SCIENTIFIC ARTICLE

Australian Dental Journal 1999;44:(1):40-45

# Ethnic dental analysis of shovel and Carabelli's traits in a Chinese population

John W. Hsu*
Pei L. Tsai†
Tin H. Hsiao†
Hong P. Chang‡
Li M. Lin§
Keh M. Liu†
Hsin S. Yu*
Donald Ferguson,

**Abstract**

Chinese populations differ from Caucasoids by having a high prevalence of shovel trait and a low prevalence of Carabelli's trait. This study was conducted to investigate the association between the shovel and the Carabelli's traits in a Chinese population. The research design investigated a Chinese population that resides in southern Taiwan. The ancestors of this Chinese population migrated to Taiwan from mainland China, mainly from Fukien and Kwangtung. The effects of sex and age on Carabelli's trait were controlled in this investigation, as was the association between tooth size and Carabelli's trait. Results show that males were more likely to have Carabelli's trait expressed on teeth than females. The buccolingual diameter of Carabelli's trait teeth was larger than that of teeth without the trait. After controlling for sex, age, and tooth size, the existence of the shovel trait increased the likelihood of having Carabelli's trait by a factor of five and a half, which is a significant effect.

***Key words:*** Dental traits, Chinese, Caucasoid, multivariate logistic regression.

*(Received for publication September 1996. Revised January 1997. Accepted March 1997.)*

*Graduate Research Institute of Medicine, Kaohsiung Medical College, Kaohsiung, Taiwan.
†Department of Anatomy, Kaohsiung Medical College, Kaohsiung, Taiwan.
‡Department of Orthodontics, Kaohsiung Medical College, Kaohsiung, Taiwan.
§Graduate Research Institute of Dentistry, Kaohsiung Medical College, Kaohsiung, Taiwan.
,Department of Orthodontics, School of Dentistry, Marquette University, Milwaukee, WI, USA.

## Introduction

Shovel trait incisors and Carabelli's trait molars are dental features commonly used to differentiate Chinese from Caucasoid populations (Fig. 1). Shovel or Carabelli's traits have been used as critical indicators for several decades, and this has probably been because they are simply observed in both living and skeletal materials and they can be used to show major ethnic differences in dentition that was described by Lee and Goose[1] in 1972. Two features of the Mongoloid dental complex, namely a high frequency of shovel incisors and a low frequency of Carabelli's trait molars, were reported by Dahlberg[2] in 1951 and by Hanihara[3] in 1968. Although it might have been hypothesized that shovel incisors repress the appearance of Carabelli's traits, Tsai *et al.*[4] found a preliminary positive association between these two dental traits in a Bunun aboriginal population.[4] However, the real association between shovel and Carabelli's traits has been obscure in other populations.

Shovel trait is a combination of a concave lingual surface and elevated marginal ridges enclosing a central fossa in the upper central incisor teeth. Carabelli's traits are found on the lingual aspect of the mesiolingual cusp of the upper first molar teeth on which the traits may take the form of a pit, fissure or cusp. Few studies have examined the degree to which the existence of the shovel trait in the incisor teeth influences the Carabelli's trait in the molar teeth, although dental inter-trait studies have been carried out before.[5-11]

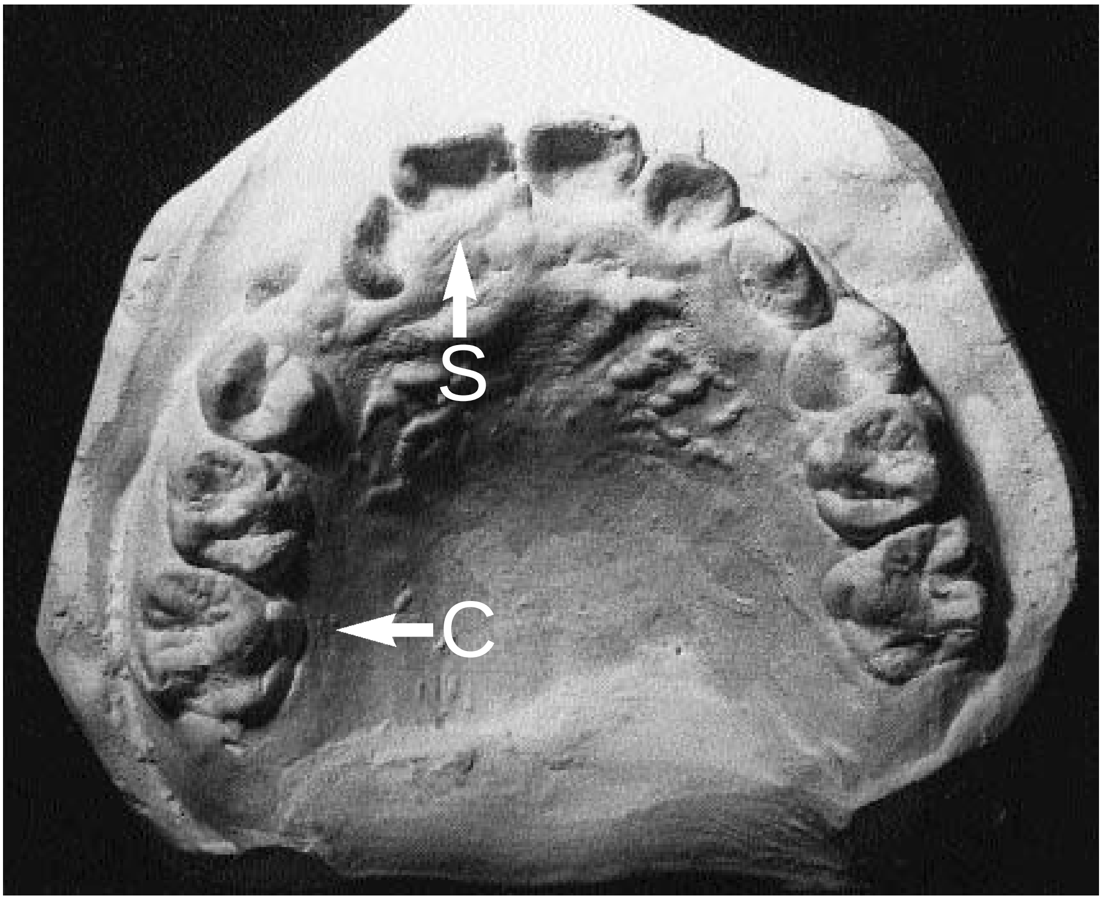


**Fig. 1.** – Shovel trait (S) on upper right central incisor and cusp form of Carabelli's trait (C) on upper right first molar.

In order to decrease the possible population differences in the manifestation of Carabelli's trait, this present investigation was limited to a Chinese population. The Chinese people who live in southern Taiwan are the descendants of Chinese mainlanders who migrated to Taiwan largely from Fukien and Kwangtung in the period after 1600.[12] Before the migration, the aborigines had been already living in Taiwan. Besides reducing the impact of population differences, other possible factors, such as sex and tooth size, which might affect the value for Carabelli's trait and might interfere with the association between the shovel trait and Carabelli's trait, have to be considered. Although sex differences in the expression of Carabelli's trait have been reported,[13-17] other authors have found no significant male-female differences in Carabelli's trait.[18-22] To control for potential differences caused by dimorphism, sex was considered as a possible confounding variable in this study.

The association has been described between the increased maxillary molar tooth size and the occurrence of Carabelli's trait.[20,23] Tooth size is reported to be larger in Carabelli's trait-positive than in Carabelli's trait-negative molars.[24] Because tooth size may be a confounding variable in the analysis of Carabelli's trait, adjustments were made for tooth size. The present study investigated the statistical effects of confounding variables, such as demography and tooth size, on Carabelli's trait in a Chinese population in southern Taiwan. After removing the effects of possible confounding factors, this analysis also investigated the extent to which the shovel trait might affect Carabelli's trait in this Chinese population.

## Materials and methods

### *Measurement acquisition*

Two hundred and ninety-seven subjects participated in this study. In order to reduce the confounding effects of the admixture of race on Carabelli's trait, subjects had to be members of the Chinese population in southern Taiwan. Tooth impressions were taken in rigid disposable trays and poured immediately in dental stone to prevent distortion. To reduce the possible discrepancy between deciduous and permanent dentitions, this study was restricted to permanent teeth.[22] In order to avoid the decrease in observable characteristics caused by dental caries and wear associated with advancing age, the subjects were also limited to 12-15 year old adolescents.

Two hundred and ninety-seven dental casts were used for morphological and metric inspections. Of this number, 280 could be appraised for upper right first molar and upper right central incisor measurements. Seventeen casts were excluded due to inability to measure tooth size and traits. There was no significant deviation in demography between the participating group (280) and the non-participating group (17). In order to eliminate potential problems of asymmetry, analysis was limited to traits and measurements of the right side of the dentition.[25-27] If a tooth was missing or could not be precisely measured due to the loss of measuring points through caries, restoration or attrition, the corresponding contralateral tooth was not used as a substitute.

Various patterns of Carabelli's trait have been classified and contain (a) no evidence of Carabelli's trait – smooth surface with the absence of pits or fissures, (b) pits or fissures, (c1) cusp without free tip, and (c2) cusp with free tip.[28] Thereafter, more patterns of Carabelli's trait have been described, and even intermediate forms have been included.[21,29-31] The non-metrically categorical data of trait patterns have been dichotomized into two types, including the existence and the non-existence of Carabelli's trait. The presence or absence of Carabelli's trait was recorded for the upper right first molar. When there was any manifestation of the trait, cusp, fissure, or pit, the presence of Carabelli's trait was coded.

Some classifications of the shovel trait have been suggested and include (a) shovel – enamel rim distinct with an enclosed well-developed fossa, (b) semishovel – enamel rim distinct but enclosed fossa shallow, (c) trace shovel – traces of enamel rim which can not be classed as semishovel, and (d) no shovel – no perceptible trace of rim or fossa.[32] Upper right central incisor teeth were examined by using this system of grouping and the modified classifications.[30,31,33] These categorical figures were also dichotomized into two groups, including the existence and the non-existence of shovel trait. The shovel trait-positive incisors were coded when rim or fossa could be noticed.

Tooth size of upper right first molars of permanent teeth for each dental cast was measured by a sliding electronic digital calliper with 0.01 mm resolution. Tooth size variables included mesiodistal and buccolingual diameters. The measurements of mesiodistal and buccolingual diameters followed Seipel[34] and Moorrees *et al.*[35] The mesiodistal diameter was measured as the greatest distance between the approximal surfaces of the crown with a sliding calliper parallel to the occlusal and vestibular surfaces of the crown. When a tooth was rotated or malposed in relation to the dental arch, the measurement was taken between the points on the approximal surface of the crown at which place it was judged that normal contact should have occurred with neighbouring teeth. Buccolingual diameter was measured as the greatest distance between the labial or buccal surface and the lingual surface of the tooth crown, measured with a sliding calliper held at right angles to the mesiodistal diameter.

To limit inter-observer errors, mesiodistal and buccolingual crown dimensions of upper right first molars were measured directly on the cast by a single well-trained examiner. A significant test-retest reliability ($r>0.95$, $p<0.001$) was found. Diameters were measured three times and the average value was recorded for each diameter. The morphological traits were classified independently by another examiner, whose incorrect percentage of trait classification was less than three per cent.

### *Statistical analysis*

Each confounding variable was computed for means and proportions according to the teeth with versus the teeth without Carabelli's trait. Multivariate logistic regression was used in this comparative dichotomy analysis between the two groups by using the SAS/STAT computer program.[36] Logistic regression was employed which has become the standard method of analysis in cases where the dependent outcome variable, such as presence or absence of Carabelli's trait, is dichotomous or discrete.[37] Because of the possible variation of dental size and morphology, age was controlled for in this investigation. In addition to sex, the diameters of teeth were also controlled for in the analysis to explore the differences in Carabelli's trait of upper right first molars between presence and absence of shovel trait of upper right central incisors. This logistic method enabled the comparison between presence and absence of the shovel trait for the differences in Carabelli's trait, while controlling for the effects of independent variables such as sex, age, and size of upper right first molars simultaneously. Tests for inference allowed a type I error rate of 5 per cent. The odds risk and 95 per cent confidence interval of odds risk were calculated. Odds risk is a measure that shovel trait is associated with Carabelli's trait. An upper and lower 95 per cent confidence limit of odds risk not containing the value of one was defined as a significant odds risk.

**Table 1. Confounding variables controlled in multivariate logistic regression in the Chinese**

| Variables | Carabelli's trait (n=103) | No Carabelli's trait (n=177) |
|---|---|---|
| Sex (% male) | 75.73 | 44.63 |
| Age (mean years) | 13.47 | 13.56 |
| MD URM1 (mean mm)* | 10.54 | 10.41 |
| BL URM1 (mean mm)† | 11.29 | 10.99 |

*MD URM1: Mesiodistal diameter of upper right first molar.
†BL URM1: Buccolingual diameter of upper right first molar.

**Table 2. Estimates and standard errors in multivariate logistic regression: Carabelli's trait versus no Carabelli's trait**

| Factors | Log odds | | Statistical significance* |
|---|---|---|---|
| | Estimate | Standard error | |
| Sex | 1.21 | 0.37 | † |
| Age (years) | -0.47 | 0.36 | ns‡ |
| MD URM1 (mm)§ | 0.56 | 0.39 | ns‡ |
| BL URM1 (mm), | 1.01 | 0.42 | ¶ |
| Presence of shovel trait | 1.71 | 0.45 | † |

*Significant difference between with and without the Carabelli's trait measurements.
†p<0.001.
‡Not significant, p>0.05.
§MD URM1: Mesiodistal diameter of upper right first molar.
,BL URM1: Buccolingual diameter of upper right first molar.
¶p<0.05.

## Results

More than half (56 per cent) of the sample were male subjects. Of all participants, 36.8 per cent had Carabelli's trait in the upper right first molars, and of male subjects, 49.7 per cent had this trait. However, only 20.3 per cent of female teeth had Carabelli's trait. The means and proportions of confounding variables of teeth with versus the teeth without Carabelli's trait are shown in Table 1. The coefficients and the significance of independent variables in multivariate logistic regression are shown in Table 2. Significant differences were found between males and females for Carabelli's trait. A tooth exhibiting Carabelli's trait was significantly more likely in males than in females (p<0.001). No age difference was observed between presence and absence of Carabelli's trait.

The possible confounding variables that were controlled for in the analysis are shown in Tables 1 and 2. Regarding tooth size, the total studied sample had mean±standard deviation of mesiodistal and buccolingual diameters of 10.45±0.51 mm and 11.23±0.54 mm, respectively. After adjusting for the confounding variables, the mean buccolingual diameter of the tooth with Carabelli's trait was significantly larger than that of the tooth without Carabelli's trait (p<0.05). On the other hand, the mean mesiodistal diameter of the tooth with Carabelli's trait was slightly larger than that of the tooth without Carabelli's trait, but it was not statistically significant after adjusting for sex, age, and buccolingual diameters.

The presence of the shovel trait in the upper right central incisors predicted the existence of Carabelli's trait in the upper right first molars five and a half times more often than the absence of the shovel trait did (odds risk, 5.51; 95 per cent confidence interval, 2.26-13.44; p<0.001) (Table 3). Of the non-shovel trait group in the Taiwan Chinese, only 11.8 per cent had Carabelli's trait teeth. Carabelli's trait teeth were found in 42.4 per cent of the shovel trait group.

## Discussion

Quasi-continuous, or continuous variables have been used to treat non-metric dental traits in prior studies. Usually, the real trait expression intervals have been unequally classified into several categories, but equally continuous intervals have been assumed to apply. Further, incorrect percentages for several types of dental trait classifications have ranged from 22 per cent to 56 per cent.[38] Finally, the classification criteria of Carabelli's trait have been variably set into different categories by different authors. For example, the 'pit' feature has been given different values or degrees in different classifications. Some investigators have viewed 'groove' and 'cusp' as independent categories, but some have had categories for 'cusp' in contact with 'groove' or 'cusp' with no contact. Another method, assuming the threshold mechanism, has dichotomized the non-metric dental traits into present and absent groups to view dental traits as entities.[20,31,32,39-43] On the basis of these prior studies, dichotomization reduces possible classification bias and has another trait entity significance.

The present study found that Carabelli's trait is sexually dimorphic in Taiwan Chinese. Similar findings have occurred elsewhere,[13-17] but these are in contradiction with some other studies.[18-22] It appears difficult to conclude that sex differences exist in Carabelli's trait. However, it is noted that these previous studies are not completely comparable due to varying sample sizes and different methods of analysis. The effects of confounding variables such as mesiodistal and buccolingual diameter have been rarely removed. These methodological deficiencies

**Table 3. The association between shovel and Carabelli's traits in the Chinese***

| Groups | Carabelli's trait (n=103) | No Carabelli's trait (n=177) | Odds risk | 95% confidence interval | p |
|---|---|---|---|---|---|
| Shovel | 97 | 132 | 5.51 | 2.26-13.44 | <0.001 |
| No shovel | 6 | 45 | | | |

*Statistical significance was determined by logistic regression controlling for the effects of sex, age, as well as both mesiodistal and buccolingual diameters of upper right first molars. The non-shovel group was the control compared with the shovel group and the group of shovel trait with greater than grade 1.

in other investigations may have led to contradictory findings. Certainly such analytic shortcomings influenced the use of multivariate methods in the present analysis, which then identified the existence of significant sexual difference.

Among Taiwan Chinese, after adjusting for sex and age, significant differences are present in buccolingual, but not in mesiodistal diameters. Such differences have been observed elsewhere.[24,44,45] De Terra[44] and later Dahlberg[45] suggested that Carabelli's cusp is an adaptation that enlarged the occlusal surface of the first molars in the buccolingual dimension as compensation for evolutionary reduction in the length (mesiodistal diameter) of the maxillary molar row. Another study reported that Carabelli's cusp is related to larger first molars overall, and not especially with an increase in the buccolingual diameter.[20] The opinion from the evolutionary perspective has been that Carabelli's trait might be a primitive structure that tends to disappear with molar reduction in all hominoid evolutionary lines.[24,46,47] A functional argument for the existence of Carabelli's trait has been the proposal that it may be a structure that resists excessive biomechanical stresses on the first molar.[48] The results of this Chinese population study show that smaller first molars tend to have fewer occurrences of Carabelli's trait and, developmentally, Carabelli's trait is a disappearing structure as the first molar becomes smaller in a Chinese population. That Carabelli's trait serves a structural function needs further biomechanical experimentation to prove.

According to prior studies,[2,3,32,49] shovel trait occurs almost universally, and occurs particularly frequently in the Chinese, Taiwan aborigines, Eskimos, American Indians, and Australian Aborigines. Carabelli's trait is less commonly found in these populations.[1] On the other hand, populations derived from Europe have a low frequency of shovel trait and a high frequency of Carabelli's trait.[1,32,50-52] The literature shows that Chinese and Caucasoid population frequencies differ remarkably in the expression of shovel trait on the upper right central incisor teeth and Carabelli's trait on the upper right first molar.[1,53,54] As a consequence of this, shovel and Carabelli's traits have been regarded as dental markers of Chinese and Caucasoid ancestry. Understanding the real interaction between these two prominent dental markers is therefore of biological and anthropological importance.

Comparatively, little attention has been paid to the outcome of multivariate analyses of the influence of shovel trait on Carabelli's trait, though many papers have examined dental traits in Chinese populations.[1,32,55-57] By confining the present study to the Taiwan Chinese only, it can be shown that after adjustment, the presence of the shovel trait tends to increase the likelihood of Carabelli's trait by a factor of five and a half. The authors found a positive impact of the shovel trait on Carabelli's trait after proper data adjustment in a Chinese population which was similar to the positive interaction, using similar analytical method, between these two dental markers in a Bunun aboriginal population in the report by Tsai *et al.*,[4] which has anticipated an analogous developmental relationship between shovel and Carabelli's traits. Given the positive association found in the present study, the reduction of Carabelli's trait is related to the reduction of shovel trait. Accordingly, it seems that the present study shows further evidence to support an analogous developmental relationship between these two dental traits. Moreover, the positive association between these two dental traits may be hypothesized as a common characteristic in the Mongoloid population that needs further studies.

Other models which include genetic and environmental factors for the manifestation of Carabelli's trait have been reported.[13,20,51] In addition to the environment, Tsai *et al.* reported that genes play a major role in the association between Carabelli's and shovel traits.[4] Therefore, the positive interaction between shovel and Carabelli's traits in the Chinese population may be explained by a similar hypothesis. However, this assumption also needs to be verified with family studies. Although the generalization of the intensity of the effect of shovel trait on Carabelli's trait seen in Taiwan Chinese to other populations may be limited, this study also promotes a method to investigate the association between shovel and Carabelli's trait entities in other populations, which are of critical importance as well.

## Acknowledgements

The authors are grateful to Dr S. Chen for his statistical advice in this study and also to Mr P. Hsu for his preparation of the materials and manuscript. This investigation was supported in part by a research grant from the Institute of Biological Research, National Science Council, Taipei, Taiwan.

## References

1. Lee GTR, Goose DH. The dentition of Chinese living in Liverpool. Hum Biol 1972;44:563-572.
2. Dahlberg AA. The dentition of the American Indian. In: Laughlin WS, ed. The physical anthropology of the American Indian. New York: Viking Fund, 1951.
3. Hanihara K. Mongoloid dental complex in the permanent dentition: Proceedings VIIIth International Congress of Anthropological and Ethnological Sciences. Tokyo: Science Council of Japan, 1968:298-300.
4. Tsai PL, Hsu JW, Lin LM, Liu KM. Logistic analysis of the effect of shovel trait on Carabelli's trait in a Mongoloid population. Am J Phys Anthropol 1996;100:523-530.
5. Scott GR. Lingual tubercles and the maxillary incisor-canine field. J Dent Res 1977;56:1192.

6. Scott GR. Interaction between shoveling of the maxillary and mandibular incisors. J Dent Res 1977;56:1423.
7. Scott GR. The relationship between Carabelli's trait and the protostylid. J Dent Res 1978;57:570.
8. Scott GR. Association between the hypocone and Carabelli's trait of the maxillary molars. J Dent Res 1979;58:1403-1404.
9. Doran GA. Characteristics of the Papua New Guinean dentition. I. Shovel-shaped incisors and canines associated with lingual tubercles. Aust Dent J 1977;22:389-392.
10. Mizoguchi Y. Shovelling: A statistical analysis of its morphology. Tokyo: University of Tokyo Press, 1985.
11. Motayam A, Gridly MM, Dass HK. Relationship between two super structure traits. Carabelli and protostylid. Egypt Dent J 1985;31:183-189.
12. Sung WH. A review of Taiwan from an archeological perspective. In: Chen CL, ed. Chinese Taiwan. Taipei: Central Material Center, 1980:93-220.
13. Goose DH, Lee GTR. The mode of inheritance of Carabelli's trait. Hum Biol 1971;43:64-69.
14. Kaul V, Prakash S. Morphological features of Jat dentition. Am J Phys Anthropol 1981;54:123-127.
15. Kieser JA, Preston CB. The dentition of the Lengua Indians of Paraguay. Am J Phys Anthropol 1981;55:485-490.
16. Townsend GC, Brown T. The Carabelli's trait in Australian aboriginal dentition. Arch Oral Biol 1981;26:809-814.
17. Noss JF, Scott GR, Potter RHY, Dahlberg AA, Dahlberg T. The influence of crown dimorphism on sex differences in the Carabelli's trait and the canine distal accessory ridge in man. Arch Oral Biol 1983;28:527-530.
18. Garn SM, Kerewsky RS, Lewis AB. Extent of sex influence on Carabelli's polymorphism. J Dent Res 1966;45:1823.
19. Bailit HL, DeWitt SJ, Leigh RA. The size and morphology of the Nasioi dentition. Am J Phys Anthropol 1968;28:271-288.
20. Lombardi AV. Tooth size associations of three morphologic dental traits in a Melanesian population. J Dent Res 1975;54:239-243.
21. Scott GR. Population variation of Carabelli's trait. Hum Biol 1980;52:63-78.
22. Kieser JA. An analysis of the Carabelli trait in the mixed deciduous and permanent human dentition. Arch Oral Biol 1984;29:403-406.
23. Keene HJ. The relationship between Carabelli's trait and the size, number and morphology of the maxillary molars. Arch Oral Biol 1968;13:1023-1025.
24. Reid C, Van Reenen JF, Groeneveld HT. Tooth size and the Carabelli trait. Am J Phys Anthropol 1991;84:427-432.
25. Keene HJ. Epidemiologic study of tooth size variability in caries-free naval recruits. J Dent Res 1970;50:1331-1345.
26. Saunders SR, Mayhall JT. Fluctuating asymmetry of dental morphological traits: new interpretation. Hum Biol 1982;54:789-799.
27. Mayhall JT, Saunders SR. Dimensional and discrete dental trait asymmetry relationships. Am J Phys Anthropol 1986;69:403-411.
28. Kraus BS. Carabelli's anomaly of the maxillary molar teeth. Am J Hum Genet 1951;3:348-355.
29. Dahlberg AA. Analysis of the American Indian dentition. In: Brothwell DR, ed. Dental anthropology. London: Pergamon Press, 1963;5:149-177.
30. Turner CG II, Nichol CR, Scott GR. Scoring procedures for key morphological traits of the permanent dentition: The Arizona State University dental anthropology system. In: Kelly MA, Larsen CS, eds. Advances in dental anthropology. New York: Wiley-Liss, 1991:13-31.
31. Hanihara T. Negritos, Australian aborigines, and the "Proto-Sundadont" dental pattern: The basic populations in East Asia, V. Am J Phys Anthropol 1992;88:183-196.
32. Hrdlička A. Shovel-shaped teeth. Am J Phys Anthropol 1920;3:429-465.
33. Dahlberg AA. Materials for the establishment of standards for classification of tooth characters, attributes and techniques in morphological studies of the dentition. Mimeograph associated with plaster casts. Chicago: University of Chicago Press, 1956.
34. Seipel CM. Variation of tooth position. Svensk Tandlak Tidskr 1946;39:50-51.
35. Moorrees CFA, Thomsen SO, Jensen E, Yen PK. Mesiodistal crown diameters of the deciduous and permanent teeth in individuals. J Dent Res 1957;36:39-47.
36. SAS Institute Inc. SAS/STAT User's Guide. Version 6. 4th edn. Cary, NC: SAS Institute Inc, 1989.
37. Hosmer DW Jr, Lemeshow S. Applied logistic regression. New York: John Wiley & Sons Inc, 1989.
38. Kieser JA, Van Der Merwe CA. Classificatory reliability of the Carabelli's trait in man. Arch Oral Biol 1984;29:795-801.
39. Schuman EL, Brace CL. Metric and morphologic variants in the dentitions of the Liberian chimpanzee: comparisons with anthropoid and human dentitions. Hum Biol 1954;26:139-168.
40. Carlsen O. Carabelli's structure in the human maxillary first molar. Acta Odontol Scand 1968;26:398-408.
41. Liu KL. Dental condition of two tribes of Taiwan aborigines – Ami and Ataya. J Dent Res 1976;56:117-127.
42. Smith P, Brown T, Wood WB. Tooth size and morphology in a recent Australian aboriginal population from Broadbeach, South East Queensland. Am J Phys Anthropol 1981;55:423-432.
43. Manabe Y, Rokutanda A, Kitagawa Y. Nonmetric tooth crown traits in the Ami tribe, Taiwan aborigines: Comparisons with other east Asian populations. Hum Biol 1992;64:717-726.
44. De Terra M. Beitrage zu einer Odontographie der Menschenrassen. Berlin: Berlinische Verlagsanstalt, 1905.
45. Dahlberg AA. The dentition of the American Indian. In: Laughlin WS, ed. The physical anthropology of the American Indian. New York: Viking Fund, 1949:138-176.
46. Frisch JE. Trends in the evolution of the Hominoid dentition. Bibliotheca Primatologica No. 3. Basel: Karger, 1965.
47. Hillson S. Teeth. Cambridge: Cambridge University Press, 1986.
48. Mizoguchi Y. Adaptive significance of the Carabelli trait. Bull Natl Sci Mus Tokyo Ser D 1993;19:21-58.
49. Turner CG II. Major features of sundadonty and sinodonty, including suggestions about East Asian microevolution, population history and late Pleistocene relationships with Australian aborigines. Am J Phys Anthropol 1990;82:295-317.
50. Mayhall JT, Saunders SR, Belier PL. The dental morphology of North American whites: A reappraisal. In: Kurten B, ed. Teeth: Form, function and evolution. New York: Columbia University Press, 1982.
51. Townsend GC, Martin NG. Fitting genetic models to Carabelli trait data in South Australian twins. J Dent Res 1992;71:403-409.
52. Townsend GC, Richards LC, Brown T, Burgess VB, Travan GR, Rogers JR. Genetic studies of dental morphology in South Australian twins. In: Smith P, Tchernov E, eds. Structure, function and evolution of teeth. London: Freund Publishing House Ltd, 1990:501-518.
53. Koski K, Hantala E. On the frequency of shovel-shaped incisors in Finns. Am J Phys Anthropol 1952;10:127-132.
54. Moorrees CFA. The aleut dentition. A correlative study of dental characteristics in an Eskimoid people. Cambridge, MA: Harvard University Press, 1957.
55. Lee GTR, Goose DH. The inheritance of dental traits in a Chinese population in the United Kingdom. J Med Genet 1972;9:336-339.
56. Goose DH. The dental condition of Chinese living in Liverpool. In: Dahlberg AA, Graber TM, eds. Orofacial growth and development. The Hague: Mouton, 1977:183-194.
57. Huang ST, Miura F, Soma K. A dental anthropology study of Chinese in Taiwan. 3. Dental traits. Kaohsiung J Med Sci 1992;8:665-678.

*Address for correspondence/reprints:*
John Wen-Chain Hsu,
Kaohsiung Medical College,
Kaohsiung,
Taiwan 80708.