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Modifying Dental X-ray Production using a Magnetic Field

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ABSTRACT

The x-ray output of a handheld dental x-ray tube unit (Aribex Nomad unit, KaVo Kerr) was measured in the presence of fixed magnetic fields of different strengths and orientations. X-ray photon output was increased (by 1.7%) when the magnetic field was in one orientation, when compared with identical measurements without a magnetic field.

Keywords: Magnetic Field; Dental X-Ray; Dental Radiology

Introduction

Traditionally, x-ray photon beams have been modified by changing the x-ray production parameters (primarily tube current, voltage and exposure time), or with physical filtration and collimation techniques.

The purpose of this preliminary research was to extend previous research that explored the possibility of using external magnetic fields to alter the output of an x-ray production tube [1], with the goal of making dental x-ray tubes more efficient.

Materials and Methods

Using a Nomad handheld dental x-ray tube unit and an RTI piranha dosimeter, the tube output exposure was recorded in the absence of an external magnetic field (magnetic field - None). The Nomad unit's tube voltage, current and exposure time were set to 60kV, 2.5mA and 0.3 secs for all the measured exposures. The position and orientation of the x-ray tube within the Nomad unit was determined from the unit's focal spot markings and the manufacturer's diagrams (Figure 1). Two neodymium cube magnets [2], with approximately 180 lbs of pull strength along the positive-negative pole axis (12,900-13,200 Gauss ratings at their center), were used to generate the magnetic field. The magnets' dimensions measured 25.4mm x 25.4mm x 38.1mm. When two magnets were used, they were aligned directly opposite from one another and centered on the x-ray tube at the external location "crosses" on the nomad unit. Magnets were thus positioned at either side of the focal spot of the x-ray tube, such that the magnetic field lines were oriented perpendicular to the anode-cathode axis. When magnets were removed from the Nomad unit, they were placed at least two meters away so that measurements of exposure output could be recorded without externally applied magnetic fields. In each of the following magnet orientations (including removal of the magnets/no magnetic field), three exposures and x-ray output measurements were made.

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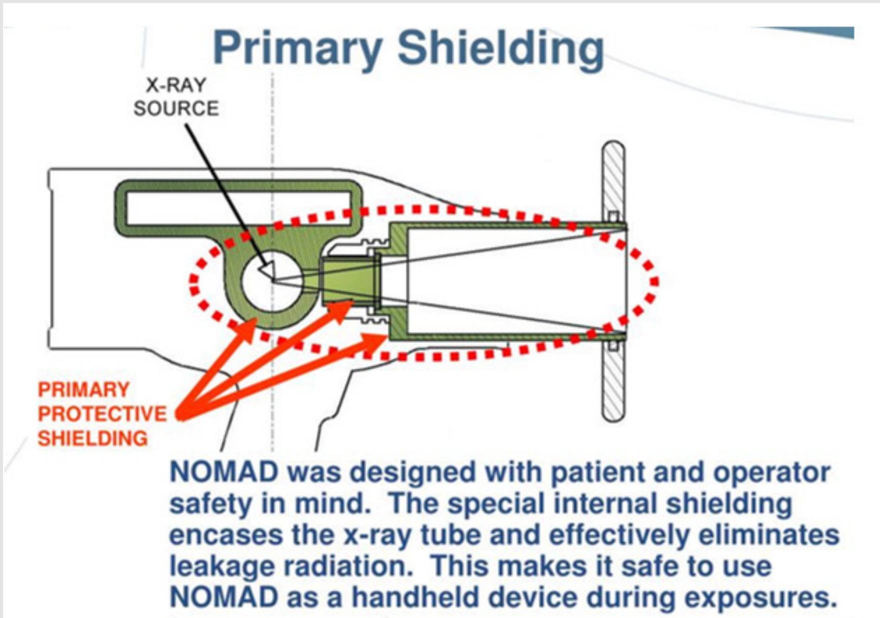

Figure 1: A sagittal or profile view of the internal layout of the Aribex Nomad unit (KAVO). The internal position of the x-ray tube is shown.

When the poles were aligned with one other and oriented with both of the "north" poles directed towards the west wall of the room and both of the "south" poles towards the east wall of the room, this was labelled as magnetic field B_{LR}. When the poles were reversed in relationship with the "north" poles facing the east wall and the "south" poles facing the west wall, this was labelled as magnetic field B_{RL}. It was determined that the x-ray tube within the Nomad unit is oriented in the same axis as B_{LR}/B_{RL} (Figures 1 & 2). When the poles were oriented with both of the "north" poles directed towards the room ceiling and both of the "south" poles towards the room floor, this was labelled as magnetic field B_{AP}. When the poles were reversed in relationship with the "north" poles directed towards the floor and the "south" poles directed towards the ceiling, this was labelled as magnetic field B_{PA}. The distance between the focal spot markings on the exterior of the nomad unit (and therefore the distance of separation for the magnets in the B_{LR} and B_{RL} orientations) was 133mm. The distance between the upper and lower surfaces of the nomad (and therefore the distance of separation of the magnets in the B_{AP} and B_{PA} orientations) was 108mm.

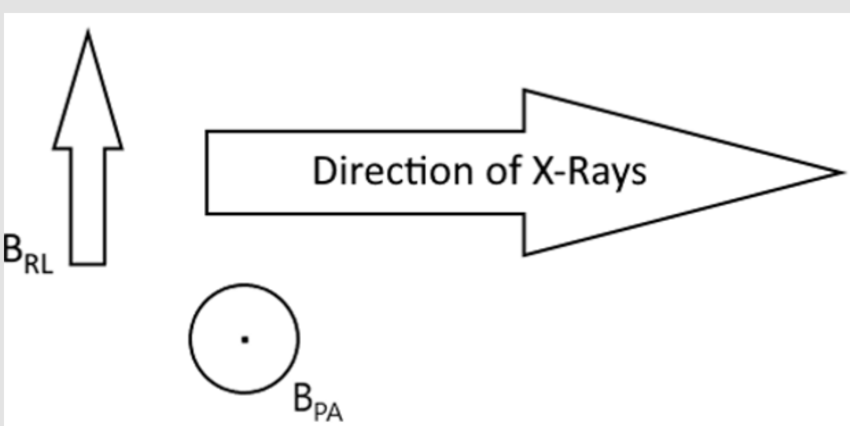

Figure 2: An overhead or plan view of the orientation of the external magnetic fields BPA and BRL in relation to the direction of the main x-ray beam.

The difference in the distance of separation for the magnets in the B_{LR}/B_{RL} versus the B_{AP}/B_{PA} orientations was 25mm (18.79% of 133mm). According to Coulomb's Law, the B_{LR}/B_{RL} magnet orientation will result in a magnetic force which is $(108/133)^2 = 0.659$ (66%) of the magnetic force generated by the B_{AP}/B_{PA} orientation (Tables 1 & 2).

Table 1: Various tube voltage and exposure readings for the various orientations and absence of magnetic fields.

Magnetic Field	Tube Voltage (kV)	Exposure Time (ms)	Exposure (mGy)	Exposure rate (mGy/s)
B_{LR}	60.2096	304.6350	0.2102	0.6615
	60.2601	305.1131	0.2097	0.6609
	60.1083	305.6149	0.2102	0.6605
None	60.0138	305.6149	0.2099	0.6596
	60.0460	305.6438	0.2099	0.6617
	60.1771	305.1275	0.2100	0.6622
B_{LR} - Repeat	60.2237	305.1373	0.2109	0.6669
	60.2749	305.6391	0.2115	0.6656
	60.0935	305.0949	0.2110	0.6407
B_{RL}	60.1932	305.1229	0.2114	0.6654
	60.1766	305.1466	0.2108	0.6645
	60.1100	305.6247	0.2113	0.6652
B_L (single magnet)	60.0915	305.1234	0.2098	0.6626
	60.1900	305.1182	0.2104	0.6623
	60.1098	305.1132	0.2099	0.6639
B_{AP}	59.3848	305.0996	0.2076	0.6382
	59.3364	304.6113	0.2071	0.6548
	59.4712	305.0996	0.2079	0.6313
None	59.7141	305.1275	0.2095	0.6606
	59.7932	305.1182	0.2101	0.6613
	59.8066	305.1136	0.2100	0.6599
B_{AP} - Repeat	59.4383	305.1182	0.2078	0.6542
	59.4332	305.1326	0.2079	0.6391
	59.3410	305.1182	0.2078	0.6560
B_{PA}	59.8377	305.6200	0.2134	0.6480
	59.9063	305.1094	0.2133	0.6726
	59.6173	305.1132	0.2129	0.6732
None	59.6287	304.5931	0.2093	0.6356
	59.6545	305.6149	0.2094	0.6600
	59.6528	305.1140	0.2090	0.6589

Table 2: Mean values (and standard deviations in parentheses) for the data in Table 1.

Magnetic Field	Number of Measurements	Tube Voltage (kV)	Exposure Time (ms)	Exposure (mGy) ± 0.2%	Exposure rate (mGy/s)
None	9	59.8 (± 0.2)	305.2 (±0.3)	0.2097 (±0.0004)	0.658 (±0.008)
B_{LR}	6	60.19 (± 0.08)	305.2 (±0.4)	0.2105 (±0.0007)	0.659 (± 0.009)
B_{AP}	6	59.4 (±0.06)	305.0 (±0.2)	0.2077 (±0.0003)	0.646 (±0.010)
B_L	3	60.1 (±0.05)	305.1 (±0.2)	0.2101 (±0.0003)	0.663 (±0.001)
B_{RL}	3	60.16 (±0.04)	305.3 (±0.3)	0.2112 (±0.0003)	0.665 (±0.001)
B_{PA}	3	59.79 (±0.15)	305.3 (±0.29)	0.2132 (±0.0003)	0.665 (±0.014)

Results

The mean total exposure for the B_{PA} orientation was 0.2132mGy, with a standard deviation of +/-0.0003. The mean exposure without a magnetic field (None) was 0.2097mGy, with a standard deviation of +/-0.0004. This represents a 1.7% difference in mean exposure values, while the measurement error was consistently < 0.2%. The difference in mean exposure rate values was 1.06% between B_{PA} (0.665mGy/s) and no magnetic field (0.658mGy/s). The difference in mean exposure rate values was 1.06% between B_{RL} (0.665mGy/s) and no magnetic field (0.658mGy/s). The difference in mean exposure rate values was 2.9% between B_{AP} (0.646mGy/s), and B_{PA} (0.665mGy/s). There was no significant change in the dosimeter readings between orientations when the magnets were positioned in the B_{LR} orientation.

Discussion

Both the mean total exposure and exposure rates were increased when compared to no magnetic field when the magnets were placed in the B_{PA} orientation. However, the mean exposure rate increase was within the margin of error. The mean total exposure and exposure rates were also increased when compared to no magnetic field when the magnets were placed in the B_{RL} orientation. Again, the mean exposure rate was within the margin of error. The increase in the mean total exposure in the B_{PA} orientation was much greater than the increase in the relatively perpendicular B_{RL} orientation. Additionally, when magnets were placed in the orientation B_{AP}, so that the North-South pole axis and thus the magnetic field, was at 90 degrees relative to the focal spot markings, there was a small but measurable decrease in the exposure readings from the dosimeter. The variations seen between exposure measurements made in the B_{PA}/B_{AP} orientation of the magnetic field, versus exposure measurements in the B_{LR}/B_{RL} orientation, may in part be due to changes in the magnetic field strength caused by variations in the distance between the magnets and the x-ray tube.

However, the variations in exposure readings observed between measurements in the B_{PA} versus the B_{AP} magnet orientations, and between the B_{RL} and B_{LR} orientations cannot be explained by variations in the magnetic field strength caused by variations in the distance of the magnets from the x-ray tube. It is hypothesized that these observed variations in x-ray tube output are due to the varied direction of the magnetic field lines between the bar magnets for the changed orientations. It has been previously hypothesized that the position and orientation of external magnets can affect the electron flow through the x-ray tube by increasing or decreasing the number of electrons hitting the tungsten target through beam focusing and deflection, respectively.

Conclusion

In conclusion, the use of relatively weak magnetic forces from bar magnets can modify the x-ray tube output in certain orientations, whilst not in others. More research is required to better describe the preliminary effects seen in this research.

Conflict of Interest

Both authors declare that they have no conflict of interest.

References

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