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

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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.

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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.

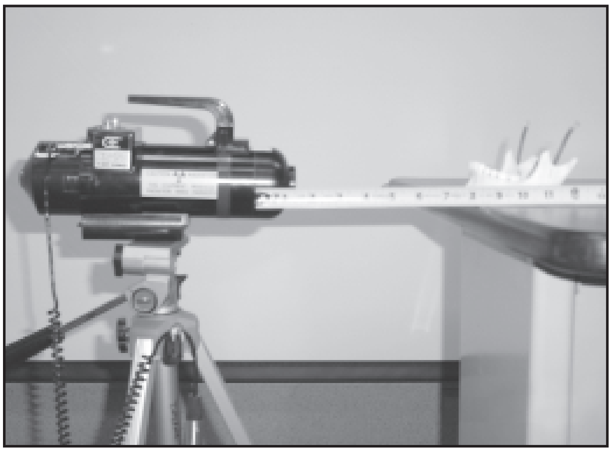

***Fig.1:** XR-150™ portable x-ray unit mounted on a tripod*

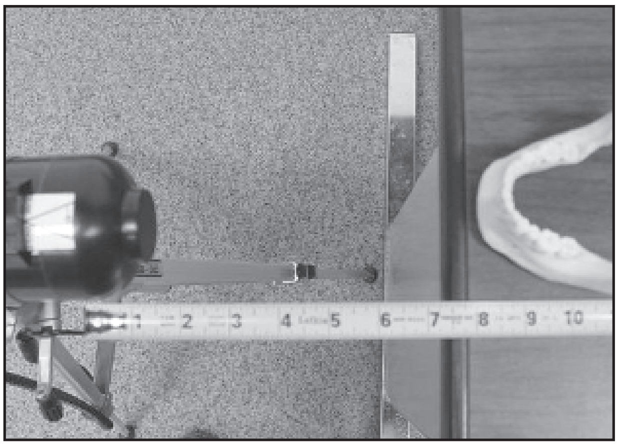

***Fig.2:** Target to object distance of 20 cm (8 inch)*

**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.

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).

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 1: *Evaluators (N=5)*

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

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

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.

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