ISSN 2219-6749

I-O-F-O-S

The Journal of Forensic Odonto-Stomatology

Volume 22, n. 1 - Jun 2004

OFFICIAL PUBLICATION OF THE
INTERNATIONAL ORGANIZATION FOR
FORENSIC ODONTO-STOMATOLOGY

COMPUTERIZED RECORDING OF THE PALATAL RUGAE PATTERN AND AN EVALUATION OF ITS APPLICATION IN FORENSIC IDENTIFICATION

K.S. Limson, R. Julian

Department of Prosthetic Dentistry, Tamilnadu Government Dental College and Hospital, Chennai, India

ABSTRACT

In circumstances where identification of an individual by fingerprint or dental record comparison is difficult, palatal rugae may be considered as an alternative source of comparative material. This article evaluates the use of palatal rugae patterns for forensic identification with an indigenously developed computer software program. Comprehensive computerized antemortem records were constructed for 250 subjects and a comparison matching process performed using both recorded and unrecorded samples. The efficiency of this computer-based identification method was then assessed. The program proved to have an average sensitivity of 0.93 and specificity of 1 and had a success rate of 92-97% in matches with digitized rugae pattern samples. **(J Forensic Odontostomatol 2004;22:1-4)**

Key words: Palatal rugae, Forensic identification, Computer software, Antemortem records

INTRODUCTION

Keiser-Nielson described Forensic odontology as "the proper handling and examination of dental evidence in the interest of justice, so that the dental findings may be properly presented and evaluated."[1] Identification of humans is a prime requisite for certification of death and for personal, social and legal reasons. Fingerprint and dental record comparisons are the most commonly used scientific methods of forensic identification.[2, 3]

Limitations to the use of fingerprints occur in situations where the hands are charred or mutilated[4] and, while teeth are more durable, identification using dental records may also prove to be inconclusive, since many records may be inaccurate or incomplete, or contain fraudulent data. Additional dental treatment might have been done in the time interval between the creation of a dental record and death of the individual.[5]

Palatal rugae have been shown to be highly individual and consistency in shape throughout life.[6-10] The anatomical position of the rugae inside the oral cavity, surrounded by cheek, lips, tongue and buccal pad of fat, also afford some protection in cases of trauma or incineration. The purpose of this study was to assess the use of palatal rugae, based on Lysell's classification of palatal rugae[6] and the modifications of Thomas and Kotze,[7] as an aid to forensic identification.

Technological advances now available to the forensic dentist such as computers, image capturing devices and ability to transfer information quickly have simplified the task of human identification in deceased individuals as well as in mass fatality situations.[11,12]

Use of such technology has been employed in this study where the principle behind commonly available personal identification systems for fingerprints was modified to create an indigenous computer software program RUG FP-ID Match. The same methodology of fingerprint comparison was used in this computer-based identification using palatal rugae.

MATERIALS AND METHODS

Creation of antemortem records

Two hundred and fifty undergraduates of the Tamilnadu Government Dental College constituted the initial study group, with distribution of the sample shown in Table 1. Comprehensive computerized antemortem records consisting of personal and physical details, digitized fingerprint, digitized rugae pattern and dental record were created and stored for each subject in the study group.

A fingerprint of each subject was recorded by placing the left thumb on the scanning surface of the Fingerprint Scanning Device* (Fig.1). The image was directly transferred to the computer and characteristic 'Minutiae' points processed and stored (Fig.2).

* *Hanno Technologies, Korea*

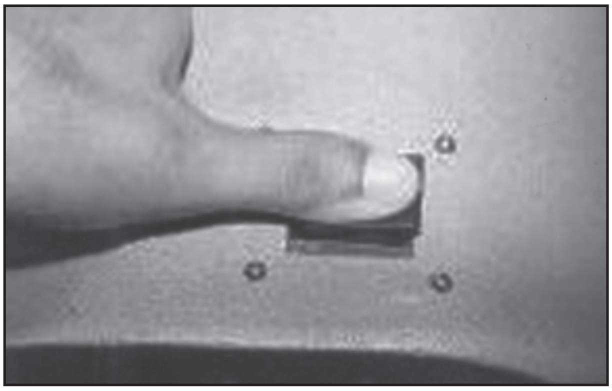

Fig.1: *Left thumb of a subject placed on the scanning surface of the Fingerprint Scanning Device*

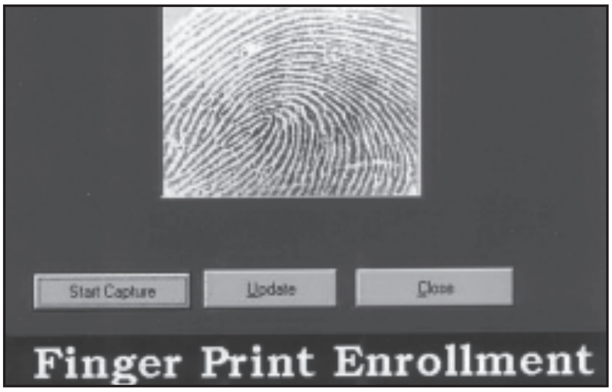

Fig.2: *Fingerprint recording screen*

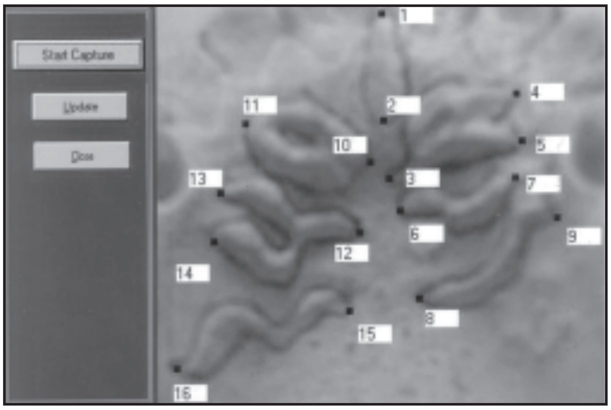

Fig.3: *Sequential manual plotting of characteristic points on the rugae pattern image*

An irreversible hydrocolloid impression of the upper arch of each of the subject was made and casts were prepared with Type III dental stone. Rugae on the casts were delineated with a sharp graphite HB pencil under a spotlight. Fragmentary rugae less than 3mm in length were omitted. The rugae pattern image was captured with a Digital camera* under standardized conditions. The camera was mounted on a stand, inclined forward to 45 degrees and focused at a distance of ten cm from the surveyor table of a Ney's† surveyor. After delineation casts were placed on the surveyor table and adjusted until the occlusal plane of the cast was parallel to the floor. The rugae pattern was photographed and transferred to the computer as a Jpeg image file.

Anatomical characteristics on the rugae pattern image were marked manually with a 'Target' shaped cursor on the computer image. (Fig.3). A strict protocol was undertaken for the order in which points were plotted - tip and base of incisive papilla, then each ruga was plotted at the medial and lateral ends, working from anterior to posterior. Left sided rugae were plotted before right. These plotted points were processed by the software and the information sequentially stored corresponding to pixel position.

Comparison matching process

A sub-sample of 120 individuals were randomly selected, 60 from the original sample group for whom comprehensive data had been collected and recorded in a database (recorded subjects) and 60 new individuals from the general population (unrecorded subjects) for whom maxillary casts were constructed.

The left thumb of each individual was placed on the scanning surface of the Fingerprint Scanning Device* and checked for a database match using the search mode in the software. Four operators, a dentist with forensic odontology training, a general dental surgeon, a computer professional and a general physician, each produced computer images of the

Table 1: *Distribution of sample*

Age group	Males	Females
17-18	21	29
18-19	24	26
19-20	18	32
20-21	22	28
21-22	26	24

* *Canon Inc. Tokyo, Japan*

† *JM Ney Co, Bloomfield CT, USA*

rugae patterns of those in the sub-sample using the study protocol. Each operator then matched the images that he produced against the stored antemortem records.

RESULTS

RUG FP-ID Match was tested using both fingerprint and rugae samples. All the fingerprint samples of recorded subjects correctly matched the stored antemortem records and none of fingerprint samples of unrecorded subjects matched with the stored antemortem data. The efficiency of the computer-based matching process using rugae pattern was then assessed, using the 100% correct fingerprint matching as a standard. The statistical data of the matching process with digitised rugae pattern of sample subjects and the success rate of each of the operators were tabulated in Table 2. The sensitivity of this software in the matching process was 0.97, 0.91, 0.93 and 0.91 respectively for each operator, with an average of 0.93. The specificity and positive predictive values were one. The negative predictive values were 0.97, 0.92, 0.94 and 0.92 respectively for each operator, with an average of 0.94 (Table 3)

DISCUSSION

It is widely acknowledged that there are limitations in identification by fingerprints and dental records in some forensic situations, and the palatal rugae pattern of an individual may be considered as a viable alternative for identification purposes. This study aimed to assess the feasibility of using palatal rugae patterns for identification with the aid of a computer and software program. The program proved to be completely reliable for fingerprint matching, but somewhat less so for matches of palatal rugae. The error rate of 3-8% observed during the matching process for several operators may be due to errors in the delineation of rugae or incorrect sequential plotting of characteristic points on the rugae pattern image manually on the computer screen. The error rate may be reduced by development of an intraoral scanning device to capture palatal rugae pattern, with image transfer directly to a computer, with appropriate software, as is presently available for fingerprints. This would eliminate the manual errors and time involved in the process of digitization of rugae pattern samples. With the use of interconnected computers networks it would be possible to store a large amount of data, facilitating quick retrieval of information and fast and effective identification.

Table2: *Analysis of results of the matching process with rugae pattern samples*

S.No	OPERATORS	% success	True positive	False positive	False negative	True negative
1	Forensic Odontologist	97	58	0	2	60
2	Dental Surgeon	92	55	0	5	60
3	Computer professional	93	56	0	4	60
4	General Physician	92	55	0	5	60

Table 3: *Analysis of the efficiency of identification using the software program*

S.No	OPERATORS	Sensitivity	Specificity	Positive predictive value	Negative predictive value
1	Forensic Odontologist	0.97	1	1	0.97
2	Dental Surgeon	0.91	1	1	0.92
3	Computer professional	0.93	1	1	0.94
4	General Physician	0.91	1	1	0.92

REFERENCES

1. Fearnhead RW, Furness J, Midda M, Waller DF. Report of working party. Forensic odontology. Br Dent J 1969 Dec 2;127:521-6.

2. Whittaker DK. Introduction to forensic dentistry. Quintessence Int 1994;25:723-30.

3. Morlang WM. Forensic dentistry. Aviat Space Environ Med 1982;53:27-34.

4. Buchner A. The identification of human remains. Int Dent J 1985;35:307-11.

5. Chester D, ed. Forensic dentistry. Colgate oral care report 2002;12:1-3.

6. Lysell L. Plica palatinae transversae and papilla incisiva in man: a morphological and genetic study. Acta Odontol Scand 1955;13:5-137.

7. Thomas CJ, Kotze T. The palatal ruga pattern: a new classification. J Dent Assoc S Afr 1983;38:153-7.

8. Harrison A. The palatal rugae in man. Proc Acad Nat Soc 1889;6:245.

9. English WR, Robinson SF, Summitt JB, Oesterle LJ, Brannon RB, Morlang WM. Individuality of human palatal rugae. J Forensic Sci 1988;33:718-26.

10. Abou EF, Mona M, Gamal ZHES. A study of palatal rugae pattern (rugoscopy) in Egyptian population. Egypt Dent J 1998;44:3177-84.

11. McGivney J, Fixott RH. Computer assisted dental identification. Dent Clin North Am 2001;45:309-25.

12. Lorton L, Rethman M, Friedman R. The computer assisted postmortem identification (CAPMI): a computer based identification program. J Forensic Sci 1988;33:977-84.

Address for correspondence:
Dr.K.S.Limson
157 Gangawar Lane
Oppanakara Street
Coimbatore 641001
Tamilnadu – India.
Phone: +91 0422-2399541
Email: lovelimson@yahoo.co.in

IN VITRO EVALUATION OF THE XR-150™ PORTABLE X-RAY UNIT FOR FORENSIC ODONTOLOGY

S. Varghese, A. Kimmel, T. Radmer, T.G. Bradley, J. Bahcall

Department of Orthodontics, Marquette University School of Dentistry, Milwaukee, USA

ABSTRACT

The purpose of this research was to investigate if a portable, light-weight radiographic generator, Golden Engineering's XR-150™, can be used in forensic odontology to aid identification. Dental periapical radiographs produced by the XR-150™ were evaluated for diagnostic quality based on sharpness, detail, and whether the lamina dura, periodontal membrane space and bone trabeculae could be observed. Logistic regression was used to calibrate the evaluators for reliability and for comparison of impulse values within the different sites at $p<0.01$. Spearman's Correlation was used to test for significance between the four quadrants at $p<0.01$. The XR-150™ produced statistically significant ($p<0.01$) diagnostic images between five and ten impulses in all locations tested: anterior maxilla, anterior mandible, posterior maxilla, and posterior mandible.

(J Forensic Odontostomatol 2004;22:5-8)

Key Words: Portable x-ray, cold cathode, XR-150™, postmortem identification

INTRODUCTION

Practitioners of Forensic Odontology are often called upon for their expertise in the identification of human remains. Antemortem information may be gathered from written dental records, dental casts, bite records and dental radiiographs.[1] Frequently postmortem examinations take place in less than ideal locations, far away from a forensic laboratory. This poses the challenge of obtaining diagnostic postmortem records quickly which will not deteriorate over an extended period of time.

The use of x-ray instruments provides a swift and reliable method for comparing postmortem radiographs with antemortem records. To date, the size and weight of current equipment has made field identification cumbersome.

Most portable x-ray instruments utilize a cathode ray tube and typically weigh from 30 to 40 kilograms. The conventional x-ray machine utilizes a metal filament that is heated at the cathode to generate electrons and the tungsten target at the anode converts the kinetic energy of the electrons into x-ray photons. The intensity of x-ray radiation is proportional to the electron current and square of the acceleration voltage. The thermionic cathodes possess the limitations of low response time and excessive consumption of power. Moreover, when the thermionic cathode is used for extended times, the filament may overheat and melt.[2]

Another type of portable x-ray instrument harnesses radiographic isotope sources, which significantly decreases the weight of the unit to about 15 kilograms. Disadvantages to this include the additional expenses accrued from disposing of the isotopes, Iodine 125 or Gadolinium 153, and the required operator licensing fees as stated by the Nuclear Regulatory Commission.[3]

An alternative method of portable instrumentation is through the use of field emission. High voltage is utilized to generate the strong fields necessary to make electrons leave the surface of a cold metal. Using field emission, electrons can be extracted at room temperature and the output of the current is voltage controllable.[4] The technology is used currently in photography and electron guns in microscopes[5] ,but field emission radiology is still in an early stage of development for medical applications.[6,7] Researchers in North Carolina have generated radiographs of fish and a human hand using carbon nanotubes as the basis for field emissions.[7]

The Golden Engineering's XR-150™* portable x-ray unit was initially developed for law enforcement use to detect implanted explosive devices and to reveal hidden objects such as weapons and other contraband in packages. It measures 26.7 x 7.6 x 10.2 centimeters and weighs just 2 kg. The electronics defining this machine rely upon orbital electrons being emitted once a strong electrical field is applied to a cold metal surface (Schottky effect).[4] For any particular metal, the ability of electrons to escape the potential barrier is dependent upon the voltage supplied. For the XR-150™, storing the voltage on a capacitor prior to discharge creates the electrical potential. Since only electrons of the highest energy level are likely to escape the electric potential barrier of the metallic surface, a nearly uniform level of energy is produced from the emitted electrons. This entire process of field emissions occurs without the heating of the metal, resulting in the use of a cold cathode.

Several advantages of field emission tubes include relatively small size, low manufacturing costs, and the lack of separate filament circuitry. The pulsed emission technology provides constant focal spot size when KV and mA are changed thus eliminating the blooming effect of cathode.[4] The blooming effect of traditional radiographic machines produced as the mA increases generates a larger electron cloud leading to the loss of definition and anatomical visibility.

To date, radiographic instruments using field emission have not been tested for dental imaging utilizing conventional radiographic film or digital sensors. The purpose of this research was to investigate if a portable, light-weight radiographic generator, Golden Engineering's XR-150™, can be used in forensic odontology to assist postmortem identification.

MATERIALS AND METHODS

The XR-150™ was mounted on a tripod and aligned with a dried human skull placed on table top (Fig. 1). In order to standardize the resulting magnification, density, contrast and image resolution, a 20 cm (8 inch) target to object distance was used (Fig 2). The portable unit was used to produce dental periapical radiographs using Kodak F† dental film.

The XR-15™ provides a setting of 1 to 99 that represents three pulses of 20 nanoseconds per setting. A setting of "one," for example, provides 60 nanoseconds of exposure time, representing an average of 2 to 3 milliroentgens of output. Increasing the setting on the portable machine only alters the exposure times. The kVp of the unit is fixed at 150 kVp. Collimation of the beam was accomplished using a standard dental x-ray collimator mounted to the XR-150™ output source on the housing of the instrument.

Fig.1: *XR-150™ portable x-ray unit mounted on a tripod*

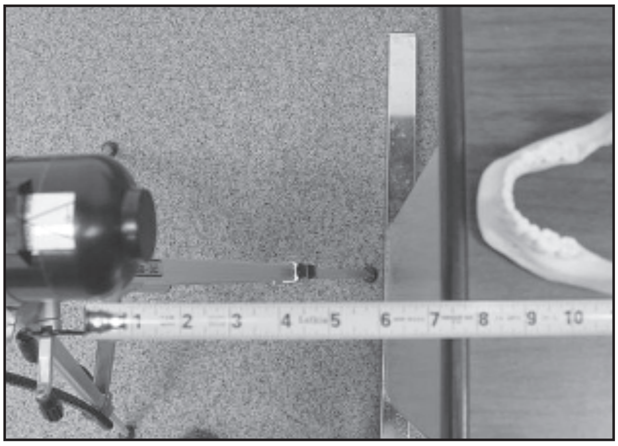

Fig.2: *Target to object distance of 20 cm (8 inch)*

**Golden Engineering, Inc. Centerville, Indiana. USA*

†Eastman Kodak Company. Rochester, New York. USA

Fifteen radiographs, varying in impulses from one to fifteen, were taken by one technician in each of four locations: anterior maxilla, anterior mandible, posterior maxilla, and posterior mandible. The XR-150™ unit remained in the fixed position and the skull was manipulated to obtain the radiographs in different quadrants. One set location in each quadrant was chosen to expose the radiographs. For consistent results and to allow comparison, fifteen impulses were taken without moving the unit or the skull. The films were processed using a Gendex GXP processor.*

Two oral & maxillofacial surgeons, two clinical radiology technicians and one general dentist, a certified forensic odontologist, examined the exposed radiographs. The four sets of fifteen radiographs were mounted in a random fashion unknown to the clinical interpreters and radiographs evaluated as either diagnostic or non-diagnostic. Criteria for interpretation of the radiographs as diagnostic included sharpness, detail, and whether the lamina dura, periodontal membrane space and bone trabeculae could be observed.

Table 1: *Evaluators (N=5)*

	Significance
Anterior Maxilla	0.764
Anterior Mandible	0.641
Posterior Maxilla	0.447
Posterior Mandible	0.368

RESULTS

Prior to this study, a pilot study at Marquette University was conducted to test intra-examiner reliability. The XR-150™ was tested on a different dried human cadaver skull. Fifteen radiographs varying in impulses from one to fifteen were taken in one position in each of the four quadrants: anterior maxilla, anterior mandible, posterior maxilla, and posterior mandible. Data from the pilot study were tested for significance using logistic regression. The p-values at the four sites were as follows: 0.764 for the anterior maxilla, 0.641 for the anterior mandible, 0.447 for the posterior mandible, and 0.368 for the posterior mandible (Table 1).

Data obtained in the present study from the evaluators at different impulses at each site were tested for statistical significance within and between the four sites. Since the values obtained (diagnostic/nondiagnostic) were categorical (anterior maxilla, anterior mandible, posterior maxilla, posterior mandible) logistic regression was used to test data within sites. Logistic regression values generated were significant (p<0.01) for the impulses five to ten in all quadrants tested (Table 2).

Table 2: *Prediction values based on logistic regression*

Impulse	Anterior Maxilla	Anterior Mandible	Posterior Maxilla	Posterior Mandible
1.00000	0.00001	0.00001	0.00001	0.00001
2.00000	0.00001	0.00001	0.00001	0.00001
3.00000	0.20000	0.60000	0.60000	0.00001
4.00000	0.99999	0.99999	0.60000	0.40000
5.00000	0.99999	0.99999	0.99999	0.99999
6.00000	0.99999	0.99999	0.99999	0.99999
7.00000	0.99999	0.99999	0.99999	0.99999
8.00000	0.99999	0.99999	0.99999	0.99999
9.00000	0.80000	0.99999	0.99999	0.99999
10.00000	0.99999	0.80000	0.99999	0.99999
11.00000	0.40000	0.60000	0.99999	0.99999
12.00000	0.40000	0.40000	0.80000	0.80000
13.00000	0.00001	0.00001	0.40000	0.99999
14.00000	0.00001	0.00001	0.00001	0.60000
15.00000	0.00001	0.00001	0.00001	0.00001

Spearman's correlation was used to test significance between the four sites. The Spearman's correlations values between the different sites were as follows: anterior maxilla and anterior mandible 0.815, anterior maxilla and posterior maxilla 0.368, anterior maxilla and posterior mandible 0.534, anterior mandible and posterior maxilla 0.649, anterior mandible and posterior mandible 0.427, and posterior maxilla and posterior mandible 0.712. Table 3 shows that positive correlation values were obtainedbetween all sites.

Table 3: *Correlation between groups*

	Significance Level	Spearmans Correlation
Anterior Maxilla & Anterior Mandible	P<0.01	0.815
Anterior Maxilla & Posterior Maxilla	P<0.01	0.638
Anterior Maxilla & Posterior Mandible	P<0.01	0.534
Anterior Mandible & Posterior Maxilla	P<0.01	0.649
Anterior Mandible & Posterior Mandible	P<0.01	0.427
Posterior Maxilla & Posterior Mandible	P<0.01	0.712

**Gendex Corporation. Des Plaines, Illinois. USA*

DISCUSSION

The pilot study tested intra-examiner reliability using logistic regression. The results revealed that intra-examiner reliability was evident although evaluators differed in clinical training and expertise.

Using logistic regression, each of the four locations produced statistically significant images ($p<0.01$). The increase in density of films in this study may be attributed to the increase in impulses since the kVp and the distance between the focal spot and film were fixed. Prediction values based on logistic regression were obtained to find a range of impulses that the XR-150™ produced consistent images at the four sites. Impulses from four to ten produced diagnostic radiographs at the anterior maxilla and anterior mandible. For the posterior maxilla, consistently diagnostic impulses ranged from five to twelve. The prediction values at the posterior mandible yielded the range of impulses from five to thirteen.

The range of diagnostic impulses increased slightly from anterior to posterior. Since the posterior region is thicker than the anterior, more beam is attenuated, and the resulting image will be lighter. The slight increase in exposure going from anterior to posterior quadrants may be attributed to this phenomenon. The increase in impulse range for the posterior mandible may be attributed to the thick layer of cortical bone that surrounds a core of dense cancellous bone. More impulses are needed to penetrate the dense bone in the posterior mandible. Overall, values between five and ten were significant in all four locations.

In testing significance between groups, Spearman's correlation was used instead of ANOVA since the values of comparison were categorical in nature. The highest correlations were found between the maxilla (both anterior and posterior) and anterior mandible. The cortical plates are relatively thin in the maxilla (both anterior and posterior) and the anterior mandible compared to the posterior mandible. More penetration of the beam is needed in the posterior mandible since the cortical plates are thick compared to the other sites.

CONCLUSION

Fifteen radiographs exposed at impulses one to fifteen at a target-object distance of eight inches in each of the four sites tested (anterior maxilla, anterior mandible, posterior maxilla, posterior mandible) confirmed that impulses between five and ten consistently produced statistically significant ($p<0.01$) diagnostic radiographs. The Golden Engineering's XR-150™, a portable x-ray unit, may have potential usage in forensic odontology.

REFERENCES:

1. James SH, Nordy JJ, eds. Forensic Odontology. Forensic Science: An introduction to scientific and investigative techniques. Boca Raton, FL: CRC Press, 2003:61-78.

2. White SC, & Pharoah MJ. Oral Radiology: Principles and Interpretation 4th edn. St. Louis, MO: Mosby, 2000.

3. Kircos LT, Vandre RH, & Lorton L. Portable X-ray unit using a radioactive source for oral radiography. Dentomaxillofacial Radiology, 1986;15:107-114.

4. Selman J. The fundamentals of x-ray and radium physics (7th ed.). Springfield, IL: Charles Thomas, 1985.

5. Binh VT, Semet V, Guillot D, Legagneux P, Pribat D. Microguns with 100-V electron beams. Applied Physics Letters, 1998;73:2048-2050.

6. Semet V, Binh VT, Vincent P, Guillot D, Teo KB, Chowalla M. Amaratunga GA, Milne WI, Legagneux P, Pribat, D. Field electron emission from individual carbon nanotubes of a vertically aligned array. Applied Physics Letters, 2002;81:343-5.

7. Yue GZ, Qiu Q, Gao B, Cheng Y, Zhang J, Shimoda H, Chang S, Lu JP, Zhou O. Generation of continuous and pulsed diagnostic imagin x-ray radiation using a carbon-nanotube-based field-emission cathode. Applied Physics Letters, 2002;81:355-7.

Address for correspondence:
Shaun Varghese
Marquette University School of Dentistry
Attn: Department of Orthodontics
1801 W. Wisconsin Avenue
Milwaukee, WI 53233,USA
Email: shaun.varghese@marquette.edu

REPLICATION OF CRANIAL GUNSHOT WOUNDS

B.P.J. Pearce, A.P. Jackson, J.A. Kieser

Department of Oral Sciences, University of Otago, Dunedin, New Zealand

ABSTRACT
It is possible to differentiate between entrance and exit wounds in bone by examining the specimen concerned. Because of the evidential usefulness of providing jurists or members of a jury with such specimens, we describe an easy and reliable method for replicating gunshot wounds in the human skull utilizing dental materials and methods.
(J Forensic Odontostomatol 2004;22:9-12)

Key words: Gunshot wounds, ballistics

INTRODUCTION
Terminal ballistics is the study of the motion and penetration of a moving projectile when it comes in contact with the body.[1] The amount of tissue damage typically is determined by the efficiency of energy transfer, which in turn is dependent on the physical characteristics of the projectile, its deformation and fragmentation, kinetic energy, entrance profile and path traveled through the body.[2] It has been claimed that the direction in which a bullet was travelling may be determined by the appearance of the wound in bone.[3] Typically the entrance is round to oval with a sharp, punched out appearance, while the exit would is large, irregular and beveled. A number of cases of beveling of the entrance wound have been reported[4] but the mechanism of external beveling is not well understood.

Given the evidential value of physical examination and preservation of gunshot wounds in dry bones, we report on a simple and accurate replication method for which no specialized equipment is required.

SPECIMENS AND METHODS
Two human calvaria (that part of the skull after the facial bones have been removed), each with a single gunshot wound, were replicated. The first specimen had an execution type entry wound at the occiput (Fig.1) with a classic internal bevel (Fig.2). The second had an entry wound on the inner surface of the occipital bone (Fig.3) with a beveled edge on the outer bony plate (Fig.4).

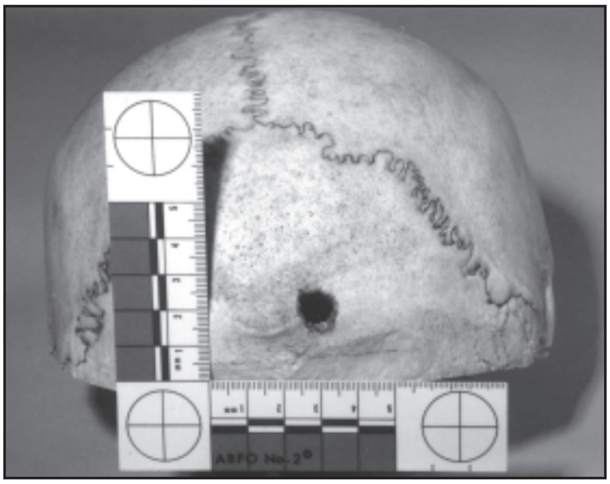

Fig.1: *Outer table entrance wound in a human occipital bone*

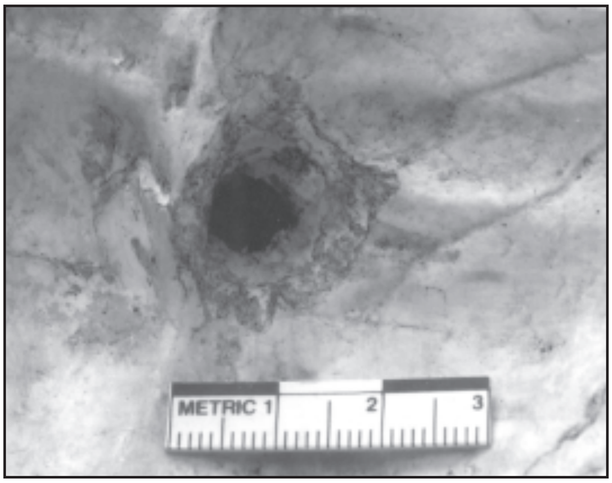

Fig.2: *Exit site with inner table bevelling*

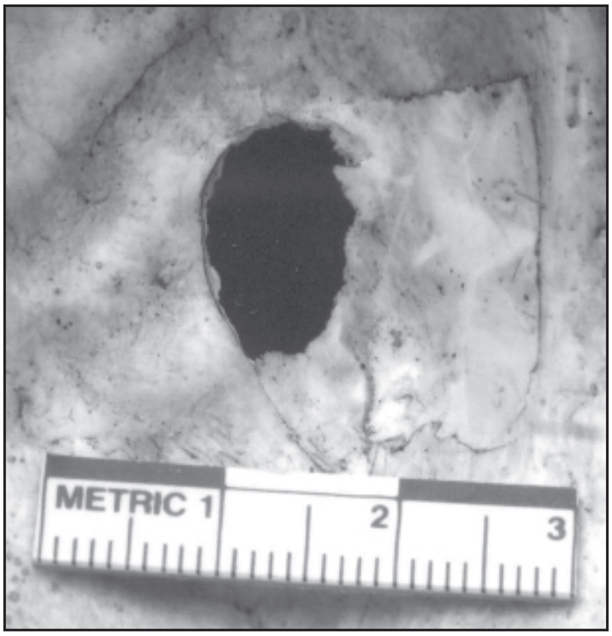

Fig.3: *Inner table entrance wound with a sharp, punched out appearance*

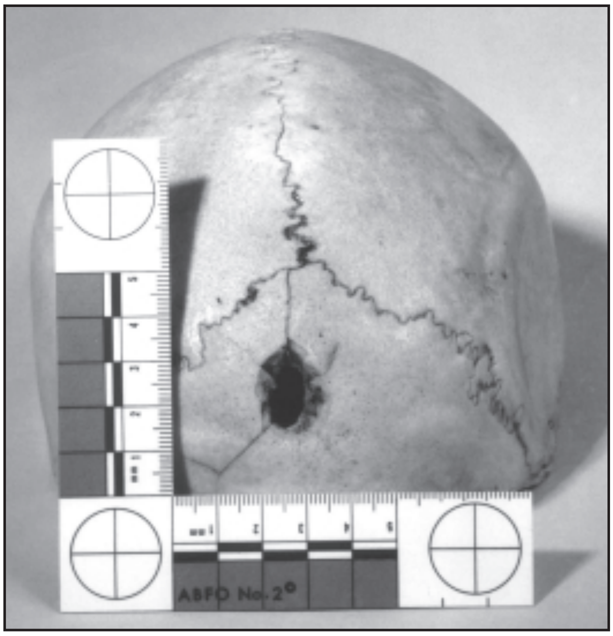

Fig.4: *Outer table exit wound with characteristic bevelling*

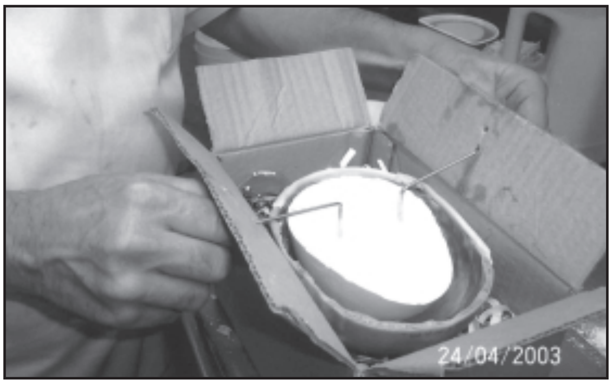

Fig.5: *Plaster plug acting as a space maintainer for the inner impression of the calotte*

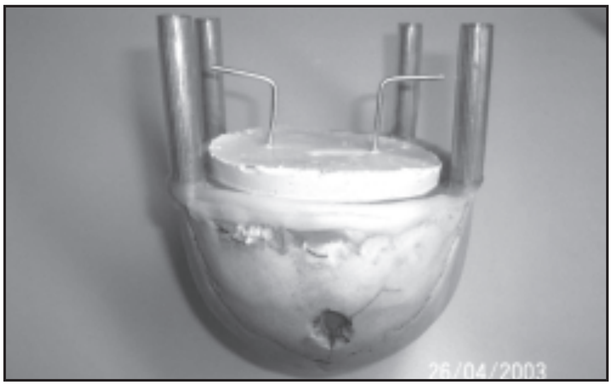

Fig.6: *Plaster plug, calotte with tubes and dowels*

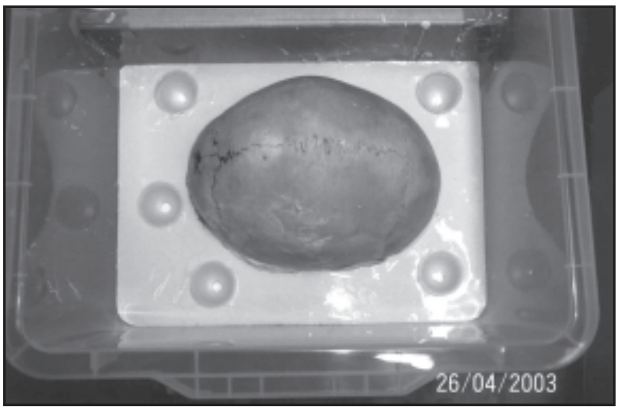

Fig.7: *Plastic container, dental stone base and calotte positioned for outer impression*

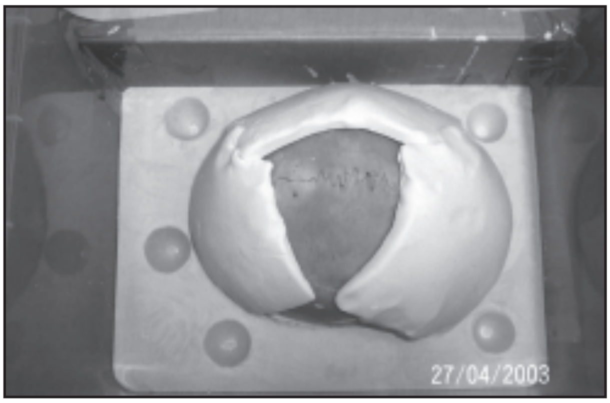

Fig.8: *Modelling clay being overlaid to provide space for silicone impression of outer surface of the calotte*

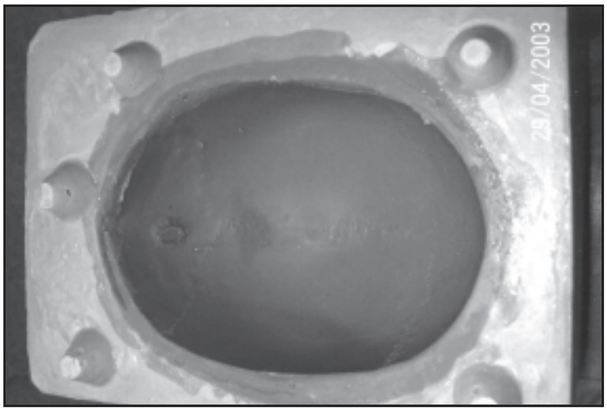

Fig.9: *Casting complete after separation of stone moulds*

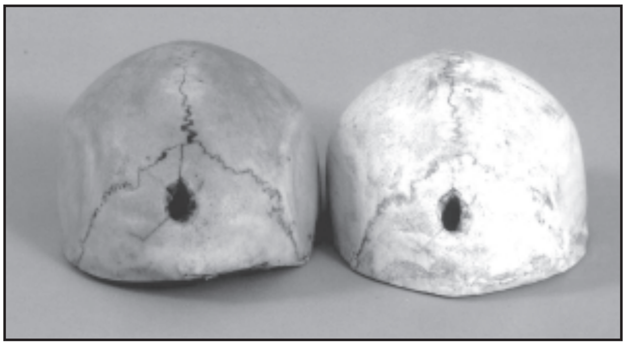

Fig. 10*: Compression of actual calotte with casting, right*

An impression of the inner surface of the skull was produced by first constructing a plaster plug as a space maintainer. The plug was then held in position while room temperature vulcanising silicone* was poured and allowed to cure (Fig.5). Once this inner replication of the skull was made, four dowel rods with plastic tubings were secured to the base of the calotte. The dowel rods would eventually be removed and the tubings would become pouring vents for the casting material (Fig.6). A plastic container was used to hold dental stone poured to the level of the base of the specimen (Fig.7). This held the plug in position and provided one half of the casting mould.

Next we made an impression of the outer surface of the skull. A 10mm layer of modelling clay was laid over the skull, to provide space for the silicone (Fig.8). A separator was applied to the first stone pour, over the modelling clay, and a second stone pour cast. When set the mould was separated, the modelling clay removed and separator applied to both moulds (Fig. 9). The moulds were then reassembled and silicone was poured and allowed to cure. The moulds were separated and the skull fragment removed. The dowel rods were also removed, leaving the plastic tubes *in situ*. After the moulds were reassembled, the casting material was poured into the mould. Once cured, the two halves of the mould were separated and the cast divested, vents and flash removed and the replica finished (Fig. 10). This procedure allowed a number of casts to be produced from the same mould.

---

* *®Ultrasil, Barnes, Bankstown NSW Australia*

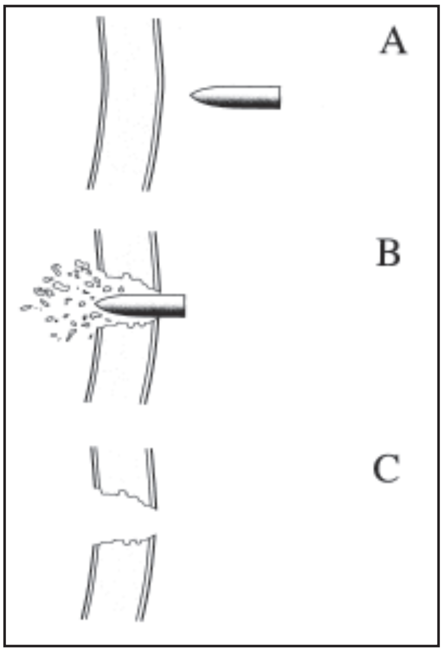

Fig. 11: *Bullet perforating cranial bone leaving a sharp, punched out entrance and bevelled exit wound*

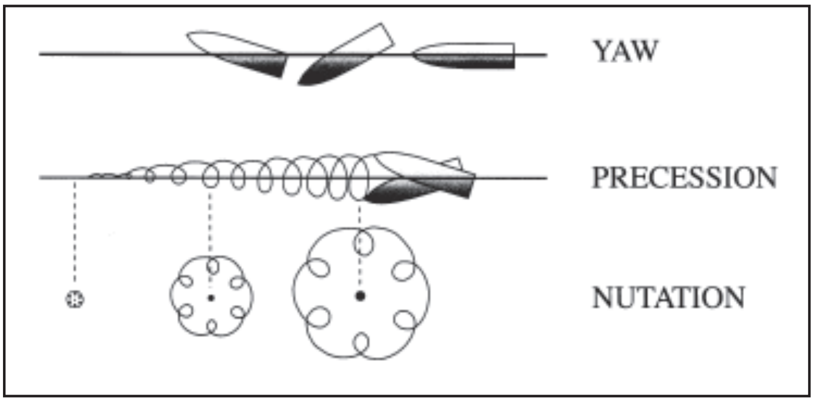

Fig. 12: *Complex three dimensional movements of a projectile in flight (after Bartlett, 2003 [2])*

DISCUSSION

When a projectile perforates bone, it creates a bevel in the direction in which it is travelling[3] (Fig.11). The degree of damage is dependent on the amount of kinetic energy lost by the projectile as it hits the bone.[5] Factors that influence the kinetic energy include the mass and calibre of the bullet as well as deviations from the flight path[6]. Briefly, the inertia of a projectile acts on its centre of mass while retarding forces act in front of the centre of mass, in the nose of the bullet. This will result in a slight deviation along the long axis of the projectile, known as yaw[7] (Fig.12). Because non-spinning bullets are unstable, gyroscopic stability has to be achieved by barrel rifling.[8] Spin, together with yaw, results in a movement called precession which, once the projectile leaves the barrel compounds into a complex motion in a rosette pattern, called nutation[6]. Both precession and nutation increase after the bullet strikes the bone and increases the wound capacity of the projectile.

Differentiation of entrance from exit wounds in bone is possible with examination of the specimen concerned. The entrance wound is cone-shaped and the exit wound beveled.[3] We present here an easy and accurate method by which such wounds may be replicated for the use of evidence or in the teaching of forensic science.

ACKNOWLEDGEMENTS

The authors thank Dennis Beale for making available the two specimens in his care.

REFERENCES

1. Barach E, Tomlanovich M, Nowak R. Ballistics, a pathophysiological examination of the wounding mechanisms of firearms. J Trauma 1986;26:225-235.
2. Bartlett CS. Clinical update: Gunshot wound ballistics. Clin Orthop Related Res 2003;408:28-57.
3. Di Maio VJM. Gunshot wounds. CRC Press: Boca Paton, Florida. 1993.
4. Coe JI. External beveling of entrance wounds by handguns. Am J Foren Med Path 1983;3:215-219.
5. Amato JJ, Billy LJ, Lawson NS, Rich NM. High velocity missile injury. Am J Surg 1974;127:454-459.
6. Adams DB. Wound ballistics. Mil Med 1982;147:831-835.
7. Hopkinson DAW, Marshall TK. Firearm injuries. Br J Surg 1967;53:344-353.
8. Hennesey MJ, Banks HH, Leach RB, Quigley TB. Extremity gunshot wound and gunshot fracture in civilian practice. Clin Orthop 1976;114:296-303.

Address for correspondence:
Professor J.A. Kieser
Department of Oral Sciences
Faculty of Dentistry
University of Otago
Dunedin, NEW ZEALAND
Telephone +64 3 479 7083
Email: jules.kieser@stonebow.otago.ac.nz

REPORTING CHILD ABUSE IN BELGIUM

K. Swaelen, G. Willems

Department of Forensic Odontology, Katholieke Universiteit Leuven, Belgium

ABSTRACT

Belgian society has become increasingly aware of the problem of abuse and neglect of children. Recent changes to both Belgian Penal Law and the Code of Medicine now allows dentists to report suspected cases of abuse to provincial trust centres or official authorities, bypassing issues of professional confidentiality. Data on different kinds of child abuse and neglect are presented for the Dutch and French-speaking parts of Belgium for 2001-2002. An increase in notified cases for both regions is noted, along with apparent differences in the type of abuse reported.

(J Forensic Odontostomatol 2004;22:13-7)

Keywords: Forensic Odontology, child abuse

INTRODUCTION

Over the last decade Belgian society has become increasingly aware of the problem of abuse and neglect of children. Several court cases, and the ensuing media coverage, has brought the discussion to the public forum. Questions have been raised about how responsibility in such cases should be apportioned. Should the close family, neighbours, school teachers, family doctors and dentists share some responsibility? In this context, dentists must be aware of the problem of child abuse, be able to recognize such cases and to inform the proper authorities.

The legal obligation of the medical profession in Belgium

Until recently, Belgian physicians were not legally obliged to report an abused or neglected child. The Code of Medicine now contains Article 61, § 1 and 2, in which physicians are able to inform a confidential team or eventually, when necessary, official authorities. This text is as follows: *"Whenever a physician is of the opinion that a minor is being maltreated, undernourished or insufficiently cared for, he is obliged to inform the parents, the tutor or the judicial authorities. When the physician observes an arbitrary deprivation of personal freedom, he is obliged to inform the judicial authorities. In all these cases the physician acts in the first place to protect the victim."*[1] Nevertheless, the Code of Medicine is not legally binding.

A recently published law has also introduced some modifications to penal law in order to strengthen the protection of minors. Article 458bis of Belgian Penal law allows individuals (such as dentists) who are normally held to a legally binding obligation of confidentiality to put aside, under certain conditions, their duty of discretion in cases of either maltreatment or sexual offences towards minors. This article states textually: *"Anyone who, in virtue of his condition or his profession, is privy to secrets, and in this way obtains knowledge about an offence (as defined in articles 372 to 377, 392 to 394, 396 to 405ter, 409,423,425 or 426), committed on a minor, has the possibility, without affecting the obligations imposed on him by art. 422bis, to report the offence to the Public Prosecutor, provided that he has either examined the victim or has been taken into his trust, that there exists a serious and immediate threat to the mental or physical integrity of the person concerned, and that he is not in a position to protect this integrity either alone or with the help of others."* [Article 458bis Belgian Penal Code (Law regarding penal protection of minors) inserted by the Act of November 28th 2000 and published in Belgisch Staatsblad March 17th, 2001].

The moral and legal obligation of the dentist to inform the proper authorities about his suspicion or opinion

Under American law, which differs in many aspects from that of most European countries, dentists are obliged to report all cases of suspected child abuse. The Code of Professional Conduct of the American Dental Association expressed this as follows: "*Dentists shall be obliged to become familiar with the perioral signs of child abuse and to report suspected cases to the proper authorities consistent with state law.*"[2]

In Belgium, the situation is different. Dentists are legally bound by professional confidentiality. Dentists who have knowledge of confidential information are not allowed to reveal this information to third parties, except in two cases where the breach is not punishable: firstly, legal obligation or subpoena by law and secondly, at the request of a parliamentary committee of inquiry. This may lead to an apparently contradictory situation: for instance, certain infectious diseases must be reported in the framework of national health statistics.[3] In Belgium there is no legal obligation to report a crime where a patient is either the victim or the perpetrator.

If a dentist suspects that a patient is the perpetrator of a crime then the legal system accepts that the dentist, in the community interest, should report the perpetrator to the police.[3]

When a minor is the victim of a crime it is also accepted in practice that the professional privacy codes may be violated. In this case the duty to assist a person in great danger has priority over confidentiality. The dentist may inform a provincial trust centre, which specialises in sheltering children who are the victims of child abuse.[1] In these cases, the trust centre in turn may alert the Office of the Public Prosecutor.

Detection of child maltreatment

Maltreatment of children includes physical, sexual or emotional abuse as well as child neglect. Physical abuse can best be defined as any non-accidental injury or trauma to the body of a child inflicted by a parent, guardian or sibling. It can either be the result of an occasional trauma or of a continuous behaviour pattern. Examples can include whipping, biting, burning, scalding and severe shaking.

Sexual abuse describes sexual activity with, or exploitation of, a minor. According to a modification of Belgian penal law of 1989, the legal definition of 'rape' is '*any act of sexual penetration, in any form or by any means, perpetrated on a person who does not consent to it*.' [Article 375-376 Belgian Penal Code (Law regarding penal protection of minors) modified by the Act of November 28th 2000 and published in Belgisch Staatsblad March 17th, 2001]. Examples can include intercourse (anal, vaginal or oral), incest, touching a child in the genital area, buttocks or breast area for a sexual purpose, inviting a child to touch for a sexual purpose or the use of a child for pornography or prostitution.

Emotional abuse is a pattern of behaviour consisting of unreasonable demands, constant belittling or criticising, and withholding of love, affection and guidance, so that it retards the development and self-esteem of the child.

Child neglect embraces a variety of failures to provide the basic needs of the child: to let it endure pain and suffering, to withhold the child the proper education, or basic medical or dental care. Neglect can be physical, educational or emotional. A severe form of maltreatment in infants is called "failure to thrive". This condition is identifiable by marked retardation or cessation of growth during the first 3 years of their life.

It is obvious that all cases of child abuse should be detected as soon as possible. Abuse of any kind disturbs the normal development of the child, and destroys its *'basic trust':* often, abused children develop a post-traumatic stress syndrome.[4]

Four diagnostic criteria help to identify this syndrome:
1. The child had lived through an experience that does not belong to the pattern of usual human experience.
2. The child relives the traumatic experience, e.g. hears anew certain sounds, or recognises the odour of the perpetrator.
3. Persistent avoidance of any stimulus that refers to the trauma, general dulling of the child's reactivity, or a diminished involvement in the outside world.
4. An increased level of irritability, e.g. sleep disorders, acute concentration troubles, partial amnesia, and distorted memories.

According to a study covering a five-year period, Becker et al.[5] found head and/or facial trauma in 65% of 260 documented cases of child abuse. These regions are often the easiest targets of abuse. The younger the children are, the more likely they are to be the victims of abuse (boys are abused more than girls by a ratio of 6 to 4).[6] Other risk factors leading to abuse are: premature birth, children with a social, physical, mental, emotional or intellectual handicap.[7] The parents also may have characteristics which increase the likelihood of abuse of the child, for example, parents who have been beaten or molested themselves, parents with a low self-esteem, parents who suffer a great deal of stress. Culture and religion may also play a role.

Dental health professionals have to be alert to a variety of physical and behavioural indicators to identify child abuse. Firstly they need to be made aware of the existence of child abuse, and of the fact that it may happen to one of their patients. The indicators that may be noticeable to the dental profession include trauma to the teeth and injuries to the mouth, lips, tongue or cheeks that are not consistent with an accident.[8] Adult bite marks may also indicate abuse. Lesions, irritation, swelling or bruising around the mouth, bruising of the hard palate, palatal petechiae, frequent sore throat, acid breakdown of enamel (sperm kept in the mouth over extended periods of time can result in cervical enamel erosion and buccal decay) and poor oral hygiene can indicate sexual abuse.[8] Behavioural indicators visible at the dentist's consultation can include fear of being touched around the mouth area. Neglect can be noticed by unattended tooth decay, gum disease and poor overall oral hygiene.[8] Table 1 gives an overview of head and face injuries for which the dentist should be alert.[9]

Table 1: Overview of possible head and race injuries from Senn et al., 2001

The Head	
Skull injuries	
Bald spots (pulling of the hair)	
Bruises behind ears (battle's sign)	
The Face	
Eyes	Retinal haemorrhage
	Blackened eyes (raccoon eyes)
Nose	Fractures
	Displacement
Lips	Bruises
	Lacerations
	Angular abrasions (gag marks)
Intraoral	Frenum tears (forced spoons)
	Palatal bruising (forced fellatio)
	Residual tooth roots
Maxilla/mandible	
	Fractures or improperly healed fractures
	Malocclusion from previous fractures
Teeth	Fractured, mobile, avulsed, or discoloured teeth in the absence of reasonable explanations
	Untreated rampant caries
	Untreated infections or bleedings

*Burns, patterned injuries caused by an object, such as a belt, and adult bite marks can be added to this list.

Whenever suspicions of child abuse arise, a routine protocol should be followed which includes questions about patient history and how the accident occurred, and all relevant information should be documented with radiographs, photographs and impressions when necessary.[8]

Reported cases in Belgium

In Flanders, the Dutch-speaking region of Belgium, which constitutes the Northern part of the country, for the years 2001 and 2002, 7112 and 8252 actual cases of maltreatment, neglect or abuse of minors were reported. However, this picture is incomplete since the various authorities that register the occurrences fail to centralise their data.

***Table 2:** Number of cases of child maltreatment reported in Belgium [10-11]*

	2001		2002	
	Flanders	**Wallonia**	**Flanders**	**Wallonia**
Number of reports	5151	3417	6037	3434
Number of involved children	7112	n.a.	8252	n.a.

***Table 3:** Breakdown of reported occurrences by category[10-11]*

	2001				2002			
	Flanders		**Wallonia**		**Flanders**		**Wallonia**	
		%		%		%		%
Physical abuse and neglect	1987	27.9	563	16.4	2424	29.4	570	16.6
Sexual abuse	1764	24.8	1195	35.0	1899	23.0	1059	38.8
Emotional abuse and neglect	1298	17.3	145	4.2	1458	17.7	253	7.4
Risk situation abuse and neglect	1142	16.1	856	25.0	1283	15.5	825	24.0
Other problem cases	991	13.9	658	19.4	1188	14.4	727	21.2
Total	7112	100.0	3417	100.0	8285	100.0	3434	100.0

Table 4: *Age distribution of the children (in %)*[10-11]

Years	2001		2002	
	Flanders	Wallonia	Flanders	Wallonia
Unborn	0.1	1.4	0.2	0.0
0 – 3	13.3	13.7	14.5	14.9
3 – 6	19.5	18.9	19.5	21.4
6 – 9	19.6	19.5	18.6	20.3
9 – 12	17.7	17.8	17.0	17.2
12 – 15	15.4	18.4	15.9	15.0
15 – 18	14.3	10.3	13.8	9.5
Unknown	0.2	0.0	0.5	1.7
	100.0	100.0	100.0	100.0

Table 5: *Reporting instances, by category (in %)*[10-11]

	2001		2002	
	Flanders	Wallonia	Flanders	Wallonia
Child's immediate environment	45.4	47.0	47.1	49.8
Professional reporting (*)	51.8	51.2	50.1	48.6
Others	2.8	1.8	2.8	1.6
	100.0	100.0	100.0	100.0

(*) Such as: care providers, justicial authorities, school and pre-school, social workers

Data could also be obtained for Wallonia, the Southern or French-speaking part of Belgium. Cases increased from 3417 in 2001 to 3434 in 2002, with the caveat that the number of reporting centres increased from 13 in the year 2001 to 14 in 2002. Although it is doubtful that a significant comparison can be made, we present the aggregate data nonetheless. (Table 2)

There appears to be a considerable increase in the number of reported cases especially in Flanders. It is possible that this reflects not so much an actual increase as a heightened awareness about child maltreatment, as well as an improvement in the collection mechanisms of statistical data. The Belgian Government has certainly contributed to this through a publicity campaign promoting the role of 'trust centres'.

Table 3 presents a breakdown of child abuse cases in their various forms. There appears to be a significant and persistent difference in the risk profile for both regions. This may be due either to a different interpretation of the statistical categories used, or to significant cultural differences. Either way, the fact that differences of this magnitude exist should warrant a thorough analysis.

The age distribution of the children reported in the previous tables is shown in Table 4. It is clear that the majority of reports concern children between the ages of 3 and 9. This is true in both Wallonia and Flanders. But it is also clear that child maltreatment occurs in all categories, so that no age class should be neglected.

Table 5 presents a breakdown of the reporting instances by category. From this table we conclude that the proportion of reports has slightly changed in both Flanders and Wallonia and that there is a marked increase of reports from the child's immediate environment. Therefore the importance of care providers from the health or social sectors is striking. It is clear that a major responsibility may be reserved for dentists, in that they should accurately report such cases to a trust centre.

Belgium still has a long way to go as far as collecting and analysing statistical data is concerned: the data collected by both the Flemish and Walloon regions are not mutually comparable, and thus are of little use to support a national policy to combat child abuse. No breakdown is available concerning the occurrences of physical injuries to the head and neck areas, which should be of particular interest to dentists.

CONCLUSION

Globally we should not deny that child abuse and neglect occur in our society, and as dentists we are in a position to detect the signs of abuse. It is important, however, to follow the right procedures, and to handle the eventual evidence in a responsible and thoughtful manner. This will be dictated by the legal obligations in each particular country.

Belgian Penal Law (art. 458 bis) allows dentists to bypass professional confidentiality and to report to the Office of the Public Prosecutor. Nevertheless, it is preferable at first to turn to a trust centre or to a health assistance organisation. In this way, confidentiality will in effect not be violated but shared.

REFERENCES

1. Van der Straete I, Put J. Het spanningsveld tussen beroepsgeheim en kindermishandeling: wetgevende initiatieven in België en Nederland. Vlaams Tijdschrift voor Gezondheidsrecht 2001; 70-84.

2. Lee JR. Dentistry in the war against child abuse. Dentistry, 1994;14(3):6-8.

3. Nijs M. Medisch recht. Leuven: Uitgeverij Acco, 2001:84-93.

4. Adriaenssens P, Smeyers L, Ivens C, Vanbeckevoort B. In vertrouwen genomen. Tielt: Uitgeverij Lannoo, 1998:64-65.

5. Becker DB, Needleman HL, Kotelchuck M. Child abuse and dentistry; orofacial trauma and its recognition by dentists. J Am Dent Assoc 1978;97:24-28.

6. Rupp RP. The dentist's role in reporting suspected child abuse and neglect. Gen Dent 2000;48(3):340-2.

7. Kenney J, Spencer D. Child abuse and neglect. In: Bowers MB, Bell G. Manual of Forensic Odontology, 3d edn. American Society of Forensic Odontology, 1997:191-199.

8. Sibbald P, Friedman CS. Child abuse: Implications for the dental health professional. J Can Dent Assoc 1993;59:909-912.

9. Senn D, McDowell J, Alder M. Dentistry's role in the recognition and reporting of domestic violence, abuse and neglect. Dent Clin North Am 2001;45(2):343-63.

10. Annual Reports 2001 and 2002. Brussels: Kind en Gezin.

11. Annual Reports 2001 and 2002. Brussels: Office National de l'Enfance

Address for correspondence:
Prof. Dr. Guy Willems
Katholieke Universiteit Leuven
Faculty of Medicine
School of Dentistry, Oral Pathology and Maxillo-Facial Surgery
Department of Forensic Odontology
Kapucijnenvoer 7
B-3000 Leuven, Belgium
Phone: + 32 16 33.24.59
Fax: + 32 16 33.24.35
Email: Guy.Willems@med.kuleuven.ac.be