Fundamentals of Oral and Maxillofacial Radiology

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☢ This symbol is used throughout this textbook to inform the reader that a definition of the adjacent italicized word (e.g. *barrier*) is defined in the Glossary of Terms section located toward the end of the book. It is actually the universal symbol for radiation that must be posted in public areas when ionizing radiation is in the immediate vicinity.

Acknowledgments

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J. Sean Hubar, DMD, MS

About the Companion Website

This book is accompanied by a companion website:

www.wiley.com/go/hubar/radiology

The website includes:
- PowerPoint files of all images from the book for downloading
- Spot the difference x-ray puzzles from Section T

Part One Fundamentals

A Introduction

The objective of this textbook is to offer the reader a concise summary of the fundamentals and principles of dental radiology. In addition, brief synopses are included of the more common osseous pathologic lesions and dental anomalies. This book is intended to be a handy resource for the student, the dental auxiliary and the practicing clinician.

What is dental radiology?

Dental radiology is both an *art* and a *science*. An *art* is a skill acquired by experience, study or observation and a *science* is a technique that is tested through scientific method. Scientific principles of physics, chemistry, mathematics and biology are integral to dental radiology. Capturing and viewing a digital dental image requires sophisticated technology, while the operator's proper physical positioning of the intraoral receptor requires a skill that is based upon scientific principles. The art of dental radiology involves the interpretation of black and white images that often resemble ink blots. Deriving a differential diagnosis involves the application of the clinician's knowledge, cognitive skills and accumulated experience. The term "radiograph" originally applied to an x-ray image made visible on a processed piece of x-ray film. A photograph is similar to a radiograph except it is taken with a light-sensitive camera and printed on photographic paper. Today the term "radiograph" is used to describe an image whether it was acquired with x-ray film or with a digital receptor. It is more accurate to use the term "x-ray image" when viewing it on a monitor and "digital radiograph" when a hardcopy is viewed. In the future, "radiograph" should be updated to a more appropriate term.

What are x rays?

X rays are a form of energy belonging to the electromagnetic (EM) spectrum. Some of the members of the EM family include radio waves, microwave radiation, infrared radiation, visible light, ultraviolet radiation, *x-ray radiation* and gamma radiation. These examples are differentiated by their wavelength and frequency. A *wavelength* is defined as the distance between two identical points on consecutive waves (e.g. distance from one crest to the next crest) (Fig. A1). Longer wavelengths have lower frequencies and are considered to be less damaging to living tissues. Conversely, shorter wavelengths

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have higher frequencies and are considered to be more damaging to living tissues. One end of the EM spectrum includes the long wavelengths used for radio signal communications while at the short wavelength end of the spectrum is gamma radiation. The EM spectrum covers wavelengths, ranging from *nanometers* to kilometers in length (Fig. A2). Dental x rays are 0.1 to 0.001 nanometers (nm) in length. For comparison purposes, dental x rays may be the size of a single atom while some radio waves are equivalent to the height of a tall building. As with all types of EM radiation, x rays are pure energy. They do not have any mass and because they have very short wavelengths, x rays can easily penetrate and potentially damage living tissues. All forms of EM radiation must not be confused with *particulate radiation*, such as *alpha* and *beta radiation*. Particulate radiation is not discussed in this textbook.

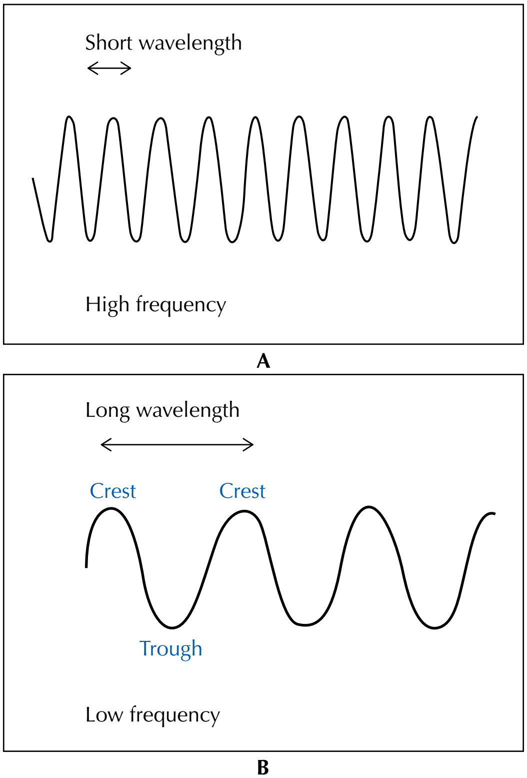

Fig. A1 Diagrams showing wave pattern of electromagnetic radiation. A. High frequency equals short wavelength. B. Low frequency equals long wavelength.

The EM spectrum is divided into the *non-ionizing* forms and the *ionizing* forms of radiation. The boundary between non-ionizing and ionizing radiation is not sharply delineated. Ionizing radiation is considered to begin with the shorter wavelength ultraviolet rays and the increasingly shorter wavelengths which include x rays and gamma rays. The longer wavelengths of ultraviolet rays and beyond which include microwaves, radio waves, etc. are all considered to be non-ionizing forms of radiation. The difference is that ionizing radiation is powerful enough to knock an *electron* out of its atomic orbit, while non-ionizing radiation is

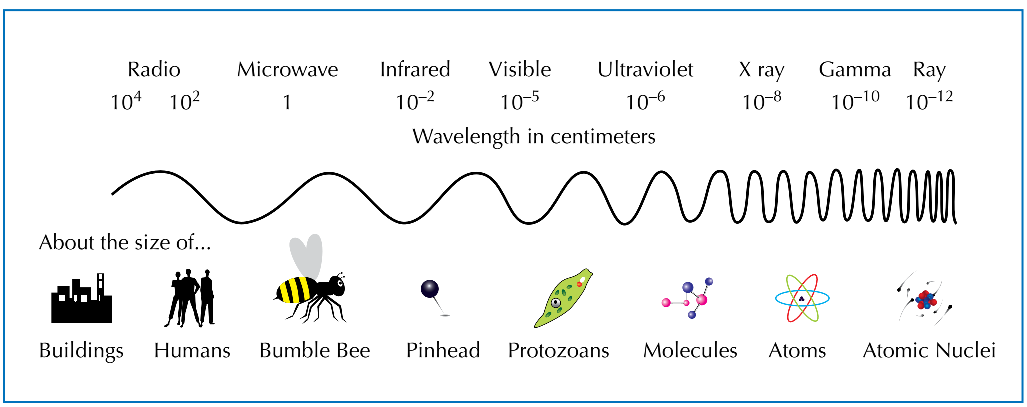

Fig. A2 Electromagnetic (EM) spectrum.

not powerful enough to remove an electron. The removal of an electron from an atom is referred to as "ionization." Exposure to ionizing radiation is recognized as being more hazardous to living tissue than non-ionizing radiation.

Note: "X ray" is actually a noun composed of two separate words and it should only be hyphenated when it is used as an adjective, e.g. *x-ray tube*. In addition, each individual unit of electromagnetic radiation is referred to as a *photon*. Consequently, the correct term for x ray is *x-ray photon*. In published literature, x-ray photons are often incorrectly referred to as "x-rays."

In lay terms, x-ray images reveal the different parts of our bodies or other matter in varying shades of black and white. Why? This is because skin, bone, teeth, fat and air absorb different quantities of radiation. Within the human body, the calcium in bones and teeth absorbs the most x rays. Tooth enamel is the most mineralized substance in the human body (over 90% mineralized). Consequently, mineralized structures such as teeth and bones appear as varying shades of white (i.e. *radiopaque*) on dental images. Fat and other soft tissues absorb less radiation, and consequently they will look darker (i.e. *radiolucent*) in comparison to bone. Air absorbs the least amount of x rays, so airways and sinuses typically look black in comparison to mineralized substances. The denser or thicker the material, the more x-ray photons are absorbed by it. This results in a more radiopaque appearance on an x-ray image. The thinner or less dense an object is, the fewer the number of x-ray photons absorbed or blocked by it. Thus more x-ray photons are able to penetrate through the object to expose the image recording receptor. This results in a more radiolucent appearance.

What's the big deal about x-ray images?

Just as the early pioneers in radiology were astonished to see the previously unknown in their first x-ray images, modern day clinicians may be astonished to see osseous and dental pathology, anatomic variations, effects of trauma, etc. on their x-ray images. Consequently, the benefits of x-ray images are immense. The combination of both clinical and x-ray images provides vital information to the dentist for preparing comprehensive dental treatment plans. The end result is a continual improvement in oral healthcare today.

B History

Discovery of x rays

On November 8, 1895, *Wilhelm Konrad Röntgen* (alternately spelled Wilhelm Conrad Roentgen), a professor of physics and the director of the Physical Institute of the Julius Maximilian University at Würzburg in Germany, while working in his laboratory discovered what we commonly call "x rays" (Fig. B1). On that day in his darkened laboratory, he noticed light emanating on a table located across the room, far from the experiment that he was conducting. Professor Röntgen was researching the effects of electrical discharge using a *Crookes–Hittorf tube*. The glowing object was a fluorescent screen used in another experiment. This perplexed him because electrons emanating from his electric discharge tube were known to only travel short distances in air. His fluorescing screen was too far away for these electrons to produce the fluorescence. In addition, his lab was completely darkened and the Crookes–Hittorf tube was completely covered with black cardboard to prevent light leakage. Light leakage otherwise could have caused the screen to fluoresce. It was obvious to Professor Röntgen that he was dealing with an unknown invisible phenomenon. Professor Röntgen called this new phenomenon "x rays." "X" because that is the universal symbol for the unknown and "ray" because it traveled in a straight line. He was a modest gentleman and did not wish to call these new rays "Röntgen rays" after himself which is standard protocol for new discoveries. Following his discovery of x rays, he was determined to learn what were the properties and characteristics of these mysterious invisible rays. He secretly tested this phenomenon for weeks and did not divulge any information about his new discovery to anyone. At first he experimented by placing objects in the path of the x rays between the tube and the fluorescent screen. Ultimately, he decided to place his own hand in front of the x-ray beam and he was amazed at what he saw on the fluorescent screen. He observed shadows of his skin and underlying bones. For the first recorded image, he asked his wife, Bertha, to place her hand on a photographic plate while he operated the experimental apparatus. Professor Röntgen was able to produce an x-ray image of her bones and soft tissue. This x-ray image, which includes the wedding ring on her finger, is recognized as the first *x-ray image* of the human body (Fig. B2).

On December 28, 1895, Professor Röntgen delivered his first of three manuscripts on x rays to the president of the Physical Medical

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Fig. B1 Wilhelm Konrad Röntgen: credited with being the first person to discover x rays.

Fig. B2 First x-ray image of the human body: Bertha Röntgen's hand.

Society of Würzburg. The first manuscript was entitled "On a New Kind of Rays, A Preliminary Communication." The unedited manuscript went to press immediately and was published in the *Annals of the Society*. Immediately afterwards, announcements were published in newspapers and in scientific journals around the world. In the United States, the announcement of Professor Röntgen's discovery was on January 7, 1896 in the *New York Herald* newspaper. The English translations of the original paper were printed in *Nature*, a London publication, on January 23, 1896 and in *Science*, a New York publication, on February 14, 1896. Professor Röntgen did not seek nor enjoy public acclaim and as a result he would make only a single presentation on the topic of x rays. This presentation was given to the Physical Medical Society of Würzburg on January 23, 1896.

The prevalence of *Ruhmkorff coils* ☢ and Crookes–Hittorf tubes in nearly every physics laboratory at the time permitted x-ray research to be conducted globally without much delay. These two ingredients were the primary components necessary for producing x rays. Consequently, prior to Professor Röntgen's discovery anyone who was studying high voltage electricity was unknowingly generating x rays. But no one prior to Professor Röntgen recognized this phenomenon, nor understood the value of it even if they did suspect something unusual. Sir William Crookes, whose collaboration produced the Crookes–Hittorf tubes, had outright complained to the manufacturer that unopened boxes of photographic plates were arriving at his lab already exposed. Sir Crookes