular Molars in Published Studies

Ethnic group	Author	Number of subjects examined	Protostylid trait		
			Absent	Line or pit	Cusp
Southern Chinese ^S	Present study	725	62.5	27.4	10.1
	Ling 1992 [69]	435	91.6	3.2	5.2
Mongoloid					
Japanese	Suzuki and Sakai 1954 [56]	108	81.5	-	-
Aleuts	Moorrees 1957 [5]	60	100.0	0	0
Pima Indians ^D	Scott <i>et al.</i> 1983 [23]	♂532	51.3	41.3	7.4
		♀554	59.0	36.5	4.5
Japanese	Ooshima <i>et al.</i> 1996 [17]	745	-	-	0.4
Caucasian					
Canadian whites ^D	Saunders and Mayhall 1982 [65]	827	95.8	-	-
Northern American ^D	Edgar and Lease 2007 [67]	52	92.0	8.0	0
Negroid					
Sub-Saharan African	Irish 1997 [24]	976	79.0	-	-
Others					
Taiwan aborigines (Ami) ^D	Liu 1977 [68]	♂70	85.3	6.4	8.3
		♀42	78.4	13.5	8.1
Taiwan aborigines (Atayal) ^D	Liu 1977 [68]	♂81	96.3	3.7	0
		♀49	95.2	4.8	0

^DDahlberg's index (Dahlberg 1963) was used in the study. The original data were reanalysed for comparison (Absent = 0, Line or pit = 1+2, Cusp = 3+4+5+6+7).

^SSnyder's index (Snyder *et al.* 1969) was used in the study. The original data were reanalysed for comparison (Absent = 0, Line or pit = 1, Cusp = 2+3+4).

Table 12. The Frequency of Various Traits in the Permanent Dentition of Southern Chinese People, other Mongoloid Groups and Caucasians

Dental Trait	Southern Chinese	Mongoloid (not southern Chinese)	Caucasian
Shovelling trait	high	high	varied
Lingual tubercle trait	low	low to moderate	low to moderate
Carabelli's trait	moderate	varied	moderate to high
Carabelli's cusp	low to moderate	low	varied
Protostylid trait	low to moderate	low to moderate	low
Protostylid cusp	low	low	low

Chance of occurrence:

low: <30%

moderate: 30% - 60%

high: >60%

studies may be one of the reasons why there is some variation in the results that have been published. Comparability is further worsened by investigators not studying the same teeth; most of the investigations of shovelling omitted to look at the maxillary canines and the mandibular incisors.

Even though the age of the subjects was selected to provide the maximum number of teeth in the best condition,

there may have been some loss of potential data. For instance, the maxillary canines were not always fully erupted, especially in the males. The additional information that could have been gained from the canines could have slightly increased the prevalence of the shovelling and lingual tubercle traits. The same issues may be applicable to the second molars in respect of the protostylid trait.

The four major traits will be discussed respectively by first considering the physical characteristic, followed by the prevalence of that trait in the permanent dentition. The objective is to demonstrate any similarities or differences between the Mongoloid and Caucasoid dentitions, and where data are available to identify any distinctive features in the data for the permanent dentition of the southern Chinese.

Shovelling

The resemblance of an incisor to a shovel results from the combination of a concave lingual surface with elevated marginal ridges [4]. The maxillary as well as the mandibular anterior teeth can be found to have marginal ridges [4]. However, the more exaggerated forms of shovelling are usually exhibited by the maxillary rather than mandibular incisor teeth. Furthermore, the trait is more common in permanent than primary incisor teeth [4, 18]. Although females were affected more than males in one study, the differences were not statistically significant [19], so gender variation is unlikely.

Most studies have adapted the classification proposed by Hrdlicka which recognised four degrees of shovelling; which are pronounced shovelling, "semi" shovelling and the trace type of shovelling [4]. However, the diagnostic criteria in different studies have not always been consistent. There may be errors in the classification of the shovel-shaped central and lateral incisors because the lateral incisor has a smaller mesio-distal dimension and, consequently, the same depth in the shovel may be classified as a higher degree of shovel-shape [6, 20]. Therefore, Carbonell [6] added a quantitative measuring device to classify the different degrees of shovelling. Using this device, a measurement of +1 mm was considered to indicate shovel, 1 mm semi-shovel, and -1 mm a trace.

Since Hrdlicka's report of this anomaly in 1920, shovelling has been accepted as a trait of the Mongoloid dentition. High prevalences have been reported in Eskimos [4], Pima Indians [21-23], north American Indians [4], and Aleuts [5]. The reverse has been found for Europeans [24] and Negroids [25]. Negroids have had almost no intermixing with Chinese, and they have an extremely low prevalence of shovelling, while in Hawaii, where Europeans have mixed with Polynesian, Melanesian and Chinese, the prevalence is intermediate. Therefore, it has been hypothesised that China was the source of this trait, so that when a population is geographically further removed from China, it demonstrates a lower frequency of shovelling [1]. Furthermore, environmental factors do not appear to play a role in the expression of this trait because it was found that Chinese born in China and the United States of America had similar prevalence of the trait [26]. Thus, it is quite accurate to describe shovelling as a characteristic for populations of Mongoloids, irrespective of the geographic region.

As expected, most of the maxillary incisors examined in this study were found to demonstrate shovelling, giving this trait a prevalence comparable to that of other Mongoloid groups and making it much higher than reported for Caucasians and Negroids. But what is interesting is that not all of the children in this study were affected to the same degree by this trait, when compared with other Chinese groups [4, 19, 27]. This could indicate that the trait has an autosomal recessive

mode of inheritance, or that it is autosomal dominant but with variable expressivity. Alternatively, it could be that the southern Chinese are composed of different subgroups whose ancestors did not exhibit this trait. Study of fossil material of different racial groups from different historical periods could provide more information about this dilemma.

The frequency distributions of the semi-shovel shaped incisors were very high in southern Chinese, 48.6% in central incisors and 42.6% in lateral incisors (Table 8). However, the lower prevalence of pronounced shovel shaped incisors was noted as compared with other Mongoloids, and even with other Chinese populations studied by Hrdlicka [4] and Jien [19]. The degree of shovelling has been used to differentiate ethnically between the Pueblo Indians and the Plains Indians [28], and some Asian and African populations [29]. Unfortunately, the proportions of the subjects who were of northern Chinese origin were not stated clearly in Hrdlicka's and Jien's studies. Further studies of the northern Chinese is required to differentiate between the sub-groups of the Chinese population.

Lingual Tubercle

Lingual tubercle is a rounded elevation on the lingual-gingival ridge of an anterior tooth. Because the tubercle has been more frequently observed and is better developed in fossil than in modern man, it is believed to be a derivative of the cingulum and a feature of evolution of the primate [3]. It may be long and narrow, or short and stumpy. It may be single, double, or multiple [30]. When double or multiple tubercles are present, the distal one is usually larger than the mesial one [30]. It has been reported that the tubercle is always present as two short projections on either side of the lingual ridge and that the mandibular canine almost never exhibits a lingual tubercle [31]. Berry [32] showed a significant correlation of lingual tubercle with Carabelli's trait. Similarly, lingual tubercle was found in this study to be closely related to Carabelli's trait, and additionally to the shovelling trait (Table 7).

There was a high prevalence of lingual tubercle on the permanent anterior teeth in southern Chinese at 38.9% (Table 1), which is similar to that which occurred in the primary dentition (43.5%), see Part IV of this paper series. Lingual tubercle occurred most frequently on the canines and to a lesser extent on the maxillary incisors in southern Chinese; similar results have also been reported for Caucasians (Table 9). Since the prevalence figures for other Mongoloids were only on canines, further comparisons are impossible to make. However, the prevalence of lingual tubercle on canines in southern Chinese was comparable to those of other Mongoloids (Table 9). In this study, the single lingual tubercle affected the teeth more than the double tubercle variation (Table 3). Nevertheless, the prevalence figures of different types of lingual tubercle were not reported for the majority of other studies.

Carabelli's Trait

Carabelli's trait is expressed as either a tubercle of varying size, or a groove, or even a pit on the lingual surface of the protocone of the primary maxillary second molar, or the permanent maxillary first molar. The name has been credited to von Carabelli, who first described this feature in 1842 in a

paper by Korenhof [33]. It has also been referred to as the tuberculum anomalies, tuberculum Carabelli and tuberculum imparon. Although some specimens of Paleolithic man have been found to exhibit Carabelli's trait on the maxillary molars [34], this has not been a consistence finding, and it is a generally held opinion that the cusp form of the Carabelli trait is a recent acquisition of man. Conversely, the pit form of the Carabelli trait has been observed in numerous specimens of Neanderthal man and has been considered to be a consistent characteristic of the maxillary molars [35]. Examples of the Australopithecinas and *Dryopithecus rhenanus* also displayed the Carabelli pit [35, 36]. Thus, it is reasonable to conclude that the Carabelli trait is significant in the evolution of man and possibly in different racial groups.

The Carabelli trait is said to be an inherited characteristic [37]. Data from studies of twins support this aetiological hypothesis. However, although an autosomal dominant mode of inheritance has been proposed, the degree of expression of the trait in twins has varied from fully concordant to fully discordant [38]. Thus, because of the varying manifestations and prevalence of Carabelli's trait the mode of inheritance is probably not a simple Mendelian pattern. A high degree of equivalence of Carabelli trait expression between primary and permanent molars was demonstrated by Kieser [39]. It was then hypothesized that the high degree of within-individual equivalence suggests a low epigenetic and high genetic influence on Carabelli trait expression and that the findings support the clonal rather than the field theory of tooth morphogenesis [39].

No dental variable has stimulated more attempts at classification than Carabelli's trait. Unfortunately, this makes the various standards unduly complicated. In the early literature, manifestations below the level of distinct tubercle were not often counted [40]. From the 1940s on, research workers started taking the full Carabelli continuum into account, and classifications included four to ten grades of expression of the trait [41-43]. For example, eight classes of expression were reported by Dahlberg [44] and six by Snyder and colleagues [16]. Thus, caution should be exercised when comparing the prevalence figures from different studies to ensure that similar features of the Carabelli's trait are being compared.

The statistically significant inter-relationship between Carabelli's trait and shoveling was demonstrated by other investigators [45, 46] and it was supported by the present work (Table 7). The prevalence of Carabelli's trait has been reported to be higher in males than in females in the permanent dentition [42, 47-50]. However, gender difference was not found in this study (Table 1). Interestingly, significant differences were observed in the occurrence of Carabelli's trait between the upper and lower income groups for the primary dentition, and between the upper and middle income groups for the permanent dentition in a study conducted in south India [49].

It was reported by some researchers that children with Carabelli's cusp tend to have teeth with crown that have a larger bucco-lingual dimension [51-52]. Kondo and Townsend [52] postulated that larger molar crowns in individuals with the genotype for Carabelli trait expression, are more likely to display Carabelli cusps, whereas their teeth with smaller crowns are more likely to display reduced

forms of the trait. Moreover, the pattern of folding of the internal enamel epithelium in developing molar crowns, particularly in the protocone region, can be modified by a developing Carabelli cusp [52].

Prevalence data for the primary dentition for all degrees of Carabelli's trait indicate that it is more common in Caucasian children than Mongoloid children (Part IV of this paper series). For the permanent dentition, Carabelli's trait appears to be generally commonest among European populations, followed by African populations, and American Indians, with the lowest prevalence occurring in the other Mongoloid races (Table 10). However, the prevalences of 41.9% to 50.5% for southern Chinese are comparable to the prevalence for some Caucasian groups (Table 10). The general trend is for this trait to be more common in southern Chinese than other Mongoloid groups. When only the tubercle and cusp forms are considered, the pattern of geographic variation in Carabelli's trait is not particularly striking [40]. Moreover, the prevalence of Carabelli's cusp in southern Chinese, of between 23.7% and 35.8%, was the highest among the Mongoloids (Table 10). Nevertheless, some of the variation in the published data for different populations probably reflects the use of different diagnostic criteria by the investigators rather than a real difference.

Protostylid

Bolk [53], adopted the term "paramolar cusps" for supernumerary cusps occurring on the buccal surfaces of second and third molars. He believed that the paramolar cusps were derived from supernumerary teeth which had become fused with the permanent molars during their development. In 1945, Dahlberg proposed that the term "protostylid or parastyle" be used to refer to all anomalous cusps on the buccal surface of both the maxillary and mandibular premolars and molars. However, he did point out that the presence of a protostylid should not be considered to be an example of atavism [54].

The protostylid trait can range from a shallow depression through pits and grooves of varying depths, to tubercles and cusps with and without apical independence. Bilateral symmetry of this trait is common and it is usually seen in the form of a buccal pit; while expression as a cusp is rare [5, 16, 44]. The protostylid continuum was standardized into seven classes by Dahlberg [44]. A simplified index proposed by Snyder and co-workers [16] has also remained popular.

The protostylid trait was reported to be more common on primary than permanent molars [55]. It is supported by our study because for southern Chinese, the prevalence in the primary dentition was as high as 93.7% (Part IV of this paper series), while in the permanent dentition the prevalence was only 37.5% (Table 1). It has also been found that the protostylid trait always appears on the permanent tooth which replaces a primary molar which also exhibited the trait. However, the reverse does not always occur [54, 55].

In the primary dentition the protostylid trait is found on the buccal surface of the protocone of the mandibular second molar. As the protostylid is a genetic structure of the architecture of the primary dentition, the primary mandibular second molars can be expected to manifest the trait to a greater extent than the first primary molar and in turn the trait has a

decreasing chance of occurring on the first, second, and third molars of the permanent dentition [54].

Suzuki and Sakai [56] reported that 18.5% of their 108 Japanese subjects had protostylid in varying degrees of prominence, and of these 65% had the Carabelli's cusp on their permanent maxillary molars. An inter-relationship between protostylid and Carabelli's trait was also noted in the present study (Tables 6 and 7).

In the primary dentition, the protostylid trait occurred in more than 40% of Mongoloid children, while in non-Mongoloid populations the occurrence was less than 20% (Part IV of this paper series). Therefore, the protostylid trait has been regarded as a characteristic feature of the Mongoloid dentition [57]. By contrast, Dahlberg [20] suggested that when the mandibular first permanent molar tooth was considered, this trait had a tendency to occur more commonly in Caucasians than Mongoloids, and was rarely seen in Negroids. Furthermore, Dahlberg [44] indicated that living Aleuts have no protostylid cusp or pit, as reported by Moorrees [5], and that their condition was "a reflection of admixture". However, the figures showed on Table 11 seem to indicate that some Mongoloids, including southern Chinese, have higher prevalences of protostylid trait than Caucasians. Moreover, the prevalence of the cusp type of the protostylid trait found in this study (10.1%) was higher than for other ethnic groups. Nevertheless, only two studies involving Caucasians were available for comparison.

Since the criteria in each study used to investigate the prevalence of the four dental trait varied, it is difficult, without careful reconsideration of the diagnostic criteria, and possibly re-analysis of the data in respect of each trait, to make valid comparisons between the studies. This further supports the notion of developing universally accepted criteria for the various dental traits and the subtypes.

CONCLUSION

From the findings of this study it was determined that southern Chinese children have a lesser degree of shoveling than the other Mongoloid groups, including other Chinese populations. The prevalence of the cusp type of Carabelli's trait in southern Chinese was higher than the other Mongoloids, and the prevalence of the cusp type of protostylid trait was even higher than for other ethnic groups. Therefore, it may be appropriate to consider semi-shovel shaped maxillary incisors and the protostylid cusp on the mandibular molars as being characteristics of the permanent dentition of southern Chinese children.

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