**An analysis of dental intercanine distance for use in court cases involving bite marks**

*Suzana Reinprecht*[1.] *Paul J.van Staden*[2.] *Joyce Jordaan*[2.] *Herman Bernitz*[1]

Corresponding author: Dr Suzana Reinprecht, MSc. Department of Oral Pathology and Oral Biology, School of Dentistry, University of Pretoria, Pretoria. P.O. Box 1266, Pretoria, 0001 Tel.:+27 824529845,Suzana.Reinprecht@gauteng.gov.za

[1]Department of Oral Pathology and Oral Biology, School of Dentistry, University of Pretoria, South Africa

[2]Department of Statistics, University of Pretoria, Pretoria, South Africa.

## Abstract

High levels of crime in South Africa and the resulting court cases requiring bite mark evidence have necessitated continuous research into the prevalence and interrelationship of recognisable dental features present in bite marks. This study represents the largest data set of descriptive statistics related to intercanine distance, in which the means, standard deviations, medians and interquartile ranges across four racial groups were determined. Intercanine distances were also statistically weighted by determining the common, uncommon and very uncommon values for each of the racial groups. The results of this research show that we can consider any maxillary intercanine distance more than 24.1 mm and less than 43.0 mm to represent a human bite mark. Black males had the largest mean(average) intercanine distance of 36.33mm (standard deviation 2.49 mm) and white females the smallest mean intercanine distance of 33.4 mm (standard deviation 2.13 mm). The analyses showed statistically significant differences between the mean intercanine distances of different race and gender groupings. The authors do not advocate trying to determine the race or gender from intercanine distances determined, but rather the relevance of the intercanine distances in the specific race and gender groupings. This study makes a meaningful scientific contribution to the presentation of bite mark evidence at a time when subjective opinions need to be replaced with scientific data.

**KEYWORDS:** Forensic Science· Forensic Odontology· Intercanine distance· arch shape· interrelationships· bite marks· court cases.

## Introduction

High levels of crime in South Africa and a resulting court cases requiring bite mark evidence, have necessitated continuous research into the prevalence and interrelationship of recognisable dental features present in bite marks. The 2016 South African crime statistics report shows that between April 2015 and March 2016, 18673 people were murdered in South Africa [1].

The adult intercanine distance represents the most stable measurement in both the maxillary and mandibular arches [2].Two known studies have investigated dental arch shape and intercanine distances present in their respective populations, but have not been representative of their respective populations [2, 3]. The intercanine distance is generally used to establish whether the bite mark is indeed a human mark, and also to exclude individuals whose dental arch widths are clearly larger or smaller than the examined material [4].

Tooth patterns observed on skin and in inanimate objects reflect the incisal surfaces of the suspect's dentition and generally include marks left by the canine teeth [4]. The tooth marks left by canines tend to be more prominent in skin bite marks as these teeth are usually longer and cause more bruising [4]. This also applies in dog bite marks, where the canines are much longer [5, 6]. The measured distance between these marks present in the dental arch are referred to as the intercanine distance and plays an important role in orientation of bite marks on skin [4].Bites inflicted are inadvertently left as clues at crime scenes and can be used to convict or exonerate suspects [7, 8].Skin bite marks are generally present on the body of the victim and inflicted by the assailant, but in some cases the wounds are self-inflicted or inflicted by the victim on the assailant [9]. The location of the tooth marks observed on victims is related to the nature of the crime e.g. sexual assault, child abuse, burglary or kidnapping [10]. It has also been shown that in 48% of cases where tooth marks are involved, multiple marks are usually present [11]. Suspects can be physically linked to or excluded from a crime scene through fingerprints, DNA samples and tooth marks [12].

No prevalence studies quantifying the intercanine distance between different races, ages and genders representative of a specific geographic area are available.

The aim of this study was to analyse intercanine distance for use in court cases where bite mark evidence is required. The study analysed four racial groups and included gender and age differences.

**Materials and Methods**

Bite mark research was conducted on 4286 racially self-classified volunteers in the province of Gauteng, South Africa. The sample included 3240 Blacks,777 Caucasians, 148 Coloureds and 121 Indians, aged between 18-75 years. Bite registrations were taken at private companies, private dental practices, government dental clinics and University clinics so as to include individuals from a range of socio-economic backgrounds. This sample is representative of the Gauteng population and reflects the population profile of the 2011 Census [13].

Data collection procedure:

Bites were registered on a double layer of pink wax folded around a cardboard strip based on the technique described by Bernitz [14]. This wax platform gives sufficient support to register both the upper and lower anterior dentitions during the biting process. All bites were checked, and those that had perforated the wax platform were redone. Bites which showed little detail were also redone.

After each bite registration session, the recorded bites were transported in cooler boxes to a dental laboratory where yellow plaster models (KUG yellow stone plaster type 3) of the bite mark registrations were cast. Each plaster model carried the same unique number present on the wax bites.

The intercanine distance was measured with a digital Vernier calliper, and was defined as the "horizontal distance between the cusp tips or central facet areas of the canines in the mandibular and maxillary arches measured in mm".

An intra-rater reliability study was performed on 51 cases. The interclass correlation coefficient (ICC) was used to evaluate the intra-rater reliability of the intercanine distance measurements.

Statistical analyses consisted of basic statistics such as frequencies and descriptive statistics ( including means, standard deviations and percentiles).Percentiles such as median, first and third quartiles were reported in addition to the mean and standard deviation ranges. In order to determine common, uncommon and very uncommon values for maxillary and mandibular intercanine distances, the 0.5th, 2.5th, 97.5th and 99.5th percentiles were computed according to Allan's classification for the percentiles [15].

Analysis of covariance (ANCOVA), where the averages of intercanine distances were compared across race and gender, controlling for age of the maxillary and mandibular arches, was also performed.

## Results

*Mean, Standard Deviation, median and Interquartile ranges*

The maxillary intercanine distances measured in mm for different race and gender groups are provided in Table 1.

**Table 1. Maxillary intercanine distances measured in mm for different race and gender groups**

| | ***N*** | **Mean** | **Standard deviation** | **Median** | **Interquartile range** |
|---|---|---|---|---|---|
| Black male | 1306 | 36.33 | 2.49 | 36.40 | 3.2 |
| Black female | 1772 | 35.12 | 2.33 | 35.10 | 2.9 |
| Coloured male | 65 | 35.74 | 2.58 | 35.80 | 3.4 |
| Coloured female | 74 | 34.45 | 2.32 | 34.7 | 2.5 |
| Indian male | 59 | 34.60 | 2.17 | 34.5 | 2.9 |
| Indian female | 59 | 34.27 | 2.36 | 34.3 | 3.2 |
| White male | 330 | 34.79 | 2.62 | 35.0 | 3.5 |
| White female | 365 | 33.44 | 2.13 | 33.2 | 2.9 |

The mandibular intercanine distances measured in mm for different race and gender groups are provided in Table 2

**Table 2. Mandibular intercanine distances measured in mm for different race and gender groups**

| | ***N*** | **Mean** | **Standard deviation** | **Median** | **Interquartile range** |
|---|---|---|---|---|---|
| Black male | 1340 | 28.02 | 2.24 | 28.0 | 2.8 |
| Black female | 1812 | 27.34 | 2.13 | 27.3 | 2.8 |
| Coloured male | 67 | 27.58 | 2.20 | 27.5 | 3.3 |
| Coloured female | 78 | 26.81 | 2.40 | 26.8 | 3.0 |
| Indian male | 61 | 26.77 | 2.54 | 26.3 | 2.7 |
| Indian female | 58 | 26.73 | 2.01 | 26.6 | 2.6 |
| White male | 361 | 26.65 | 2.14 | 26.6 | 2.9 |
| White female | 390 | 25.69 | 1.93 | 25.6 | 2.6 |

A summary of 4030 observations used to determine common, uncommon and very uncommon values for the maxillary inter-canine distances measured in mm according to Allan's classification is provided in Table 3.

**Table 3. A summary of 4030 observations used to determine common, uncommon and very uncommon values for the maxillary inter-canine distances measured in mm according to Allan's classification**

| | Very uncommon | Uncommon | Common | Uncommon | Very uncommon |
|---|---|---|---|---|---|
| Black male | <28.9 | ≥28.9 < 31.4 | 31.4–40.9 | >40.9 ≤ 43.0 | >43.0 |
| Black female | <28.5 | ≥28.5 < 30.4 | 30.4–39.7 | >39.7 ≤ 41.7 | >41.7 |
| Coloured male | <24.1 | ≥24.1 < 31.6 | 31.6–39.9 | >39.9 ≤ 40.3 | >40.3 |
| Coloured female | <28.3 | ≥28.3 < 30.2 | 30.2–39.0 | >39.0 ≤ 39.7 | >39.7 |
| Indian male | <29.1 | ≥29.1 < 29.9 | 29.9–38.8 | >38.8 ≤ 39.5 | >39.5 |
| Indian female | <27.9 | ≥27.9 < 29.2 | 29.2–38.7 | >38.7 ≤ 39.3 | >39.3 |
| White male | <27.1 | ≥27.1 < 28.8 | 28.8–39.2 | >39.2 ≤ 40.8 | >40.8 |
| White female | <28.3 | ≥28.3 < 29.2 | 29.2–37.6 | >37.6 ≤ 38.7 | >38.7 |

A summary of 4167 observations used to determine common, uncommon and very uncommon values for the mandibular inter-canine distances measured in mm according to Allan's classification is provided in Table 4.

**Table 4. A summary of 4167 observations used to determine common, uncommon and very uncommon values for the mandibular intercanine distances measured in mm according to Allan's classification**

| | Very uncommon | Uncommon | Common | Uncommon | Very uncommon |
|---|---|---|---|---|---|
| Black male | <22.0 | ≥22.0 < 23.9 | 23.9–32.6 | >32.6 ≤ 35.2 | >35.2 |
| Black female | <21.6 | ≥21.6 < 23.5 | 23.5–31.7 | >31.7 ≤ 33.5 | >33.5 |
| Coloured male | <23.2 | ≥23.2 < 23.6 | 23.6–31.8 | >31.8 ≤ 32.1 | >32.1 |
| Coloured female | <21.9 | ≥21.9 < 22.1 | 22.1–32.7 | >32.7 ≤ 36.0 | >36.0 |
| Indian male | <21.7 | ≥21.7 < 23.2 | 23.2–30.4 | >30.4 ≤ 32.2 | >32.2* |
| Indian female | <22.6 | ≥22.6 < 23.1 | 23.1–30.4 | >30.4 ≤ 32.5 | >32.5 |
| White male | <20.5 | ≥20.5 < 22.6 | 22.6–30.9 | >30.9 ≤ 33.5 | >33.5 |
| White female | <19.5 | ≥19.5 < 22.1 | 22.1–29.4 | >29.4 ≤ 31.0 | >31.0 |

*Excluding case number 824-extreme outliner

*ANCOVA analysis*

ANCOVA analysis was performed, since it is believed that aging has an effect on intercanine distance. Age was included as a covariate in the model.

For male participants, the mean maxillary intercanine distances differed significantly across race, while controlling for age ($F_{4,1754}$ = 32.31 ; *p*-value < 0.0001). Age was significantly related to the maxillary intercanine distance ($F_{1,1754}$ = 8.42 ; *p*-value = 0.0038). Furthermore, the mean maxillary intercanine distances differed significantly across race ($F_{3,1754}$ = 36.96 ; *p*-value < 0.0001). To ascertain which means differed significantly across race, the Least Square Means were investigated. The mean intercanine distances in the upper jaw differed significantly at the 1 per cent level of significance between Black and Indian males (*p*-value < 0.0001) and between Black and White males(*p*-value < 0.0001)(Table 5).

**Table 5. *p* values for pairwise comparisons of mean maxillary intercanine distances between males of different races with age as covariate.**

| | **Black male** | **Coloured male** | **Indian male** |
|---|---|---|---|
| Black male | | | |
| Coloured male | 0.049* | | |
| Indian male | <.0001** | 0.0095* | |
| White male | <.0001** | 0.0128* | 0.3631 |

*5%, **1% level of significance

For male participants, the mean mandibular intercanine distances differed significantly across race, while controlling for age ($F_{4,1823}$ = 40.34 ; *p*-value < 0.0001). Age was significantly related to the mandibular intercanine distance ($F_{1,1823}$ = 33.71 ; *p*-value < 0.0001). Furthermore, the mean mandibular intercanine distances differed significantly across race ($F_{3,1823}$ = 34.77; *p*-value <0.0001). The Least Square Means differed significantly at a 1% level between Black and Indian males (*p*-value < 0.0001) and also between Black and White males(*p*-value < 0.0001)(Table 6).

**Table 6. *p* values for pairwise comparisons of mean mandibular intercanine distances between males of different races with age as covariate**

| | Black male | Coloured male | Indian male |
|---|---|---|---|
| Black male | | | |
| Coloured male | 0.0705 | | |
| Indian male | <.0001** | 0.0223* | |
| White male | <.0001** | 0.0112* | 0.6297 |

*5%, **1% level of significance

In the case of female participants, the mean maxillary intercanine distances differed significantly across race, while controlling for age ($F_{4,2264}$ = 44.38 ; $p$-value < 0.0001). Age was significantly related to the maxillary intercanine distance ($F_{1,2264}$ = 9.99 ; $p$-value = 0.0016). Furthermore, the mean maxillary intercanine distances differed significantly across race ($F_{3,2264}$ = 47.79 ; $p$-value <0.0001). The Least Square Means differed significantly between Black and Indian females ($p$-value = 0.0034); between Black and White females($p$-value < 0.0001) and also between Coloured and White females ($p$-value = 0.0020)(Table 7).

**Table 7. *p* values for pairwise comparisons of mean maxillary intercanine distances between females of different races with age as covariate**

| | Black male | Coloured male | Indian male |
|---|---|---|---|
| Black male | | | |
| Coloured male | 0.0138* | | |
| Indian male | 0.0034** | 0.5719 | |
| White male | <.0001** | 0.0020** | 0.0356* |

*5%, **1% level of significance

In the case of female participants, the mean mandibular intercanine distances differed significantly across race ($F_{4,2332}$ = 62.95 ; $p$-value < 0.0001). Age was significantly related to the mandibular intercanine distance ($F_{1,2332}$ = 47.70 ; $p$-value < 0.0001). Furthermore, the mean mandibular intercanine distances differed significantly across race ($F_{3,2332}$ = 53.06 ; $p$-

value <0.0001). The Least Square Means differed significantly between Black and White females (*p*-value < 0.0001); between Coloured and White females(*p*-value = 0.0002) and between Indian and White females (*p*-value = 0.0031)(Table 8).

**Table 8. *p* values for pairwise comparisons of mean mandibular intercanine distances between females of different races with age as covariate**

| | **Black male** | **Coloured male** | **Indian male** |
|---|---|---|---|
| Black male | | | |
| Coloured male | 0.0282* | | |
| Indian male | 0.0303* | 0.8292 | |
| White male | <.0001** | 0.0002** | 0.0031** |

*5%, **1% level of significance

The mean intercanine distances for maxillary and mandibular dental arches were also analysed. Race and gender were not considered in this analysis. A one-way ANOVA showed that the mean maxillary intercanine distances differed significantly across arch shape ($F_{2,4027}$ =76.28; *p*-value < 0.0001). To ascertain which means differed significantly across race, the Least Square Means were investigated. According to these, the mean intercanine distances in upper jaw differed significantly at the 1 per cent level of significance between parabolic and square arch shapes ( *p*-value = 0.0001); parabolic and V-shaped arches ( *p*-value < 0.0001) and square and V-shaped arches ( *p*-value < 0.0001)(Table 9).

**Table 9. *p* values for pairwise comparisons of mean mandibular intercanine distances between arch shapes**

| | **Parabolic** | **Square** |
|---|---|---|
| Parabolic | | |
| Square | 0.0001** | |
| V-shaped | <0.0001** | <0.0001** |

*5%, **1% level of significance

The one-way ANOVA indicated that the mean mandibular intercanine distances differed significantly across arch shape ($F_{2,4164}$=142.94; *p*-value < 0.0001). To ascertain which means differed significantly across race, the Least Square Means were investigated. According to these, the mean mandibular intercanine distances differed significantly at the 1 per cent level of significance between parabolic and square arch shapes ( p-value < 0.0001); parabolic and v-shaped arches ( *p*-value < 0.0001) and square and v-shaped arches ( *p*-value < 0.0001)(Table 10).

**Table 10. *p* values for pairwise comparisons of mean mandibular intercanine distances between arch shapes**

| | **Parabolic** | **Square** |
|---|---|---|
| Parabolic | | |
| Square | <0.0001** | |
| V-shaped | <0.0001** | <0.0001** |

*5%, **1% level of significance

*Boxplots*

Boxplots for the distributions of intercanine distances in relation to arch shape in the maxilla is provided in Figure 1.

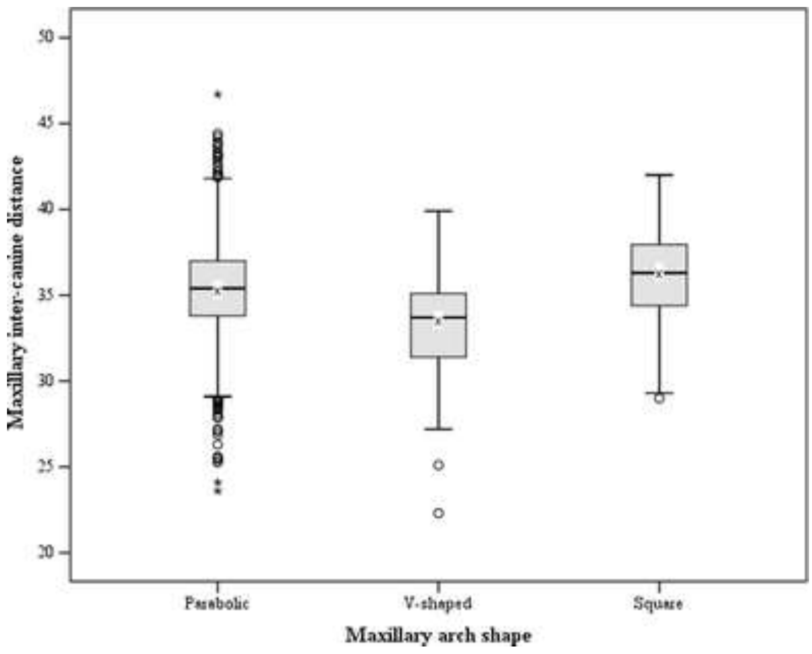


**Fig. 1. Box plots for the distributions of intercanine distances in relation to arch shape in the maxilla**

Boxplots for the distributions of intercanine distances in relation to arch shape in the mandible is provided in Figure 2.

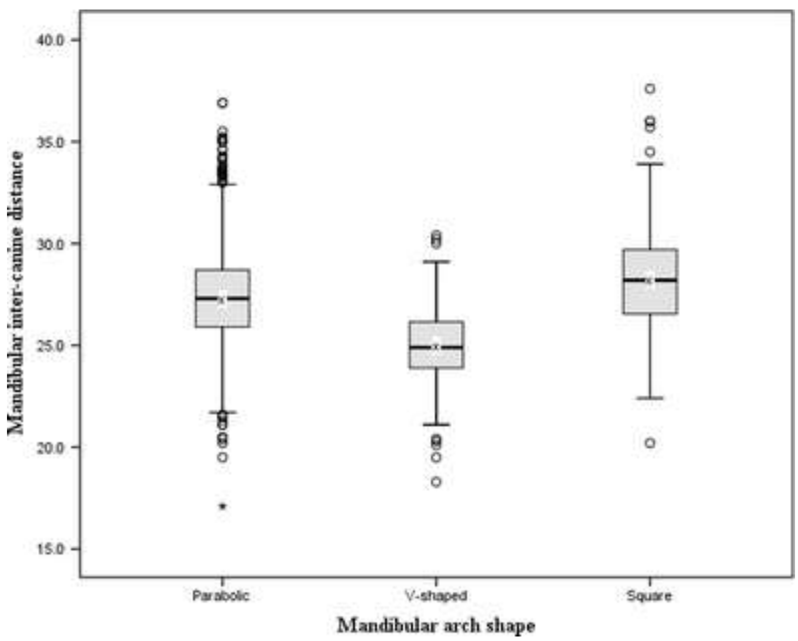


**Fig. 2. Box plots for the distributions of intercanine distances in relation to arch shape in lower jaw**

The intra-class correlation coefficient (ICC) for the maxillary intercanine distance was 0.975.The intra-class correlation coefficient (ICC) for the mandibular intercanine distance was 0.981.

**Discussion**

The need to determine the frequency of selected dental features for application in court cases involving bite marks is well documented. In the past researchers were discouraged by the magnitude and logistics involved in collecting the required samples. This sample of 4286 bite registrations is the largest of its kind and allowed the researchers to analyse a representative sample of dental features which were observed in the bite mark registrations. A literature search on intercanine distance and bite mark analysis revealed that very little was available on the subject, and that most references were older than 5 years. No literature available analysed the differences that exist between racial groups.

Although the bite mark registrations do not accurately mimic the marks seen in skin bite marks, they give us a good indication of the dental impressions/features that we can expect when analysing bite marks in general. They are better suited to bite mark feature analysis than study models which lack any resemblance to the dynamics of the biting process and penetration of the incisal edges into the substrate being bitten.

The intercanine distance is extremely important in that it is used as the initial indicator to determine if the bite mark is in fact a human bite mark or not. The results of this research show that we can consider any maxillary intercanine distance larger than 24.1mm and less than 43.0 mm to be a human bite mark. Generally the two canines are longer than the anterior incisors and cause two areas of bruising that assist in the orientation of the bite mark and the initial determination of the intercanine distance.

When determining the probabilities of a match between the mark on the skin or inanimate object and the suspect, it is important to know if the feature present is common, uncommon or very uncommon in the specific gender and racial grouping. These values (Tables 1-4) were determined for males and females in the Black, Coloured, Indian and White racial groups. The tables show that black males generally have the greatest intercanine distances while white females generally have the smallest intercanine distance. ***We do not advocate trying to determine the race and gender from the data (Tables 1-4), but rather determine the relevance of the intercanine distance in the specific race and gender grouping.*** Results of the research clearly indicate that the mean intercanine distance for males are larger than for females in all of the racial groupings. It is interesting to note that the mean intercanine distance of black females is larger than the mean intercanine distance in white males. The mean intercanine distances for blacks and coloureds in both genders are larger than the mean intercanine distances in Indians and Whites. As stated above, the importance of these data is, for example, finding an individual with a maxillary intercanine distance of 40.9 mm. This would be a common occurrence in a black male, but a very uncommon occurrence in a white male. In terms of the bite mark analysis, it would weigh heavily if both the white male suspect and the bite mark had intercanine distances of 40.9mm. The same would apply, if a black male suspect presented with an intercanine distance of 28.8mm. This measurement would be very uncommon in a black male, but common in a white male. The $p$-value of 0.0001 in the pairwise comparison between black males and white males with age as covariate shows that the results are statistically significant. Similar significant differences are shown in Tables 5-8.

It must be stressed that warping, shrinkage and distortion of both skin and inanimate objects would make exact measurement of the intercanine distance in a bite mark difficult. It does however give us a good indication of the metric value which we can apply to the above data sets. The warping, shrinkage and distortion will depend on contour of the surface bitten, the elasticity of the skin in the specific area, the postural position of the suspect or individual being bitten, dynamics of the inflicted bite mark and the time span between the biting occurrence and the analysis process. In our experience the intercanine distance remains one of the most reliable and least affected determinants in the feature analysis of skin bite marks.

When analysing a bite mark, it is important to understand that there are interrelationships present between the dental features present in the anterior dental arches and the intercanine distances. If teeth were missing in a specific dental arch, there would be a degree of drift, resulting in a smaller intercanine distance. If supernumerary teeth were present in a specific anterior dental arch, an enlarged intercanine distance could be expected. This research has also shown that V shaped arches tend to have smaller intercanine distances and square dental arches larger intercanine distance, see Figures 1 and 2. Severe tooth crowding would also tend to shorten the intercanine distance. The presence of any of the above must be borne in mind when measuring the intercanine distance and adjustments made to accommodate the obvious effects of the interrelationships that do exist. As long as the interrelationships are observed in both the bite mark and the dentition of the perpetrator, the analysis will be little affected.

The interclass correlation coefficients of 0.975 and 0.981 for the maxilla and mandible respectively, indicate that the data measurements were extremely reliable.

**Conclusion**

This study represents the largest data set of descriptive statistics related to intercanine distance in different race, age and gender groupings. It will assist forensic dentists in determining if a bite mark is in fact a human bite mark, and also facilitate in either including a suspect or exonerating an individual whose intercanine distance is obviously too small or to large. It will also aid in the weighting of intercanine distances within each racial group. This study makes a meaningful scientific contribution to bite mark analysis at a time when subjective opinions need to be replaced with scientific data.

## References


1. South African Police Service (2014) Crime situation in South Africa: South African Police Service. http://www.saps.gov.za/resource_centre/publications. Accessed 29 September 2016
2. Harris EF (1997) A longitudinal study of arch size and form in untreated adults. Am J Orthod Dentofacial Orthop 111:419-27. doi: 10.1016/S0889-5406(97)80024-8
3. Ferrario VF, Sforza C, Miani A, Tartaglia G (1994) Mathematical definition of the shape of dental arches in human permanent healthy dentitions. Eur J Orthod 16:287-94. doi: 10.1093/ejo/16.4.287
4. Bernitz H, Owen JH, van Heerden WF, Solheim T (2008) An integrated technique for the analysis of skin bite marks. J Forensic Sci 53:194-8. doi: 10.1111/j.1556-4029.2007.00618.x
5. Bernitz H, Bernitz Z, Steenkamp G, Blumenthal R, Stols G (2012) The individualisation of a dog bite mark: a case study highlighting the bite mark analysis, with emphasis on differences between dog and human bite marks. Int J Legal Med 126:441-6. doi: 10.1007/s00414-011-0575-4

6. Tedeschi-Oliveira S, Trigueiro M, Oliveira R, Melani R (2011) Inter canine distance in the analysis of bite marks: a comparison of human and domestic dog dental arches. J Forensic Odontostomatol 29:30-6

7. Atsü SS, Gökdemir K, Kedici P, Ikyaz Y (1998) Bitemarks in forensic odontology. J Forensic Odontostomatol 16:30-4

8. Furness J (1981) A general review of bite-mark evidence. Am J Forensic Med Pathol 2:49-52

9. Clark DH (1992) Bite mark examination procedures: victims and suspects. Practical Forensic Odontology. Butterworth-Heinemann, Oxford

10. Pretty IA, Sweet D (2000) Anatomical location of bitemarks and associated findings in 101 cases from the United States. J Forensic Sci 45:812-4. doi: 10.1520/JFS14775J

11. Pretty I, Sweet D (2001) The scientific basis for human bitemark analyses–a critical review. Sci Justice 41:85-92. doi: 10.1016/S1355-0306(01)71859-X

12. Bender K, Schneider PM, Rittner C (2000) Application of mtDNA sequence analysis in forensic casework for the identification of human remains. Forensic Sci Int 113:103-7. doi: 10.1016/S0379-0738(00)00223-1

13. Statistics South Africa (2011) Census: Statistics South Africa. http://www.statssa.gov.za/publications/population. Accessed 13 May 2015

14. Bernitz H, Van Heerden WF, Solheim T, Owen JH (2006) A technique to capture, analyze, and quantify anterior teeth rotations for application in court cases involving tooth marks. J Forensic Sci 51:624-9. doi: 10.1111/j.1556-4029.2006.00114.x

15. Allan JC (1982) Learning about statistics: a primer in simple statistical methods for students of the medical, biological, paramedical, social and behavioural sciences MacMillan, Johannesburg