

In a New Light:  
Early X-Ray Technology in Dentistry, 1890-1955

by

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## ABSTRACT

A dental exam in twenty-first century America generally includes the taking of radiographs, which are x-ray images of the mouth. These images allow dentists to see structures below the gum line and within the teeth. Having a patient's radiographs on file has become a dental standard of care in many states, but x-rays were only discovered a little over 100 years ago. This research analyzes how and why the x-ray image has become a ubiquitous tool in the dental field. Primary literature written by dentists and scientists of the time shows that the x-ray was established in dentistry by the 1950s. Therefore, this thesis tracks the changes in x-ray technological developments, the spread of information and related safety concerns between 1890 and 1955. X-ray technology went from being an accidental discovery to a device commonly purchased by dentists. X-ray information started out in the form of the anecdotes of individuals and led to the formation of large professional groups. Safety concerns of only a few people later became an important facet of new devices. These three major shifts are described by looking at those who prompted the changes; they fall into the categories of people, technological artifacts and institutions. The x-ray became integrated into dentistry as a product of the work of people such as C. Edmund Kells, a proponent of dental x-rays, technological improvements including faster film speed, and the influence of institutions such as Victor X-Ray Company and the American Dental Association. These changes that resulted established a strong foundation of x-ray technology in dentistry. From there, the dental x-ray developed to its modern form.

## ACKNOWLEDGMENTS

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## Chapter 1

### INTRODUCTION

In twenty-first century America, a patient's initial visit to the dentist's office follows a fairly standardized set of steps. If the patient goes to a community health center in Seattle or to a private practice in Milwaukee, the process remains the same. The patient is first asked about her health history and is prompted to describe any oral health concerns before her mouth is examined. In many cases, the patient will then have a series of x-ray images taken of her mouth. The images help the dentist diagnose abnormalities and problems, such as root abscesses and tooth caries. Dentists rely heavily on these images, called radiographs, to gain access to the parts of the mouth that are unreachable by dental exam tools and the naked eye. Prior to the introduction of x-ray technology at the end of the nineteenth century, this last crucial step of the dental exam did not exist. The state of the inner tooth and jaws could only be inferred from what a dentist could see inside the mouth and what the patient reported. In a little over a hundred years, dental practice has changed as x-ray technology has become inextricably linked with the field of dentistry.

#### Research Goals

This thesis aims to answer the question: *how* has the x-ray become a ubiquitous tool in the twenty-first century dental field? The research identifies and analyzes people, technologies and institutions that were instrumental in the development of the x-ray device and its integration into dentistry during its first 50 years. Using general principles of Actor-Network Theory, the major actors in the dental x-ray story are categorized as

people, technological artifacts and institutions. The secondary question that this research explores is: *why* did the x-ray become a ubiquitous tool in dentistry? To answer this question, three threads of change are explored. These are the development of the x-ray technology, the spread of information and the growth of safety concerns and management. X-ray technology changed from an accidental discovery to a common device purchased by dentists. Information about x-rays started out in the form of the anecdotes of individuals and led to the formation of large professional groups. Safety concerns of only a few people later became an important facet of new devices.

Focus is placed on the first 50 years of x-ray technology because the basic technology remained the same during that time. After 1950, the technology became more varied with three-dimensional and digital x-rays in dentistry. During the early period a strong foundation of x-rays in dentistry was built, which facilitated the branching of information, technology and safety in the later part of the twentieth century, as depicted in Figure 1.



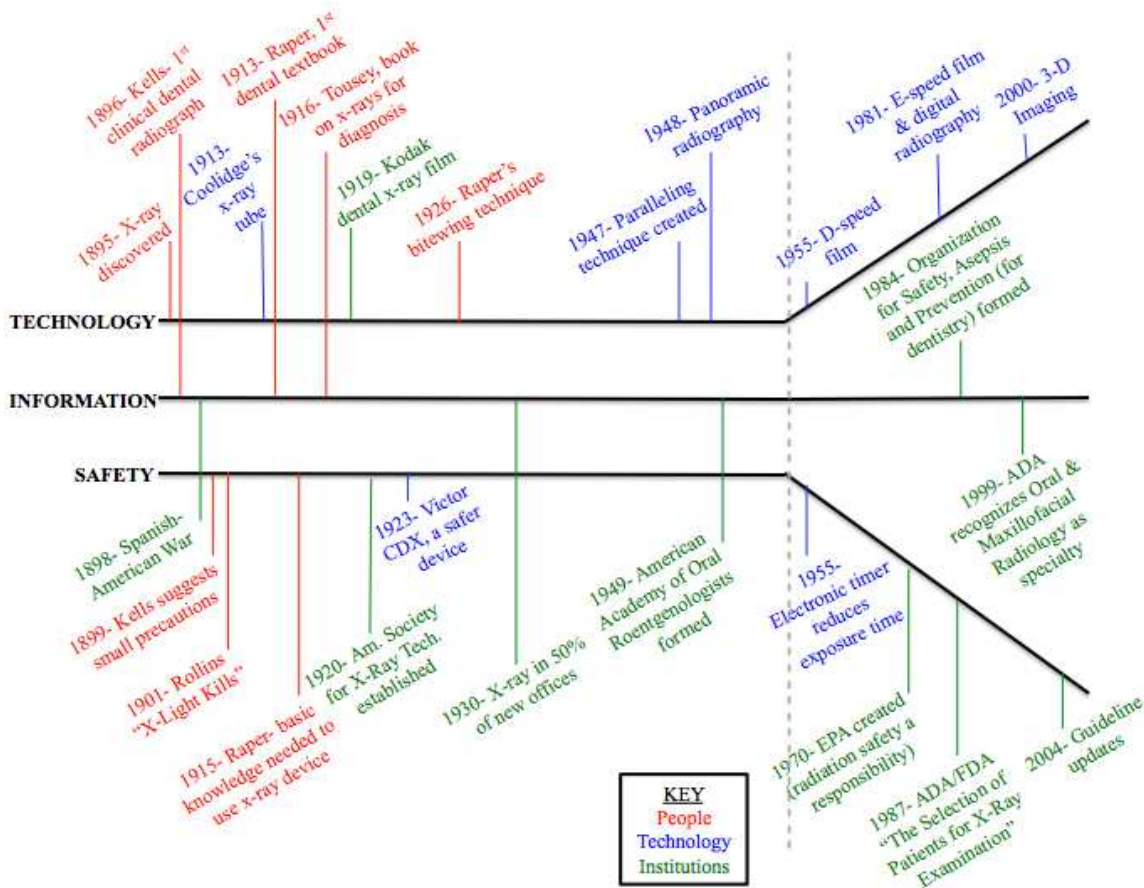


FIGURE 1: This timeline illustrates the history of dental x-ray research design. The people, technological artifacts and institution actors are analyzed by following changes in technology, information and safety concerns between 1890 and 1955. During this time, the x-ray became a ubiquitous tool in dentistry, which continued to develop after the 1950s.

Actor-Network Theory

In this thesis, Actor-Network Theory (ANT) is applied to dental x-ray technology as a way of conceptualizing its history. It is used as a tool for fleshing out questions and potential research directions. The pieces of the dental x-ray story that have been explored here—the development of the technology, the spread of information and the growth of safety concerns—illustrate the complexity of the dental x-ray network. This reinforces a

statement made by Bruno Latour, one of the developers of ANT, that networks take on a “capillary character.”<sup>1</sup>

One hallmark characteristic of ANT is that it equalizes agency—both inanimate and animate objects are seen as actors in a conceptual network. By looking at the dental x-ray story from the perspective of these various actors, which have been categorized as people, technologies and institutions, the research provides a unique holistic view of the history of dental x-ray technology.

### Research Foundations

This research is formed on the idea that x-ray technology is a ubiquitous tool in the dental field. In the United States both the regulatory and professional frameworks of dentistry support this statement. Patient selection, film selection, and radiographic equipment management are all regulated to some degree, which shows that x-ray technology is so widely used that every component must be regulated.

The United States government has also released information about how to determine who requires radiographs, another factor that illustrates the ubiquity of the dental x-ray. The Food and Drug Administration (FDA) established patient selection guidelines titled “The Selection of Patients for X-Ray Examination,” in 1987 in conjunction with the American Dental Association (ADA). These guidelines, which are periodically reviewed and updated, do not dictate a national “standard of care,

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<sup>1</sup> “On Actor Network Theory: A few clarifications,” last modified 1997, <http://www.nettime.org/Lists-Archives/nettime-l-9801/msg00019.html>. Ibid.

requirements, or regulations.”<sup>2</sup> They simply provide the dental practitioner with recommendations for determining which patients need radiographs and the frequency with which they should be taken. The guidelines are a resource for dentists to use to supplement their own expertise. For example, the ADA/FDA recommend that new patients or those with a high risk for caries have radiographs taken. Dentists, however, are encouraged to use their judgment to make the final call, after the completion of a thorough clinical exam. In conjunction with the guidelines, dental professionals are also taught to use the ALARA principle, which refers to keeping exposure to radiation “As Low As Reasonably Achievable.”<sup>3</sup> The goal is to keep radiation low and the level of patient care high.

As stated, the guidelines established by the FDA and ADA are not meant to establish a standard of care. The standard of care within the general dental field is constantly changing, but tends to be defined along the lines of “what the normal, average dentist does [and] what is taught in dental schools.”<sup>4</sup> States are responsible for setting up specific, required standards of care. The Oregon Board of Dentistry for example, has made radiographs a part of their standard of care. In order to do any procedures on a patient in Oregon, the dentist must have current radiographs. Waiving the radiograph requirement can only be done for medical reasons.

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<sup>2</sup> “The Selection of Patients for Dental Radiographic Examination,” last modified 2004.

<sup>3</sup> “ADA/FDA Guide to Patient Selection for Dental Radiographs,” last accessed January 22, 2013, <http://www.fda.gov/RadiationEmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging>. Ibid.

<sup>4</sup> Graskemper, Joseph P., “The standard of care in dentistry: Where did it come from? How has it evolved?” *The Journal of the American Dental Association* 135.10 (2004): 1449—55.

The Standard of Care in Oregon requires that current radiographs are available prior to providing treatment to a patient. If a patient without medical justification refuses to allow radiographs to be taken, even with the offer to sign a waiver, then providing treatment to that patient would violate the Standard of Care in Oregon and could be grounds for the revocation of a dentist's license.<sup>5</sup>

X-ray film and equipment guidelines are also created at a national level, which is further evidence that x-rays are prevalent in dentistry. The American National Standards Institute and the International Organization for Standardization have suggestions for film speed. Of the available films (D-speed, E-speed and F-speed) only the two fastest, E and F-speed, are recommended for dental use because they require less radiation exposure.<sup>6</sup> The National Council for Radiation Protection and Measurements (NCRP) has established guidelines for x-ray equipment, including the machine and protective gear. Although the NCRP has shown that only one percent of health care radiation exposure is dental related, states have established regulations for the use of ionizing agents, such as x-rays. There are state laws on everything from equipment to certifications.<sup>7</sup>

Not only do the regulations and guidelines from professional and governmental organizations indicate the heavy presence of x-ray technology in dentistry, but cultural artifacts do as well. Figure 2 illustrates a scene in a typical dentist's office in 1957. Prominently displayed in the background is a set of the patient's radiographs. This magazine cover shows how even in the 1950s, x-ray images were a necessary part of the

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<sup>5</sup> "Radiographs," *Oregon Board of Dentistry News* 27.1 (2012): 2.

<sup>6</sup> "The use of dental radiographs: update and recommendations," American Dental Counsel on Scientific Affairs, revised 2006. Ibid.

<sup>7</sup> "ADA/FDA Guide to Patient Selection."

dental office. The regulatory, professional and cultural examples presented illustrate the ubiquity of x-ray technology as a necessary and common tool in the dental field.

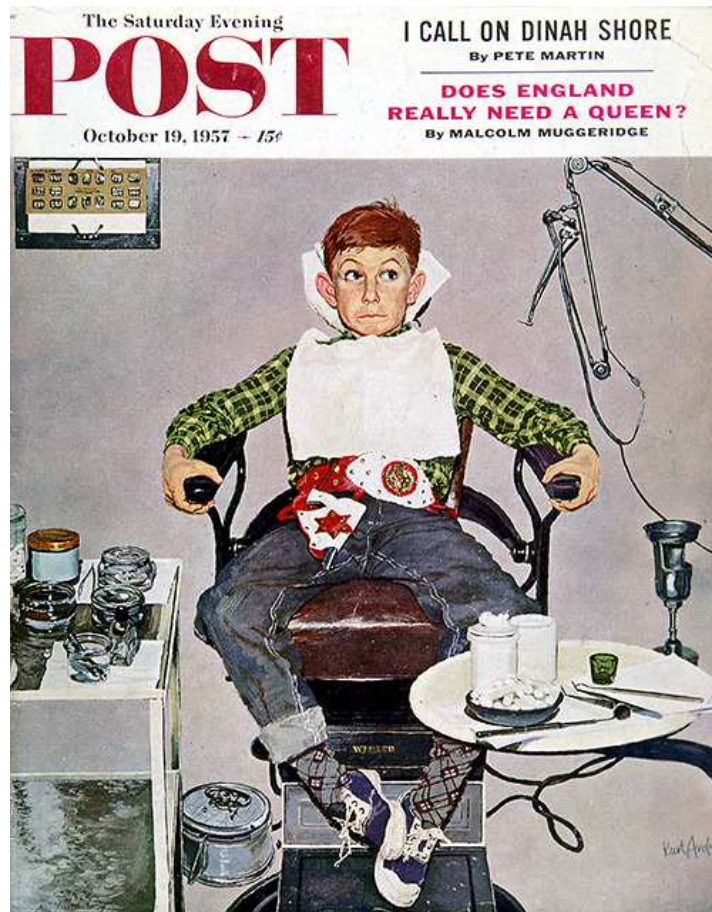


FIGURE 2: The cover art of the October 19, 1957 issue of *The Saturday Evening Post*. Artist Kurt Ard's image depicts a patient in a dentist's office in the late 1950s.<sup>8</sup>

### X-Ray Technology

X-rays are a type of electromagnetic radiation that is characterized by short wavelengths. This short length makes it possible for the rays to pass through many different materials. Radiographs, also known as roentgenograms, are the images that can be produced by exposing items to the x-rays. Figure 3 illustrates the basic design of an early x-ray apparatus, which consists of a battery, an induction coil and a glass vacuum

<sup>8</sup> Fig. 2. Kurt Ard, Cover of the Saturday Evening Post, October 19, 1957.

tube. An induction coil (static machines were sometimes used instead) amplifies voltage and is powered by a battery. Glass vacuum tubes, commonly called Crookes tubes, are oblong in shape and contain very little air. The small end of the tube houses an aluminum disc, the cathode. The larger end has a platinum wire embedded in it, which serves as the anode. The negative end of the induction coil is attached to the cathode of the tube and the positive end of the induction coil is attached to the anode. When the apparatus is powered, electrons are streamed straight across the vacuum tube. X-ray photons are then released into the environment.<sup>9</sup> These photons can easily penetrate objects. When a photographic plate or film is placed on the opposite side of an object being exposed to x-rays an image called a radiograph can be captured. The apparatus illustrated in Figure 3 is an early design. It was later improved by additions like tungsten metal to the anode, which helped make the production of x-rays more controlled.

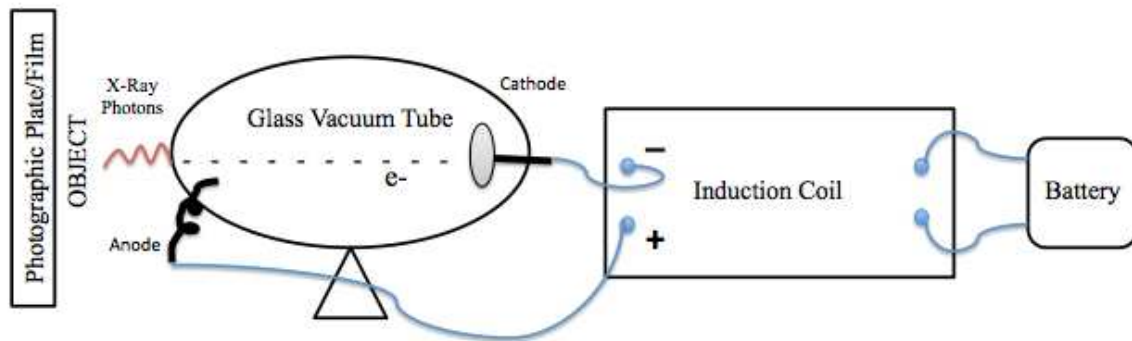


FIGURE 3: An x-ray apparatus requires an energy source (battery), an induction coil and a glass vacuum tube. This diagram has been adapted from images and descriptions by Charles Edmund Kells.<sup>9</sup>

Images are left on photographic plates and films because materials vary in their x-ray penetrability. The denser the material, the fewer rays will pass through. As shown in

<sup>9</sup> Kells, Charles E., "Roentgen rays," *The Dental Cosmos* 41 (1899): 1014—29.

Figure 4, teeth are made of several different materials. The enamel is the densest, followed by dentin and then the pulp, which contains blood vessels and nerves. This results in gradients of black and white on the exposed film.<sup>10</sup> Most body tissues have different densities, which make x-rays especially useful for medicine and dentistry. The advantages to using radiographs were recognized almost immediately. In 1896, the physician J. William White stated that x-rays were useful “(1) in diagnosis, (2) in locating [a] foreign body, (3) [and] in selecting the form of treatment.”<sup>11</sup> Radiographs are still used for the reasons listed by White in the twenty-first century.

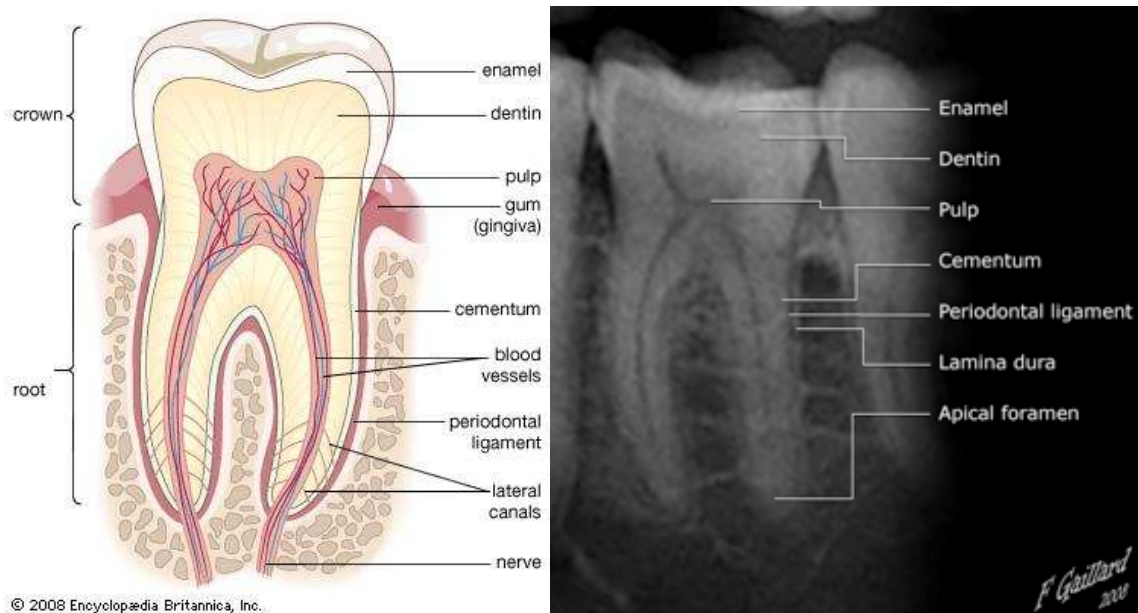


FIGURE 4: This image on the left depicts basic tooth anatomy. The crown is exposed to the inside of the mouth, while the root is embedded in the jaw.<sup>12</sup> The image on the right shows how the same tooth structures appear on a radiograph.<sup>13</sup>

<sup>10</sup> *Radiography in Modern Industry: Fourth Edition*, (Rochester: Eastman Kodak Company, 1980).

<sup>11</sup> White, J. William, “A foreign body in the esophagus detected and located by roentgen rays,” *University of Pennsylvania Medical Magazine* 8 (1896): 710—5.

<sup>12</sup> “Tooth (Anatomy),” *Encyclopedia Britannica Online*, last accessed February 2, 2013, <http://www.britannica.com/EBchecked/topic/599469/tooth>.

### X-Rays and Dentistry

Three prominent people exemplify the themes described in the “Research Goals” section: the development of the technology, the spread of x-ray information to dentists and the growth of safety concerns. Wilhelm Conrad Roentgen was the first to discover x-rays and create the apparatus. Charles Edmund Kells was instrumental in disseminating information about x-rays to dentists. William Herbert Rollins was the first to question the safety of x-rays.

The discovery of x-rays has formally been attributed to Wilhelm Conrad Roentgen. Roentgen was a German researcher who taught physics and conducted his own research on energy. While doing some late night work in his lab in the fall of 1895, he noticed a strange light near one of his Crookes tubes. Roentgen was simply replicating a popular experiment involving these tubes, which are vacuum tubes that electrons are passed through, when he observed the odd light. Knowing that he had accidentally stumbled upon something novel, he ran some tests. His first human test subject was his wife, Anna Bertha Roentgen. He found that mystery rays formed the light; he called them “x-rays.” They were able to go through objects and could leave images of the objects on photographic plates.<sup>14</sup> Roentgen made his discovery in November of 1895 and by December of that same year he had made the information public. This included the images that he had taken of his wife’s hand, which are the first x-ray images ever taken of

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<sup>13</sup> Gaillard, Frank, “Tooth anatomy,” Radiopaedia, last accessed March 1, 2013, <http://radiopaedia.org/images/847>.

<sup>14</sup> Campbell, D., “A brief history of dental radiography,” *New Zealand Dental Journal* 91 (1995): 127—33. Ibid.



a living subject. Six years after Roentgen's initial discovery, he won the Nobel Prize in Physics for his work with x-rays.<sup>14</sup>

The December 1895 announcement of the discovery of x-rays captured the interest of researchers all over the world, including the American dentist, Charles Edmund Kells. In July of 1896, Kells took the first dental x-ray showing a living person's mouth in the United States. Kells went on to have several publications and presentations promoting the use of x-ray technology in dentistry. Along with his many inventions, like the dental suction device, Kells also designed tools for taking oral radiographs, most notably a film holding device.<sup>15</sup> Throughout his career, Kells continued to be an avid supporter of the use of x-ray technology in the dental office, but also warned against the misuse of the technology. During the first half of the twentieth century, x-rays were used as evidence indicating a need for tooth extraction. Practitioners like Kells criticized this practice, which was popularized during the era of the focal infection theory.<sup>16</sup>

William Herbert Rollins is known for his work on and support of implementing safety procedures when taking radiographs. Like Kells, Rollins learned of Roentgen's discovery early on and immediately began working on the application of x-rays to dentistry. He invented a dental fluoroscope, a device similar to the x-ray machine. The fluoroscope, however, does not produce a stagnant image; it provides constant visual feedback. Rollins also experimented with electricity as a form of anesthesia.<sup>17</sup> Only a few years into his experimentation, Rollins noted burns on areas of his body that were

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<sup>15</sup> Jacobsohn, P.H. and R.J. Fedran, "Harnessing the x-ray: Coolidge's contribution," *The Journal of the American Dental Association* 126 (1995): 1365—7. Ibid.

<sup>16</sup> Jacobsohn, "Harnessing the x-ray."

<sup>17</sup> Forrai, J., "History of x-ray in dentistry," *Rev. Clin. Pesq. Odontol.* 3.3 (2007): 205—11.

frequently exposed to x-ray radiation, such as his hands. He was the first to officially link his burns to x-rays in a paper he published in 1901. He suggested that dentists and others exposed to x-rays properly protect themselves by using equipment, like glasses lined with lead.<sup>18</sup>

### Research Organization

The thesis is divided into chapters, which represent periods of development in the history of dental x-ray technology. Following this introduction, the second chapter titled, “Discovery of the X-Ray,” describes the introduction of the x-ray to the scientific and medical communities. This chapter focuses on the people and technology actors. The third chapter, “Introduction into Dentistry,” begins with William Coolidge’s creation of the high voltage vacuum tube, which made taking radiographs of human beings easier. This was a period where dentists began to recognize the potential benefits of x-rays. The fourth chapter, “Integration into Dentistry,” describes the specific tailoring of x-ray technology for dental purposes. These chapters are all subdivided by categories of actors that played large roles in that period of technological development. The categories include people, technology and institutions. The fifth chapter, “Conclusion,” gives a broad overview of this technological development and future research. The three categories of actors (people, technology and institutions) form the structure of the thesis. This facilitates the web-like conceptualization of x-ray technology. The three themes (technological development, the spread of information and the rise of safety concerns)

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<sup>18</sup> Wynbrandt, J., *The Excruciating History of Dentistry* (New York: St. Martin’s Griffin, 1998).

were identified as a result of the actor-based structure. Technology as an actor category refers to specific components or artifacts; as a theme, it is technological development or change as a whole.

## Chapter 2

### DISCOVERY OF THE X-RAY (1890-1904)

The 1895 discovery of the x-ray by Wilhelm Conrad Roentgen was rapidly introduced to the scientific and medical communities. Only months after Roentgen's lab observations, information about the new type of ray was disseminated and had made its way around the globe. This first decade of the x-ray was marked by a series of presentations, which debuted the x-ray to people such as the dentist Charles Edmund Kells and the physician William J. Morton, both strong supporters of the use of x-rays in dentistry. William Rollins, trained in both dentistry and medicine, raised health concerns about the rays. As these early supporters and critics rallied enthusiasm and exposed the potential dangers of x-rays, the technology was altered slightly to fit the professional and safety agendas of these people. As a result, technological changes during this period were strongly associated with specific people. Bonds were also created between the x-ray and institutions; companies such as Kodak and groups including the United States military began to explore the x-ray. This period in the development of x-ray technology is unique because it revolved more around the spread information than the mechanics of the technology itself. People spent this time experimenting with and adjusting the early knowledge of x-rays. Scientists developed hypotheses about how x-rays function, while dentists and doctors explored the potential applications of the device.

#### People/Technology

The advent of x-ray technology was dependent upon the earlier invention of the Crookes tube. Shown as a part of the x-ray apparatus in Figure 3 on page 8, a Crookes

tube is a glass vacuum tube, which was invented in 1879 by William Crookes. Upon electrical stimulation, electrons are sent directly from the cathode to the anode, which are located on opposite poles of the oblong tube. Many physicists experimented with the Crookes tube at the end of the nineteenth century. These experiments resulted in several accidental productions of x-rays and the eventual appreciation of their potential.

Although it was not immediately recognized, the first documented radiograph was taken on February 27 of 1890, unbeknownst to the researchers responsible for the image.<sup>19</sup>

Arthur W. Goodspeed a physics professor at the University of Pennsylvania and William Nicholson Jennings, a scientist and photographer, were experimenting with electricity when they accidentally created the image, shown in Figure 5.

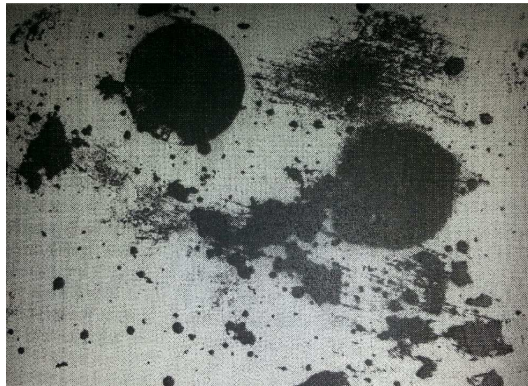


FIGURE 5: From the archives of the University of Pennsylvania, this is a copy of Goodspeed and Jennings' 1890 radiograph of two coins.<sup>20</sup>

The image was captured after Goodspeed and Jennings had completed their experiments using photographic plates. With the plates still in the room, Goodspeed showed Jennings how the Crookes tube worked. After developing the plates, they noticed the inexplicable

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<sup>19</sup> Leopold, Lynne A. *Radiology at the University of Pennsylvania, 1890-1975*, (Philadelphia: University of Pennsylvania Press, 1981).

<sup>20</sup> Walden, Thomas L., "The first radiation accident in America: a centennial account of the x-ray photograph made in 1890," *Radiology* 181.3 (1991): 635—9. Ibid.

shapes and “fogginess” of the images.<sup>21</sup> After Roentgen discovered x-rays in 1895, Goodspeed and Jennings realized that the Crookes tubes had actually been emitting rays and had thus resulted in the strange images. This early account of what is now known to be x-radiation shows how necessary the Crookes tube was for the development of x-ray technology.

In the fall of 1895, the German researcher Wilhelm Conrad Roentgen inadvertently made the discovery that would mark the start of a paradigm shift in medicine. He not only discovered x-rays, but also contributed to the technology’s development by spreading the information and exploring its applications. Roentgen taught physics at the University of Wurzburg, Germany and at the end of the nineteenth century focused his research on energy. While doing some late night work in his lab on November 8, 1895 he noticed a strange light near one of his cathode-ray (Crookes) tubes. Like Goodspeed, Roentgen was simply replicating a popular experiment involving these tubes, when he observed the odd light. This was something different than usual. Upon examination, Roentgen realized that the glow was coming from a barium-painted screen located near the tube. Even when he covered the tube with paper he could see the glow. Knowing that he had accidentally stumbled upon something novel, he ran some tests. His first human test subject was his wife, Anna Bertha Roentgen. He found that unknown rays formed the light, so he called them “x-rays.” The rays could pass through objects and even leave images of the objects on photographic plates.<sup>22</sup> Roentgen made his discovery in November of 1895 and by December of that same year he had made the

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<sup>21</sup> Walden, “The first radiation accident,” 635—9.

<sup>22</sup> Campbell, “A brief history,” 127—33.

information public. This included the images that he had taken of his wife's hand, which are the first known x-ray images of a living subject. Six years after Roentgen's initial discovery, he won the Nobel Prize in Physics for his work with x-rays.<sup>23</sup> Not only did Roentgen discover x-rays and figure out the basic apparatus components, he also effectively shared the information with the world through presentations and publications.

Roentgen presented his work to the Wurzburg Physical and Medical Society at the end of 1895 and by February of 1896, a translation of his article titled, "A New Kind of Rays" was published in the widely read journals *Nature* and *Science*. This article was very technical. In it Roentgen described the apparatus used to produce the x-ray, which he named due to its mysterious properties. To produce the x-rays, which present themselves as fluorescent light, an induction coil must be connected to a vacuum tube, such as a Crooke's tube.<sup>24</sup> Roentgen found that the x-rays could penetrate many different materials. His experiments with multiple mediums showed that the "density of the bodies is the property whose variation mainly affects their permeability."<sup>24</sup> He concluded that there are also some materials that are impermeable to the x-rays. To varying degrees, these include Copper, Silver, Lead, Gold and Platinum. In one experiment he found that "glass plates of similar thickness behave similarly; lead glass is, however, much more opaque than glass free from lead."<sup>24</sup> Proponents for x-ray protection would later expand upon Roentgen's early discovery that the lead acts as an x-ray barrier.

Roentgen found that he could create "shadow pictures," now called radiographs, by positioning an item between the x-ray apparatus and a photographic plate. The shadow

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<sup>23</sup> Campbell, "A brief history," 127—33.

<sup>24</sup> Röntgen, Wilhelm C., "On a new kind of rays," *Science* 3.59 (1896): 227—31. Ibid.

picture he presented was of a human hand. The image shown in Figure 6 of Anna Bertha Roentgen's hand was the first published radiograph of a living human. It was also the earliest evidence of the medical potential of x-rays.



FIGURE 6: The famous image of Anna Bertha Roentgen's hand taken in 1885.<sup>25</sup>

Roentgen ended his article by stating that his work “still requires a more solid foundation.”<sup>25</sup> This is a foreshadowing statement because the x-ray was rocketed into the public domain very quickly without that foundation, which cost some people their lives. This included Roentgen who continued his work until he died from cancer in 1923. Roentgen never patented his discoveries, a decision which allowed scientists and dentists to make changes to the technology freely.

Dentists were included in the groups of professionals who quickly took interest in the x-ray, and thus helped to gather and spread information. Roentgen's Wurzburg, Germany presentation took place on December 28, 1895. Two weeks later, on January 12 the dentist Otto Walkoff took the first images of a mouth in Braunschweig, Germany.

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<sup>25</sup> Röntgen, “On a new kind of rays,” 1896.



Walkoff used himself as the test subject and produced a series of bitewing images.<sup>26</sup>

Bitewing radiographs show the biting surface of the molars and premolars. The exposure time for these intraoral radiographs was 25 minutes and they are considered the first x-ray images of the oral cavity to ever be taken.<sup>27</sup> Walkoff's work illustrated how the x-ray could be relevant to dentistry.

On February 1, Walter König, a physics professor in Frankfurt, Germany also produced a series of dental radiographs. These radiographs were of higher quality than Walkoff's and only required nine minutes of exposure.<sup>26</sup> This contrast between the two men's work, which is closely linked temporally, illustrates how integral the technician was to the process of taking a radiograph. The x-ray device is one that requires an operator, which indicates that the technology incorporates more than just the machine. At the time, a standard device was also not yet on the market. Anyone with access to a Crookes tube (or a similar vacuum tube) and an induction coil could take a radiograph; this led to inconsistencies with the final image product. To combat that problem Frank Harrison, a dentist in Sheffield, England created a vacuum tube tailored to dental x-ray images in January of 1896.<sup>27</sup> Within months of its discovery, the x-ray device was already being outfitted for dental uses. This is an indicator of the high amount of interest that dental radiographs were generating.

On April 24, 1896 William James Morton, a medical doctor, presented his take on the x-ray to the New York Odontological Society. Morton's work placed a spotlight on the x-ray in American dentistry. As the son of Boston dentist William T.G. Morton,

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<sup>26</sup> Ruprecht, Axel, "Oral and maxillofacial radiology: Then and now," *The Journal of the American Dental Association* 139 (2008): 5S—6S.

<sup>27</sup> Jacobsohn, "Harnessing the x-ray."

whose work focused on inhalable ether anesthesia, W. J. Morton was well versed in dentistry.<sup>28</sup> In 1896, his paper “The X-ray and its Application to Dentistry” was published in *The Dental Cosmos*, the leading dental journal at the time. Morton was the first person in the United States to take a dental radiograph using a human skull and held strong opinions about the value of the x-ray in dentistry.

Already painless dentistry is within your grasp by aid of electricity and simple anesthetics, and now the X ray more than rivals your exploring mirror, your probe, your most delicate sense of touch, and your keenest powers of hypothetical diagnosis.<sup>29</sup>

Morton’s statement exemplified his conviction that the x-ray would become an invaluable device and change the practice of dentistry. Interestingly, the work of both Morton and his father—x-rays and anesthesia—would later be considered two of the most important discoveries in the history of dentistry.

Morton also supported his claims regarding the benefits of x-rays in dentistry by referencing the components of the x-ray device. The Crookes tube was unique because it produced a higher vacuum than similar vacuum tubes, a property called “high vacua.” This resulted in the molecules being pulled far apart, which created a steady stream of electrons. High vacuum tubes produced more detail on the radiographs.<sup>30</sup> Until Roentgen’s discovery of the x-ray the Crookes tube was only of interest to those studying energy.<sup>29</sup> Although it had been studied for almost two decades, Morton stated that no one

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<sup>28</sup> Jacobsohn, “Harnessing the x-ray.”

<sup>29</sup> Morton, William J., “The x-ray and its application to dentistry,” *The Dental Cosmos* 38 (1896): 478—86. Ibid.

<sup>30</sup> Rollins, William H., “Roentgen-ray notes,” *Electrical Review* 32.1 (1898): 12.

really understood how it produced x-rays. One view, held by Roentgen, was that x-rays are a type of vibration. Crookes believed them to be a high-speed stream of particles, while Edison held that x-rays functioned more like waves.<sup>31</sup> While little was known about the nature of x-rays, Morton thought that the resulting images were fascinating and practically important. Morton's reflections show how the first decade of the x-ray truly was a period of experimentation.



FIGURE 7: One of Morton's 1896 intraoral radiographs of a human skull. Morton's caption reads "artificial crown on molar."<sup>31</sup>

In Figure 7, Morton illustrated how x-ray technology could be useful to a dentist. In the image, some of the tooth pulps are visible, as is the placement of a crown. Morton said that these images were a "first step toward taking pictures of living teeth."<sup>31</sup> Images of a patient's mouth would be useful because a dentist could easily see problems like caries or extra teeth. While Morton presented images taken on a photographic plate in his paper, he supported a slightly different technique in dental practice. To speed up the patient examination process, he suggested using x-ray fluoroscopy. In contrast to a photographic plate, which produces a still image, a fluoroscope is a screen made of calcium tungstate, which displays a moving x-ray image in real time.<sup>31</sup> Morton liked the

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<sup>31</sup> Morton, "The x-ray and its application."

fluoroscope, invented by Thomas Edison, because the images were available almost instantly, while still images required several minutes of x-ray exposure followed by development of the photographic plate. Fluoroscopic images however were of poorer quality than photographic ones. Contrary to Morton's prediction, the fluoroscope did not end up replacing still images in dentistry. This is because the fluoroscope emits high levels of radiation and produces lower quality images. It is still used in the twenty-first century though, for surgical procedures and the study of the gastrointestinal tract.

In 1896 Morton published a book in collaboration with Edwin W. Hammer, an electrical engineer. This book, titled *The X-Ray or Photography of the Invisible and Its Value in Surgery*, has four parts: Definitions, Apparatus, Operation, and Surgical Value of the X Ray. The content of the book, as well as a publisher's note indicate that the intended audience consisted of researchers and those working in medicine and dentistry. By publishing a book, Morton created yet another outlet for the dissemination of x-ray information.

As many doctors, surgeons, dentists, and others are contemplating the addition of the X Ray apparatus to their laboratories, Dr. Morton would be pleased to give any information gained by his experiments on the selection of the best material.<sup>32</sup> This book, with the clear intention of reaching those interested in exploring the technology further, also explained why there was so much interest in the x-ray. Morton said that "interest in this subject is universal" because it raises questions about energy and matter, while also providing a new possibility for medical diagnosis and therapy.<sup>32</sup> X-rays

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<sup>32</sup> Morton, William J. and Edwin W. Hammer, *The X-Ray or Photography of the Invisible and its Value in Surgery*, (New York: American Technical Book Co., 1896).

appealed to many different disciplines, such as medicine, dentistry and physics, which made information abundant.

Among those whose interest had been piqued by news of x-rays was Brown Aryes, a professor of physics at Tulane University in Louisiana. Soon after Roentgen's official announcement, Aryes gave a presentation about the discovery. A dentist, Charles Edmund Kells, who had an affinity for electricity and technology, was in attendance at Aryes' presentation. Fascinated, Kells took the first dental x-ray of a living person in the United States in mid-1896. Kells went on to become one of the most well known proponents of the use of x-ray technology in dentistry through presentations and publications.

Kells was not only a strong advocate for the use of x-rays in dentistry, but he also contributed significantly to the physical development of the technology. Along with his many inventions, like the dental suction device, Kells designed tools for taking oral radiographs, such as a film holding device.<sup>33</sup> Throughout his career, Kells was an avid supporter of the use of x-rays in the dental office, but also warned against the misuse of the technology. During the first half of the twentieth century, x-rays were used as evidence indicating a need for tooth extraction. Some dentists claimed that spots near the roots of the teeth on radiographs indicated infection, which was treated by the removal of the tooth. Kells criticized this practice, which was popularized during the era of the focal infection theory.<sup>33</sup> The focal infection theory (FIT) is the idea that primary infections, often in the mouth, lead to other infections in the body.

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<sup>33</sup> Jacobsohn, "Harnessing the x-ray."

In July of 1896, Charles Edmund Kells presented the x-ray device to the Southern Dental Association in North Carolina. There he demonstrated the taking of a dental radiograph (also known as a skiagraph) on a live patient. Kells used a film holder of his own design, made of the highly permeable materials aluminum and rubber, to show his suggested method of taking clear images. For the image to accurately represent the mouth, “it is essential that the object be as close as possible to the plate upon which it is to be produced, and at the same time their plane surfaces should be parallel.”<sup>34</sup> Kells was one of the first to point out the importance of proper film and x-ray beam angling. In his report of the event, Kells mentioned several times that there was a large amount of excitement surrounding the ray, especially when he demonstrated the fluoroscope, the screen that displayed x-ray images in real time. His comments show how interest in seeing the inner body was a factor in the expansion of x-ray technology during its first ten years.

In addition to improving x-ray technology and information, Kells contributed to a changing ideology within the dental field. In his 1898 paper “Roentgen Rays in Practice,” Kells described his views on the over-arching effect of the x-ray discovery. He stated that dental radiographs “allow our future operations to be based upon scientific knowledge and not mere guesswork.”<sup>35</sup> Using case studies as evidence, Kells explained how misdiagnosis and incorrect treatment could easily occur when only using observations made during a basic oral exam. In a separate article “Roentgen Rays in Daily Practice,”

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<sup>34</sup> Kells, Charles E., *Three Score Years and Nine*, (New Orleans: C. Edmund Kells. D.D.S., 1926).

<sup>35</sup> Kells, Charles E., “Roentgen rays in practice,” *Items of Interest* 20 (1898): 729—31.

published in the same edition of the 1898 journal *Items of Interest*, Kells provided another case study that showed a misdiagnosis avoided by the use of radiographs. Kells concluded the article by stating, “this case is interesting in respect to the fact that this picture was taken in forty seconds.”<sup>36</sup> At the time of publication the negative effects of x-ray radiation were not yet of concern, but a need for efficiency in the dental office was important. For Kells, speed was a motivation for improving the x-ray apparatus. The more patients a dentist could see in a day, the more money he could make.

While x-rays were lauded in many ways, even supporters recognized that the technology needed mechanical improvements because radiographs were laborious to produce and were not always accurate. In 1898, the physician W.S. Hedley raised a new concern about the use of radiographs as diagnostic tools in medicine. In his paper “Radiostereoscopy,” Hedley supported a technique called stereoscopy, which utilizes several radiographs to create a three dimensional view of the image. His main argument was that traditional radiographs provided an imperfect representation of the object because they failed to display the curves and shapes of three-dimensional teeth.<sup>37</sup> This can be detrimental if the radiograph is the main source of information for a doctor or dentist and could lead to treatment errors.

Hedley’s concerns about the accuracy of x-rays were accompanied by efficacy questions posed by Kells, as well as a slew of apparatus variants. While this was problematic at times, it also allowed dentists to experiment and find what technology and

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<sup>36</sup> Kells, Charles E., “Roentgen rays in daily practice,” *Items of Interest* 20 (1898):892—3.

<sup>37</sup> Hedley, W.S., “Radiostereoscopy,” *The Lancet* 151.3888 (1898): 639.

methods worked best for their needs. In 1899, Kells published a lengthy paper titled “Roentgen Rays.” In it he evaluated many of the new technologies on the market for producing dental radiographs. He described the Ruhmkorff coil made by Queen & Co., the Tesla coil, and the Ranney-Wimshurst-Holtz machine (a static machine, which could be used instead of an induction coil as the generator) as being good for the induction component of the apparatus. Kells also mentioned the Messrs. Queen & Co. and W.E. Oelling vacuum tubes as being sufficient, but also stated that they were not optimal.<sup>38</sup> A heated vacuum tube worked best for radiographs because they were higher in energy and led to clearer radiographs, but there was not a way to regulate this property. Kells also repeated some of Hedley’s concerns about image distortion, saying that because of tooth curvature it is inevitable that images will be skewed. In an attempt to combat this problem, Kells recommended cutting the film to a more useful size and shape. Kells ended the paper by addressing claims of burns and hair loss after x-ray exposure. While acknowledging that it is possible to have adverse reactions to x-rays, he took a somewhat apathetic tone.

Not having had any experience with these injurious effects, I am consequently unable to form an opinion upon the subject, considering it a wise precaution, however, to see that the exposed surfaces are clean, and to also use the Tesla screen.<sup>38</sup>

While Kells did not directly state that x-rays could be harmful, he did advise taking some precautions.<sup>38</sup> He suggested keeping a sanitary workstation and using a Tesla screen,

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<sup>38</sup> Kells, Charles E., “Roentgen rays,” *The Dental Cosmos* 41 (1899): 1014—29.



which was made of aluminum and thought to absorb static discharge. Ironically, Kells has now been dubbed an x-ray martyr. He exposed himself to x-rays for over a decade, which eventually led to the loss of his fingers, then hand, arm, and shoulder.<sup>39</sup> After several years of battling x-ray related cancer and surgeries, Kells committed suicide in his dental office in the spring of 1928.<sup>40</sup>

William Herbert Rollins, both a medical doctor and dentist, was one of the first to support the implementation of x-ray safety procedures. Like Kells, Rollins learned of Roentgen's discovery early on and immediately began working on the application of x-rays to dentistry. He experimented with electricity as a form of anesthesia and invented a fluoroscope specifically designed for dental use.<sup>41</sup> As early as 1898, Rollins noted burns on areas of his body that were frequently exposed to x-ray radiation, such as his hands. He was the first to explicitly link his burns to x-rays in a paper he published in 1901. He suggested that dentists and others exposed to x-rays properly protect themselves by using equipment, like glasses lined with lead.<sup>42</sup>

In 1899, John Dennis published, "The Roentgen Energy To-Day," in which he stated that, "no injury results from its [Roentgen Ray] proper use."<sup>43</sup> He attributed any negative effects of the x-ray to misuse of the device by the operator. Dennis' proposal, which was ahead of its time, required that all operators have x-ray licenses. Anyone who

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<sup>39</sup> Schiff, Thomas, "Principles of intraoral imaging," *The Academy of Dental Therapeutics and Stomatology* (2012): 2—5.

<sup>40</sup> Jacobsohn, "Harnessing the x-ray."

<sup>41</sup> Forrai, J., "History of x-ray in dentistry," *Rev. Clin. Pesq. Odontol.* 3.3 (2007): 205—11.

<sup>42</sup> Wynbrandt, *The Excruciating History*.

<sup>43</sup> Dennis, John, "The roentgen energy to-day," *The Dental Cosmos* 41 (1899): 853—7.

failed to get the proper training and certification could be charged with a misdemeanor. Dennis believed that only when users were educated could the x-ray device reach its full potential.

Between 1896 and 1904 Rollins published 180 articles about x-rays, which he referred to as “notes on x-light.”<sup>44</sup> Deviating from his typical publication in *The Electrical Review*, Rollins published a short yet pointed letter to the editor in the *Boston Medical and Surgical Journal* in 1901 simply titled “X-Light Kills.” Referencing an experiment he conducted using guinea pigs Rollins explained, “when electricity is excluded, death can be produced with x-light without burning.”<sup>45</sup> Following his brief statement, Rollins detailed his three recommended safety precautions. He recommended that the physician’s eyes, the x-light tube and the patient should be covered in non-radiable material. Rollins also explained that he chose to publish in a medical journal because the “X-Light Kills” note excludes reference to electricity, he wanted to draw attention to the dangers, and he wanted to spread precaution information to people using the devices on patients.<sup>45</sup> Rollins’ 1901 note was unique because he used experimental evidence to support his claims instead of anecdotal evidence, and also provided a succinct list of ways to reduce radiation from x-rays. Although Rollins is often called “dentistry’s

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<sup>44</sup> Kathren, Ronald L., “William Rollins (1852-1929): X-ray protection pioneer,” *The Journal of the History of Medicine and Allied Sciences* 19 (1964): 287—94.

<sup>45</sup> Rollins, William H., “X-light kills,” *The Boston Medical and Surgical Journal* 144.7 (1901): 173.

forgotten man” because his warnings were largely dismissed, “X-Light Kills” marks the start of a long history of x-ray safety concerns.<sup>46</sup>

In the following edition of the *Boston Medical and Surgical Journal*, surgeon E.A. Codman responded to Rollins’ recommendations. Codman stated that while the precautions recommended by Rollins might make sense for someone constantly exposed to x-rays, they were unnecessary for practical uses. Codman presented hospital data to support his claim that “there is no danger from the use of the x-ray to *the patient* and very little to the operator.”<sup>47</sup> His data showed that out of 4,000 patients exposed to x-rays, there are no cases of burns. Anecdotally, Codman stated that his own hands had the appearance of burns at times, but had never gotten bad enough to cause pain. Limiting his direct exposure to the x-ray tube was his only precaution. Codman ended by implying that Rollins had inflated the importance of his findings. “The fact that the x-ray is in daily use in the large hospitals without harmful results should be put in blacker type than the death of two guinea pigs.”<sup>47</sup>

In 1903, Rollins published another note in the same journal titled “The Effect of X-Light on the Crystalline Lens.” In this article he introduced a concern about the effect of x-rays on the eyes. He described the eyes of people frequently exposed to x-rays as becoming “prematurely old.”<sup>48</sup> His observation is a precursor to later research on the link between cataracts and x-rays. In this article, Rollins also presented two x-light axioms.

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<sup>46</sup> “William H. Rollins Award for Research in OMR.” American Academy of Oral and Maxillofacial Radiology, last accessed February 16, 2013, <http://www.aaomr.org/?page=RollinsAward>.

<sup>47</sup> Codman, E. A., “No practical danger from the x-ray,” *The Boston Medical and Surgical Journal* 144.8 (1901): 197—8.

<sup>48</sup> Rollins, William H., “Notes on x-light: the effect of x-light on the crystalline lens,” *The Boston Medical and Surgical Journal* 148.14 (1903): 364—5. Ibid.

The first being that “no x-light should strike a patient except the smallest beam that will cover the area to be examined, treated or photographed,” and the second “no x-light should strike the observer.”<sup>49</sup> These axioms, which essentially say that everyone involved in the taking of radiographs should be exposed at the lowest level possible, are reflected in x-ray protection guidelines of the twenty-first century. He also recommended using heat sterilization and fumigation to keep equipment sanitary.<sup>49</sup> All of Rollins’ suggestions illustrate how ideas and information were being produced during the early years of the x-ray.

### Institutions

As early as 1896, x-ray technology became intertwined with various institutions. For example, Kells used a Tesla induction coil at his initial x-ray demonstration, which linked the x-ray to a big name in energy research. He also used black paper-wrapped Eastman NC film to take some of the first images on a living person.<sup>50</sup> Eastman Kodak Co. became a major manufacturer of radiographic film after producing intraoral films in 1897. As film speed improved, image exposure time decreased. Kells’ 1896 images had exposure times of between five and fifteen minutes, which was typical of early radiographs.<sup>51</sup> Exposure time however would radically decrease with film improvements over the coming century.

With the start of the Spanish-American War in 1898, the medical uses of x-ray technology became very apparent. Radiographs were quickly adopted as a diagnostic

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<sup>49</sup> Rollins, “Notes on X-Light.”

<sup>50</sup> Ruprecht, “Oral and maxillofacial.”

<sup>51</sup> Kells, *Three Score Years*.

measure, often for fractures and bullet localization.<sup>52</sup> Only two years after being introduced to the world, a prominent governmental institution—the United States military—used the rays. In his 1900 report titled “The use of the Röntgen Ray by the Department of the United States Army in the War with Spain,” Captain W.C. Borden compiled data and observations about the use of x-rays Army Medical Department.

Part of Borden’s report evaluated the effectiveness of the different technologies available. The apparatus used by the army consisted of a Crooke’s (high vacuum) tube and an electrical current device. The electrical current could be produced by either a static machine, which utilized friction or a coil machine, which used induction coils to create energy.<sup>53</sup> Borden found that both machines were effective, but that the coil machines were far better suited for military purposes because the static machine was bulky and required more work to operate.<sup>54</sup>

Of those wounded during the Spanish-American War, 95 percent recovered, which was partly due to the use of radiographs.<sup>55</sup> The images were used to locate bullets in the patients, as well as diagnose bone fractures. This is a high survival rate compared to other wars, but Borden’s report also shed some light on problems with the use of x-rays. Borden presented data and suggestions regarding burns resulting from x-ray exposure. He isolated the factors contributing to the burns to be “(a) the length of exposure; (b) the nearness of the tube to the body; [and] (c) the physical condition of the

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<sup>52</sup> Cirillo, V.J., “The Spanish-American War and military radiology,” *The American Journal of Roentgenology* 174 (2000): 1233—9. Ibid.

<sup>53</sup> Cirillo, “The Spanish-American War.”

<sup>54</sup> Borden, W. C., “The use of the Röntgen ray by the medical department of the United States military in the war with Spain,” (1898). Ibid.

<sup>55</sup> Cirillo, “The Spanish-American War.”

patient.”<sup>56</sup> Borden stated that the exposure time should be no more than 30 minutes, and the time should vary depending on the area being radiographed. Although Borden’s report showed that x-rays were beneficial to United States military medicine, radiographs did not become the norm in the military until the 1920s. According to historian Vincent J. Cirillo, this was due to technological barriers and the military’s conservative medical philosophy.<sup>56</sup>

During the first decade after the discovery of the x-ray, people in the fields of medicine, dentistry and physics helped propel the technology out of obscurity. The x-ray image was an integral part of the technology, which helped make this possible. Being able to see inside of the body was a fascination of not only medical and dental practitioners, but the public as well. Small technological changes also occurred during this time as tools were evaluated and new ones were created.

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<sup>56</sup> Borden, “The use of the Röntgen ray.”

## Chapter 3

### INTRODUCTION INTO DENTISTRY (1905-1923)

In the first quarter of the twentieth century, dentists incorporated x-ray technology into the field of dentistry. Although dentists and the mouth were present in the early life of the x-ray, the technology did not become dental-specific until the period between 1905 and 1923. The culminating event being the manufacturing of the first dental x-ray machine in 1923 by the Victor X-Ray Company in Chicago, Illinois. People, technologies and institutions also influenced the move toward specialized dental x-ray technology. The work of people, such as Charles Edmund Kells, Ed C. Jerman, and William D. Coolidge influenced professional changes in the field as dentistry became more science-based. This helped embed the x-ray in dentistry. The advancement and specification of radiographic film, vacuum tubes and the x-ray machine for dental uses are signs of the x-ray's increasing presence in dentistry as well. In this period there were a large number of technological changes that spanned all aspects of x-ray technology, from film development to x-ray exposure technique, as opposed to only the basic apparatus. Producing these components and spreading the word about x-ray technology were institutions like the Victor X-Ray Corporation, Eastman Kodak Company and the American Society for X-Ray Technicians. The institutions legitimized the technology by framing it in economic terms, as a revenue-generating tool. These various actors helped to further increase the prevalence of x-ray technology in dentistry.

## People

In Francis Ashley Faught's 1908 paper "The Dentist's Relation to Preventative Medicine" he described a shift in the professional nature of dentistry as a part of medicine and linked the change to the advent of the x-ray. Faught, a medical doctor and dentist, stated that, "today the profession of dentistry is recognized and esteemed as a distinct and peculiar branch of the healing art."<sup>57</sup> By lumping dentistry in with medicine, Faught explained that technological and knowledge advancements that affected both professions helped show that dentists should have "equal responsibility with the other specialties of medicine."<sup>57</sup> Bacteriology, for example not only influenced medicine, but also applied to dental issues like tooth decay. This allowed dentists to make diagnoses using the same type of evidence used by physicians. The x-ray also changed the way that specialties were viewed. Faught pointed to the physical connections between the fields of dentistry, rhinology and laryngology. He stated that as a result of the "co-relation of oral and naso-pharyngeal disease [the dentist's responsibility] is probably greater than many have realized."<sup>57</sup> By this Faught meant that the dentist should play an active role in preventative medicine. He used upper respiratory obstructions as an example of an affliction that dentists could help treat or prevent.

Medical doctor G.E. Pfahler justified the x-ray's place in dentistry in his 1908 article, "The use of Roentgen Rays in Dentistry." That it was published in *The Dental Cosmos*, the leading dental journal of the time shows that Pfahler wrote for those working

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<sup>57</sup> Faught, Francis A., "The dentist's relation to preventative dentistry," *The Dental Cosmos* 50.1 (1908): 7—12.



in the dental field.<sup>58 59</sup> He stated that “the use of the Roentgen rays in dentistry is nothing new,” so his goal was to simply “make men better acquainted” with the technology.<sup>60</sup> He addressed concerns about the harmful effects of dental x-rays by citing the advancements in exposure time. According to Pfahler, reported burns were associated with lengthy exposure times, which had been reduced almost ten-fold. Instead of 30 minutes, Pfahler claimed that 30 seconds was the longest exposure time needed for a dental radiograph.<sup>61</sup> Pfahler stated that the rays were “painless, aseptic, and accurate,” but was clear that they were merely a supplement not replacement for traditional oral exams.<sup>60</sup> He also clarified that while there was no danger for the patient, x-rays did pose an occupational hazard for operators, who should be cautious. Of all x-ray devices, Pfahler said that the fluoroscope was the most dangerous because of the high doses of radiation exposure, so it had “no place in dentistry.”<sup>60</sup>

Similar to Francis Ashley Faught’s discussion about the connections between dentists and other medical specialists, physician George C. Stout reviewed the connections between dentistry and laryngology. Stout’s paper reflected the growing sentiment that the role of the dentist should be viewed as not just a technician, but as a valuable member of the medical field. He explained that it was “hard to realize that it is

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<sup>58</sup> According to Gutmann 2009, *The Dental Cosmos*, which began publishing in 1859, merged with the *Journal of the American Dental Association* in 1937.

<sup>59</sup> Gutmann, James L., “The evolution of America’s scientific advancements in dentistry in the past 150 years,” *The Journal of the American Dental Association* 140 (2009): 8S—15S.

<sup>60</sup> Pfahler, G. E., “The use of the roentgen rays in dentistry,” *The Dental Cosmos* 50.9 (1908): 916—9.

<sup>61</sup> Today, only one percent of all medical radiation exposure comes from dental x-rays. About one-fourth of radiation in the US is manmade, much of which is related to medical procedures, according to the American Dental Association.

only a very few years since dentists and laryngologists discovered how much they are dependent upon each other.”<sup>62</sup> They were dependent because many of the diseases that fall within their jurisdictions overlapped. These included problems with the tonsils or sinus, extra teeth and mouth or throat cancer. Sometimes, it would be prudent for the dentist and the laryngologist to work in conjunction with one another. Stout presented one of his own cases as an example. He took an x-ray image of a patient with an infection in the sinus cavity, but “without the assistance of the expert it [the radiograph] would be of little value.”<sup>63</sup> Stout passed the radiograph around to colleagues in order to ensure he was interpreting it correctly. Stout’s descriptions of the need for doctors and dentists to work together show how the x-ray contributed to professional changes within dentistry.

Mirroring other discussions about the changing landscape of medicine and dentistry, H.W. Van Allen discussed how the development of the x-ray played into those changes. He explained that in the past “the physician did a large part of dentistry, which was extraction; now, hardly a physician is prepared to do even this primitive dental work.”<sup>64</sup> Like Stout, he implied that the dentist and physician had become co-dependent, citing the focal infection theory as a reason for the merging of the fields. The focal infection theory (FIT), popular in the early 1900s, stated that a primary infection often located in mouth causes secondary infections in the body. In Van Allen’s words, “many remote affections have their primary cause in obscure dental abnormalities.”<sup>64</sup> In light of

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<sup>62</sup> Stout, George C., “The borderline between dentistry and laryngology,” *The Dental Cosmos* 53.1 (1911): 71—6. Ibid.

<sup>63</sup> Stout, “The borderline.”

<sup>64</sup> Van Allen, H. W., “The roentgen ray in dentistry,” *The Dental Cosmos* 56.5 (1914): 587—91. Ibid.

this mouth-body connection, the physician had more reason to be in contact with the dentist. It was through the use of the x-ray that many of these oral infections were confirmed.

With disease concepts like FIT in vogue, many dentists wanted to participate in the x-ray movement, but those in smaller offices often purchased cheap, poor-quality apparatuses. According to Van Allen, this contradicted what was best for the patient, who should be “given the best, and the dentist should buy a powerful machine with a capacity for instantaneous radiographs.”<sup>65</sup> This statement shows some of the institutional influences on the prevalence of the x-ray. The device had become a business pursuit for companies such as the Victor X-Ray Corporation, which employed salesmen to get the “small X-ray instruments of the so-called ‘dress suitcase’ type” into dental offices.<sup>65</sup> Since high quality instruments were too expensive for the average dentist, Van Allen suggested that in a community one dentist with the machine would work as the x-ray specialist.<sup>66</sup>

Howard Riley Raper, the dentist who wrote the first dental textbook in 1913, produced a 1915 article that directly asserted that the best use of the x-ray was in the research realm. Raper stated that FIT was the “most important problem the dental profession has ever faced.”<sup>67</sup> He painted the x-ray device as a crucial apparatus in current dentistry. “The radiograph will be used extensively in this oral sepsis research work.

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<sup>65</sup> Van Allen, “The roentgen ray.”

<sup>66</sup> Oral and Maxillofacial Radiology was not recognized as a specialty by the American Dental Association until 1999.

<sup>67</sup> Raper, Howard R., “Uses and advantages of the x-rays as an aid to dental diagnosis, including the differentiation of the radiographic appearance of normal and abnormal tissues,” *The Dental Cosmos* 57.5 (1915): 510—2. Ibid.

Thus its use is closely linked with the solution of the most serious problem which confronts us.”<sup>68</sup> While the x-ray was of monumental importance in both research and diagnosis, Raper reiterated that radiographs were a supplemental technology. A dentist should form an initial diagnosis and use the radiograph as a way to back up the diagnosis. Raper also explained that since the x-ray was an important new technology, operators should have some basic x-ray knowledge. The operator must know “general elementary principles of making radiographs...the anatomy of the parts...the pathology of the parts... and [have] experience in reading radiographs.”<sup>68</sup> To show that he was not alone in his convictions, Raper referenced the rising number of schools that were incorporating radiography courses into their dental curricula. Of the 50 dental schools, one or two taught the material in 1910, but in 1913 the number had risen to one-third of all the schools teaching radiography.<sup>68</sup>

In 1916 Charles Horace Mayo, a founder of the Mayo Clinic, known for its collaborative medical model known as “group practice,” published an article about dentistry and preventative medicine. Stating that the “medical profession and the dental profession should not be separated,” Mayo suggested a radical merger of dentistry and medicine, both academically and professionally.<sup>69</sup> Mayo wanted dentistry to become a part of the American Medical Association and recommended that medical and dental students take many of their classes together. He referenced the focal infection theory as a reason for the two professionals to work closely with one another. Mayo’s article

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<sup>68</sup> Raper, “Uses and advantages of the x-rays.”

<sup>69</sup> Mayo, Charles H., “Dental research, its place in preventative medicine,” *The Journal of the National Dental Association* 3.2 (1916): 167—71.

illustrates how the products of the x-ray movement, such as the supposed ability to locate infections in the mouth, contributed to a professional shift in dentistry.

Although the x-ray as a potentially dangerous device was not a new concept, the rise of the focal infection theory induced a new wave of concern. In 1920, Charles Edmund Kells, a long time proponent of the x-ray, published a paper titled “The X-Ray in Dental Practice: The Crime of the Age.”<sup>70</sup> Taking a more critical tone than in some of his other works, Kells described how the misuse of the x-ray was detrimental to the patient. His paper directly linked the x-ray with both dentistry and medicine, which indicated the technology’s strong integration into the fields. Kells stated that “the center of the stage is now held by the pulpless tooth, and the X-ray is the limelight which produces the spot in which it stands.”<sup>70</sup> Kells did acknowledge that the x-ray was important, calling it “indispensible” and saying that a “practitioner of dentistry is not fully capable of rendering his patients THE VERY BEST SERVICES unless his equipment includes an X-ray machine.”<sup>70</sup> There was however a major gap in skill; radiographs were being read incorrectly and dentists operating under the assumption of the Focal Infection Theory were extracting many teeth unnecessarily. While Kells said that this could happen because dentists were not properly trained at reading radiographs, it also happened because of money. Teeth were being “promiscuously” x-rayed and extracted so the dentist could collect more fees from the patient. To contrast that way of practice, Kells also introduced what is now called conservative dentistry.

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<sup>70</sup> Kells, Charles E., “The x-ray in dental practice: The crime of the age,” *The Journal of the National Dental Association* 7 (1920): 241—72. Ibid.

Anybody can extract a tooth—let us try to save every one possible by replanting, by amputation, by apicoectomy, if you will—no matter by what means, just so it is saved for a period of usefulness, at least.<sup>71</sup>

Kells explained that extraction should be the last choice, not the first and that x-rays should only be taken when necessary so as to not place unneeded financial burden upon the patient. Kells' paper showed how entrenched the x-ray had become in the dental field. If a dentist did not have an x-ray device in his office, he would send the patient to an x-ray laboratory. Radiographs were becoming the norm.

In 1921 Kells sent a letter to the editor of *The Dental Cosmos* journal, correcting what he believed to be a dangerous piece of misinformation about how to interpret a radiograph. Kells stated that, "no radiogram can *show infection*."<sup>72</sup> It was problematic that people continued to publish articles claiming that they could see oral infections on radiographs, because it contributed to the spread of faulty information that perpetuated the problems Kells explained in 1920. A large number of unnecessary x-rays lead to false positives about infections, which then caused unneeded extractions of healthy teeth. This shows how people, including Kells affected the spread of x-ray information and thus x-ray use.

Due to the focal infection theory, much of the focus of the diagnostic uses of x-rays had been placed on tooth infections, often found at the root of the tooth. The dentist, C.N. Johnson's 1921 article "Some of the Present Problems in Operative Dentistry," highlights another use of the x-ray. Johnson stated, "dental caries is the most prevalent of

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<sup>71</sup> Kells, "The x-ray in dental practice."

<sup>72</sup> Kells, Charles E., "Radiograph as a diagnostic aid," *The Dental Cosmos* 63 (1921): 816.

human ailments.”<sup>73</sup> Caries show on radiographs as dark spots on the normally white enamel and dentin. Johnson also suggested investigating the factors that can lead to caries, such as poor nutrition. He wrote that focusing on finding infections and pus on radiographs was dangerous and unnecessary because they could not be identified on the images.

In 1922 the dentist Francis A. Macon commented on the connection between dentistry and medicine. Since the x-ray was used in both medicine and dentistry, he showed how professional connections helped to facilitate the integration of the x-ray into dentistry. Macon explains how the connection between oral sepsis and systemic disease (Focal Infection Theory) had been made even before the rise of bacteriology and x-rays. The advent of both however strengthened the link between the mouth and the body, and thus the dentist and the doctor. There was still work to be done though.

What the medical profession needed in 1801 is just precisely what it needs in 1921, i.e. the alliance of an alert, scientific, and dependable profession to share the responsibilities of preserving the fruits of research and to hold the ground to the advanced position where the dentist must take hold and command.<sup>74</sup>

Macon summarized his statement with, “Gentlemen, *the physician needs the dentist!*”<sup>74</sup> He did qualify his statements by mirroring Kells’ concerns about the over-use of x-rays and tooth extractions. Macon also explained that while the x-ray was important, it was also fallible. Radiographs do not show pus or infection and at times could be very

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<sup>73</sup> Johnson, C. N., “Some of the present problems in operative dentistry,” *The Dental Cosmos* 63.10 (1921): 963—7.

<sup>74</sup> Macon, Francis A., “The interdependence of dentists and physicians,” *The Dental Cosmos* 64.4 (1922): 441—6.

misleading. Macon's statements emphasize that professional knowledge (especially when dentist and doctor are working together) as being superior to radiographic evidence.

### Technology

During this time period, innovations began to arise across many areas, including film, techniques, and device components. In 1905 Francis Le Roy Satterlee, the director of the x-ray laboratories at the New York College of Dentistry, published a paper containing updates on the x-ray apparatus and techniques in dentistry. His article shows how small adjustments to the technological components and techniques pull the x-ray closer to dentistry. Satterlee called x-rays "tri-ultraviolet rays," and said that their wavelength was 0.014 micron. By comparison the closest wavelength, that of the cathode ray, was slightly longer at 0.21 micron.<sup>75</sup> Satterlee also explained that improvements in machinery had dramatically decreased exposure time. A radiograph of a hand that requires one second of exposure in 1905 took 25 minutes in 1895. The major change leading to this decrease was the dismissal of the static machine, a device that could be used instead of an induction coil. This was because the induction coil was much more powerful and better suited for dental uses. As for technique, Satterlee recommended using Eastman Kodak Company's cinematograph positive film. The films were a standard size that is 1 ¼ x 1 5/8 inches and could be cut as needed.<sup>75</sup> Satterlee also highlighted a need for imagination in dentists who read radiographs. The dentist needed to "[establish] a proper relationship between the radiographic outlines of the teeth and

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<sup>75</sup> Satterlee, Francis Le Roy, "The x-ray in dentistry," *The Dental Cosmos* 48.3 (1906): 260—7. Ibid.



their actual position in the mouth.”<sup>76</sup> This illustrated how even as the equipment in dental radiography was becoming more standardized the image was still subject to interpretation.

Similar to Satterlee, physician Sinclair Tousey published a paper in 1906 that reviewed the x-ray apparatus and its use in dental diagnosis. Tousey’s explanation of how the x-ray instrument worked, contrasted with the wave information presented by Satterlee showed that the debate about the nature of x-rays was still thriving. Satterlee reiterated Edison’s wave hypothesis, while Tousey sided with Roentgen by describing x-rays as vibrations.

An X-ray tube contains a partial vacuum and the very powerful electric current which passes through it gives rise to a fierce bombardment of molecules, focused by the concave cathode upon the platinum disk in the center of the tube. The cathode stream, going at the rate of twenty thousand miles a second, strikes this disk, which is called the anti-cathode, and gives rise to ethereal vibrations called the X-ray.<sup>77</sup>

Tousey also classified the density of materials in the mouth. He stated that metal fillings or crowns were the densest (on the radiograph, the darkest), followed by enamel, dentin, and then bone. In his description of the x-ray as a diagnostic tool, Tousey expressed confidence. He said that the x-ray was “useful in the diagnosis of every condition.”<sup>77</sup> He

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<sup>76</sup> Satterlee, “The x-ray in dentistry.”

<sup>77</sup> Tousey, Sinclair, “Recent work with the x-ray and high-frequency currents in the diagnosis of dental cases and in the treatment of pyorrhea and cancer,” *The Dental Cosmos* 48.6 (1906): 637—9.

detailed several conditions and structures that were clearly identified in a radiograph, such as abscesses and root canals.

As indicated by other professionals in the past, techniques for taking and reading radiographs were an important component of the evolution of the x-ray technology. Charles A. Clark's 1909 paper described one such technique for properly positioning films with patients who could not sit still, such as children.<sup>78</sup> He suggested taking three images of the tooth in question: one positioned at the middle of the tooth, one to the right and one to the left. By comparing three slightly different perspectives, it allowed the dentist to get a better idea of tooth spacing and angulation. Clark also recommended dropping the exposure time to less than a second so the patient's movement did not blur the image.

In 1913, two technological improvements occurred that increased radiograph efficiency and thus helped to tailor the x-ray for dental uses. Eastman Kodak Company produced pre-wrapped film for use in the mouth. The packets contained two sheets of film and were wrapped in waterproof paper.<sup>79</sup> Before this product was on the market, dentists had to wrap their own film. That same year, William David Coolidge, an electrical engineer and chemist working as the director of a General Electric Company laboratory in New York, invented a cathode tube specifically designed to produce x-rays.<sup>80</sup> Unlike the Crooke's tube, which used gas as an electron source, the "Coolidge

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<sup>78</sup> Clark, Charles A., "A method of ascertaining the relative position of unerupted teeth by means of film radiographs," *Proceedings of the Royal Society of Medicine* 3 (1910): 87—90.

<sup>79</sup> Ruprecht, "Oral and maxillofacial."

<sup>80</sup> Jacobsohn, "Harnessing the x-ray."

tube” used tungsten wire. Coolidge’s tube was far safer and allowed the operator to control the amount of radiation that was expelled.<sup>81</sup>

Although they do not mention the type of tube employed in their studies, George M. Mackee and John Remer, a professor of radiology and a radiologist working at Columbia University, discussed the quality and quantity of x-ray exposure in their 1914 paper. No matter what the apparatus, the qualities of the rays were never consistent. To correct this, Mackee and Remer suggested using a Benoist radiochromometer. This device measured the “hardness” of rays; the hardness was measured as the type of tissue the rays could pass through. To test the quantities of the rays, the authors recommend using the Holzkecht radiometer, which told the operator how much of the ray was actually being emitted. Mackee and Remer used reports of hair loss and burns from x-ray exposure as reasons for incorporating these devices in practice. They concluded the article by saying that they hoped to “encourage a more exact and careful technique in dental radiography.”<sup>82</sup>

In 1916 Sinclair Tousey published a book titled “Roentgenographic Diagnosis of Dental Infection in Systemic Diseases.” His goal in publishing the book was to “aid the physician and the dentist to decide when an infected tooth should be extracted and when it can be cured and remain a safe and useful member.”<sup>83</sup> The book was a compilation of information on how to treat and diagnose oral maladies suspected to be focal infections

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<sup>81</sup> Jacobsohn, “Harnessing the x-ray.”

<sup>82</sup> Mackee, George M. and John Remer, “Measurement of the amount of x ray employed in making dental radiographs,” *The Dental Cosmos* 56.1 (1914): 35—42.

<sup>83</sup> Tousey, Sinclair, *Roentgenographic Diagnosis of Dental Infection in Systemic Diseases*, (New York: Paul B. Hoeber, 1916). Ibid.

with the x-ray device. He said that the “x-ray is depended upon to show whether or not the source of the trouble is connected with the teeth,” so as to implicate, and thus remove, the teeth without evidence.<sup>84</sup> Tousey’s book established a strong link between x-ray technology and teeth. The focal infection theory placed a spotlight on the teeth, while the x-ray enabled this focus. By saying that the “x-ray is depended upon” and that it could “acquit [teeth] of any complicity in the matter” it shows how tightly bound the mouth was to the x-ray.<sup>84</sup> This example shows that a non-tangible aspect of x-ray technology—the different applications of the device—had agency in the integration of the x-ray into the dental field.

The interpretation of the radiograph, another component of the technology itself, was also important as indicated by the dentist Thomas B. Wade in 1918. Like several of his colleagues, Wade described his fear that too much emphasis was being placed on the x-ray as a diagnostic tool. Clinical exams and case histories needed precedence. “The clinical diagnosis should always precede, and should be confirmed or rejected by the X-ray diagnosis.”<sup>85</sup> Wade also detailed tips for properly reading a radiograph. He suggested using radiographs in their negative form, as shown in Figure 8.

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<sup>84</sup> Tousey, *Roentgenographic Diagnosis*.

<sup>85</sup> Wade, Thomas B., “Interpretation of roentgenograms,” *The Dental Cosmos* 60.8 (1918): 695— 700. Ibid.



FIGURE 8: Sample radiograph in the “negative” form. The densest materials are the whitest.<sup>86</sup>

Wade classified skin, membrane and tooth-pulp tissues as “radioparent,” as they appear to be black on the radiograph. Bone and hard tooth materials, like enamel and dentin, are “radiolucent;” they appear to be light in the image because they “offer slight resistance to the rays.”<sup>86</sup> The materials that are very white such as crowns, metal fillings and root-canal fillings, are labeled as “radiopaque”—only a few rays pass through them. This shows how important the skill of the person interpreting the radiograph was in x-ray technology. A radiograph had to be properly read for it to be useful.

Kells focused on a separate component of x-ray technology in his 1922 paper “The Development of Dental Films.” He explained that both the film exposure to the x-ray and the film development process were highly influenced by the operator, although film development could be done at that time by a machine. Kells suggested using a developing unit and described several of the factors, such as room temperature and climate, which could affect the outcome. To support his suggestion for using the unit,

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<sup>86</sup> Wade, “Interpretation of roentgenograms.”

Kells repeated that “time is the most important item in a busy dental office.”<sup>87</sup> This illustrates how technological advancements made the x-ray more convenient for the dentist. Kells humorously explained this at the end of his article. “This ‘Wonder’ developer and the *constant temperature* bath have taken the Dev’l out of the Dev’lopment problem for me.”<sup>87</sup>

### Institutions

Indicating a professional shift toward thinking that certain qualifications were needed in order to operate an x-ray apparatus, George M. Mackee presented a list of questions meant to weed out unqualified individuals. These included technical and causative questions, such as “How can quality be controlled?” and “what are the injurious results of the X-ray—both immediate and remote?”<sup>88</sup> This showed how institutions, like x-ray machine manufacturers, influenced the spread of x-ray information as well a professional movement toward x-ray training. Operating under the assumption that roentgenology, the study of radiographs, was a medical pursuit; he explained how manufacturers sent out salesmen who distributed the devices with few instructions. This not only led to sloppy work (which slightly discredited the x-ray), but also caused legal problems for the dentist using the instruments. Patients could take legal action against a dentist if his work resulted in radiodermatitis, skin irritation from x-ray exposure, and the dentist was found to be unqualified to take radiographs.<sup>88</sup>

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<sup>87</sup> Kells, Charles E., “Practical development of dental films,” *Dental Items of Interest* 44 (1922): 927—37.

<sup>88</sup> Mackee, George M., “Radiodermatitis following x-ray examination of the teeth,” *The Dental Cosmos* 58.4 (1916): 428—9.

In 1919, Eastman Kodak Company put the first x-ray film specifically designed for dental uses on the market, and in 1920 Kodak produced the first machine-made, wrapped x-ray film.<sup>89</sup> These advancements made film more efficient and accessible for dental practitioners. In 1920, the American Society for X-Ray Technicians (ASXT) was also established. Though the society was not specific to dentistry, it does show a general shift toward radiography as a specialty with specific training. One of its most noted members was Ed. C. Jerman. Prior to joining the ASXT, Jerman worked for Victor X-Ray Corporation. He developed a program at Victor X-Ray where he trained a group of people in medical radiography.<sup>90</sup> From this program, the idea of an x-ray technician was born.

Despite the x-ray skepticism presented by people like Francis Macon, who was concerned with overreliance on radiographs, x-ray technology was tailored to fit dental needs. In 1923 the first dental x-ray machine was developed by Victor X-Ray Company, housed in Chicago, Illinois. This machine, called the Victor CDX, was significantly safer than previous equipment because it did not have any exposed wires. The possibility of operator electrocution was a major problem with earlier x-ray machine models.<sup>91</sup> Formed in 1893, Victor Electric (later Victor X-Ray) Company quickly became a prominent manufacturer of x-ray equipment. In 1926, it was purchased by General Electric, but continued to produce high-quality materials.<sup>91</sup>

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<sup>89</sup> Ruprecht, “Oral and maxillofacial.”

<sup>90</sup> M. Hoing, R. T., *A history of the ASXT: 1920 to 1950*, (Saint Paul: The Bruce Publishing Company, 1952).

<sup>91</sup> Glenner, Richard, “80 years of dental radiography,” *The Journal of the American Dental Association* 90 (1975): 549—61.

The combination of influences on professional changes by people like Kells and Jerman, the multiple technological improvements, and heavy institutional pushes for x-rays by companies and dental schools helped to introduce x-rays to the dental field. Even with concerns about safety and efficacy, x-ray technology persisted in dentistry.



## Chapter 4

### INTEGRATION INTO DENTISTRY (1924-1955)

The years following the introduction of x-ray technology into dentistry were the time in which it became fully integrated into the field. This was facilitated by technique refinements developed by prominent people like H.R. Raper, the first to write a dental textbook, and F. Gordon Fitzgerald, the father of modern dental radiography. Technology also played a strong role in this period of x-ray history. Building upon advancements made in the beginning of the twentieth century, changes were made to the x-ray device and film to make them faster and safer for dental uses. By the end of the 1950s, the practice of taking radiographs had become a common part of the dental exam experience.

#### People

In 1925 the doctor Bernard R. Mooney wrote a paper that reflected changes in the perceived use of the x-ray. When it was first invented, the x-ray was a mysterious fascination—it provided a window into what had never before been seen—and then it progressed to a supplemental tool for dental diagnoses. With increased use during the era of the focal infection theory, it became an object of concern with critics fearing its overuse. As Mooney’s paper indicates, by 1925 the x-ray had taken another step forward by becoming integrated into the foundations of dentistry. He stated, “it is as important for the dentist to use the x-ray as to use a sterilizer.”<sup>92</sup> Mooney’s comparison shows how entrenched the x-rays were in dentistry at that point. The process of sterilization was born

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<sup>92</sup> Mooney, Bernard R., “The importance of the dental surgeon in medicine and the value of radiography in dental practice,” *Journal of the Canadian Medical Association* 15.12 (1925): 1245—7. Ibid.

from studies in bacteriology and the germ theory of disease and Mooney implied that the practice of taking radiographs was founded on those same strong concepts. He did this by referencing FIT. “In the search for infectious oral foci...the roentgen ray is indispensable.”<sup>93</sup> Not only was the x-ray deemed necessary for diagnosing and treating oral infections, but was also used for other problems associated with the teeth and jaws, such as malocclusion. Mooney made it clear that x-ray technology had become a crucial part of dentistry, but also applied agency to the technology itself.

The dentist is now more seriously concerned with the general health of the patient than with the local condition of the teeth. It is probable that the x-ray has been the greatest factor in this transformation scene.<sup>93</sup>

According to Mooney, and many of his predecessors including Faught and Stout who described the merging of dentistry and medicine a decade prior, the dental paradigm had shifted due in large part to the x-ray. Dentists changed from tooth technicians to medical professionals on the front lines of general healthcare.

### Technology

In his book “Clinical Preventative Dentistry,” H.R. Raper also reorients the x-ray in dentistry by describing it as the cornerstone of the new age of preventative dentistry. In this 1926 publication, Raper introduced a new technique, which he developed with the assistance of the Eastman Kodak Company, for taking radiographs, called the bite-wing

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<sup>93</sup> Mooney, “The importance of the dental surgeon.”

technique.<sup>94</sup> Raper called it a “five-film interproximal examination” because it reduced what was traditionally a set of ten images down to only five. Another option was to change a 14-film set to seven films. Raper’s technique was unique because, as illustrated in Figure 9, it shows the biting surfaces of the teeth, and not the tips of the roots, which had always been considered a necessity, as they were believed to be the location of primary focal infections.<sup>95</sup> Raper said that images of the roots were not needed to diagnose typical problems, like dental caries.



FIGURE 9: Raper’s sample image of the “new five-film interproximal examination.”<sup>95</sup>

Raper described his technique as being both more efficient for the dentist and more cost effective for the patient. The five-film set only required 5-10 minutes of the patient’s time. The images also cost the patient less money, especially when their use prevented more serious problems from arising. Raper’s believed that his technique was at the forefront of preventative dentistry. He stated that the most important thing to prevent was the pulpless tooth, which refers to the pulp of a tooth becoming necrotic due to infection. This is shown in Figure 10, which depicts the progression from surface decay (1) to an abscess at the root tip and the spread of infection to the surrounding tissues (4).

<sup>94</sup> Manson-Hing, L. R., “H.R. Raper: dental radiology pioneer,” *Oral Surgery, Oral Medicine and Oral Pathology* 46.3 (1978): 447.

<sup>95</sup> Raper, Howard R., *Clinical Preventative Dentistry: Based on a New Type of X-ray Examination*, (Rochester: Ritter Dental Manufacturing Company, Inc, 1926). Ibid.

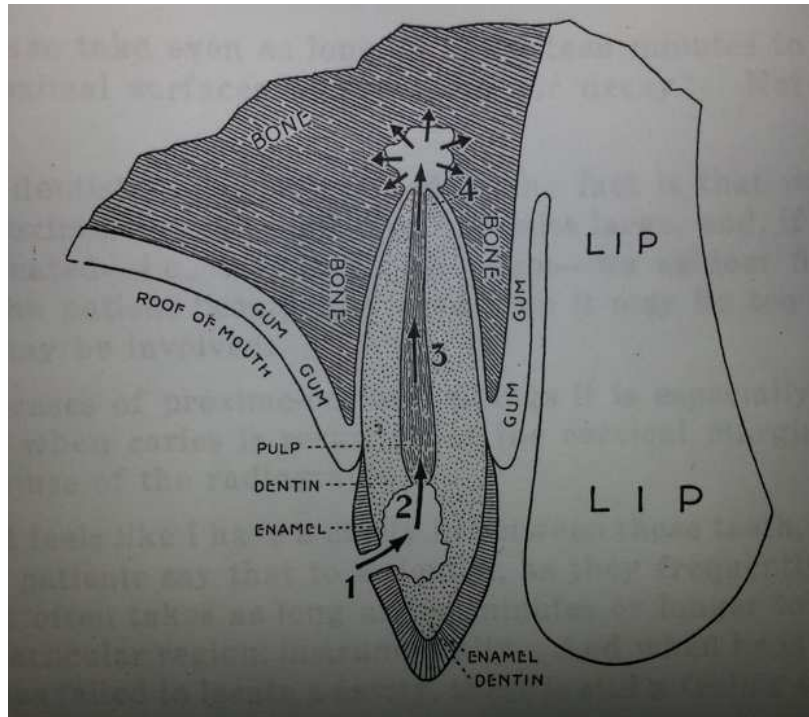


FIGURE 10: Raper's diagram of the progression (mild to severe) of dental infection.<sup>96</sup>

Raper believed that the five-film technique was perfect for preventative dentistry because it was simple and inexpensive. He also recommended that the images be taken during regular dental exams. He emphasized the importance of preventative dentistry by comparing dental caries to cancer; they both progressively cause more serious problems when untreated. Raper also staged the x-ray as a necessary device to engage in preventative dentistry.

The recent clean-up of septic mouths in America hung on the peg of the general X-ray examination. The future of preventative dentistry will, I believe, also hang on an X-ray peg.<sup>96</sup>

By describing dental caries as a major problem and x-rays being the solution, Raper created a new niche for an already heavily used device. He also showed how the

<sup>96</sup> Raper, *Clinical Preventative Dentistry*.

introduction of a new component of the technology, the technique, helped to secure its place in dentistry.

Following Raper's bite-wing technique, Gordon M. Fitzgerald also introduced an improved technique for taking oral radiographs in 1947. Expanding on the idea that radiographs were most accurate when the device is positioned parallel to the teeth Fitzgerald developed the long-cone paralleling technique. Fitzgerald's method produced clear and accurate radiographs. The basic principle behind the technique was that the x-ray device, the teeth and the film must all be parallel to one another.<sup>97</sup> The idea that the center of the x-ray beam should be in line with the center of the tooth led to the eventual modification of the shape of the cone (formerly, the glass vacuum tube). Instead of releasing the x-rays from a pointed tube, the shape became cylindrical to optimize Fitzgerald's technique.

In 1948, dental radiography took a major technological leap with Yrjo V. Paatero's invention of panoramic radiography. The device, which produced a two-dimensional image of the entire mouth, was unique because both the film and the x-ray beam were located outside of the mouth.<sup>98</sup> Figure 11 shows a patient in the process of having a panoramic radiograph taken. Panoramic radiographs are especially useful for dental specialists who work with the mouth as a whole, such as orthodontists.

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<sup>97</sup> Phinney, Donna J. and Judy H. Halstead, *Delmar's Dental Assisting: A Comprehensive Approach*, (Clifton Park: Delmar Learning, 2004).

<sup>98</sup> Glenner, Richard, "80 years of dental radiography," *The Journal of the American Dental Association* 90 (1975): 549—61. Ibid.

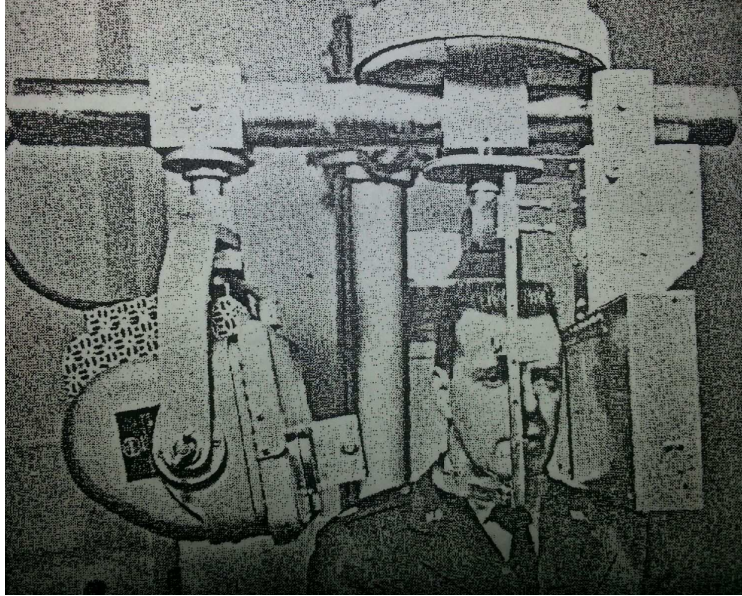


FIGURE 11: This image shows a patient using an early panoramic radiography device.<sup>99</sup>

In 1952 Albert G. Richards, a medical doctor, clarified the object localization technique created by C.A. Clark in 1909. The radiographic technique, which Richards called the “buccal object rule,” allowed dentists to see tooth structures that were typically hidden in a standard radiograph.<sup>100</sup> Richards explained that in order for these objects to be seen, two radiographs must be made—one that is aligned with the teeth and one that is at an angle. He then went into more detail about the technique in a 1953 paper. The buccal object rules made it possible for “radiographs...to portray structures and relationships more advantageously.”<sup>101</sup> This technique, a part of the technology itself, opened the scope of use of radiographs. Therefore, Richards’ clarification of the buccal

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<sup>99</sup> Glenner, “80 years of dental.”

<sup>100</sup> Richards, Albert G., “Roentgenographic localization of the mandibular canal,” *The Journal of Oral Surgery* 10 (1952): 325—9.

<sup>101</sup> Richards, Albert G., “The buccal object rule,” *The Journal of the Tennessee Dental Association* 33 (1953): 263—8.

object rule showed how to overcome problems with radiographs, making them more useful.

### Institutions

Marking thirty years since he had become involved with x-ray technology, Charles Edmund Kells published a review article in 1926, reflecting on what he believed to be important aspects of the x-ray. Kells, a prominent figure in the history of the x-ray, set a tone similar to Raper's; when defining the x-ray he described it as having "immense value to humanity, today."<sup>102</sup> By taking a reverent tone in his writing about x-rays, Kells made it seem like something that had become completely melded with dentistry. He also used this paper as a vehicle to comment on the new x-ray advancement of the year. Through the combined effort of the Victor Company and the American Telephone and Telegraph Company, radiographs were transmitted from New York to Chicago in only seven minutes and twenty seconds.<sup>102</sup> Kells described how it allowed two professionals to view the same images in a matter of only a few minutes. By referencing the movement in dentistry towards medicine, Kells implied that the new method of transmitting radiographs could contribute to the new focus of preventative dentistry.

The efforts of x-ray proponents like Kells were successful in making the use of x-ray devices in dental offices commonplace. In 1932, the American Dental Association (ADA) surveyed new dentists regarding office equipment. Of those recent graduates, 46 percent noted that an x-ray machine was one of the first pieces of technology that they

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<sup>102</sup> Kells, Charles E., "Thirty years' experience in the field of dental radiography," *The Journal of the American Dental Association* 13 (1926): 693—711.

had added to their new office.<sup>103</sup> This ADA data illustrates how quickly x-rays became a major component of the standard dental office. In only 30 years the x-ray machine went from obscurity to having a place in almost half of all new dental offices.

The formation of professional organizations also helped to spread information about x-ray technology to other dentists. In 1949, the American Academy of Oral Roentgenologists was formed. It was later renamed as the American Academy of Oral and Maxillofacial Radiology (AAOMR). Part of their purpose was to create a network of qualified dentists who could share information about oral radiography.<sup>104</sup> The creation of what would become the AAOMR also facilitated research and education initiatives. This group encouraged publication in journals for the use of other dentists, and public health outreach programs, which spread information about x-rays to the public. It allowed many different groups of people, not just dentists, to access x-ray information.

This period of time in the history of x-ray technology saw the development of new techniques and uses for x-rays. Technique improvements continued to make the device easier to use for dental professionals, while the framing of x-rays in the context of preventative dentistry further expanded the scope of use. These trends continued past 1950 in the form of panoramic x-ray technology, faster and safer equipment and digital imaging, making the x-ray a ubiquitous tool in American dentistry.

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<sup>103</sup> Glenner, “80 years of dental.”

<sup>104</sup> “About AAOMR,” American Academy of Oral and Maxillofacial Radiology,” accessed March 1, 2013, <http://www.aaomr.org/?page=VisionMission>.



## Chapter 5

### CONCLUSION

After only a century, the x-ray has developed into such a fundamental tool in the dental office that it is often grouped with anesthesia as one of the most important discoveries in the history of dentistry. In modern America, the x-ray outranks all other imaging technologies in frequency of use. In the United States, over 200 million medical-related x-ray scans are taken per year.<sup>105</sup> The foundations for the x-ray's ubiquity in dentistry were formed in the technology's first 50 years.

Between 1890 and 1904, people and technologies were important actors who influenced the spread of information. X-rays were experimented with and heavily discussed, which generated new knowledge about the device and even its safety. This was especially true for the dental field, which was the first medical specialty to use x-rays in practice.<sup>105</sup> The practical information and concerns that came about during the first decade were followed by a wave of technological changes. This period of the x-ray's introduction to dentistry was a time in which institutions began to get involved as well. Companies such as Victor X-Ray and organizations like the American Society for X-Ray Technicians were formed and influenced change. As a result the x-ray began to take the shape of an economic commodity that could be regulated by professional and governmental groups. Over the next 25 years, the x-ray became fully integrated into dentistry. Technologies like the x-ray machine and film induced change in technological

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<sup>105</sup> Kevles, Bettyann Holtzmann, *Naked to the Bone: Medical Imaging in the Twentieth Century*, (Reading: Helix Books, 1998).

efficiency as well as safety. As shown in Figure 12, the x-ray was a common part of the dental office by the end of the 1950s.



FIGURE 12: A photograph taken of a dental office in use in the early 1960s. The x-ray device is the large white machine on the left side of the image.<sup>106</sup>

This thesis focused on the changes that occurred between 1890 and 1955. This is because this was the time period in which the x-ray became pervasive in the dental field. Going into the latter half of the century, the technology was already well established in dentistry, which facilitated the development of several other technological, informational, and safety changes. Figure 13 distinguishes some of these changes. With the constant increase in use of the x-ray, technologies and institutions became more prominent actors than people after the 1950s.

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<sup>106</sup> Glenner, Richard, "How it evolved: the general dentist- early 1960's," *The Journal of the History of Dentistry* 48.2 (2000): 75—7.

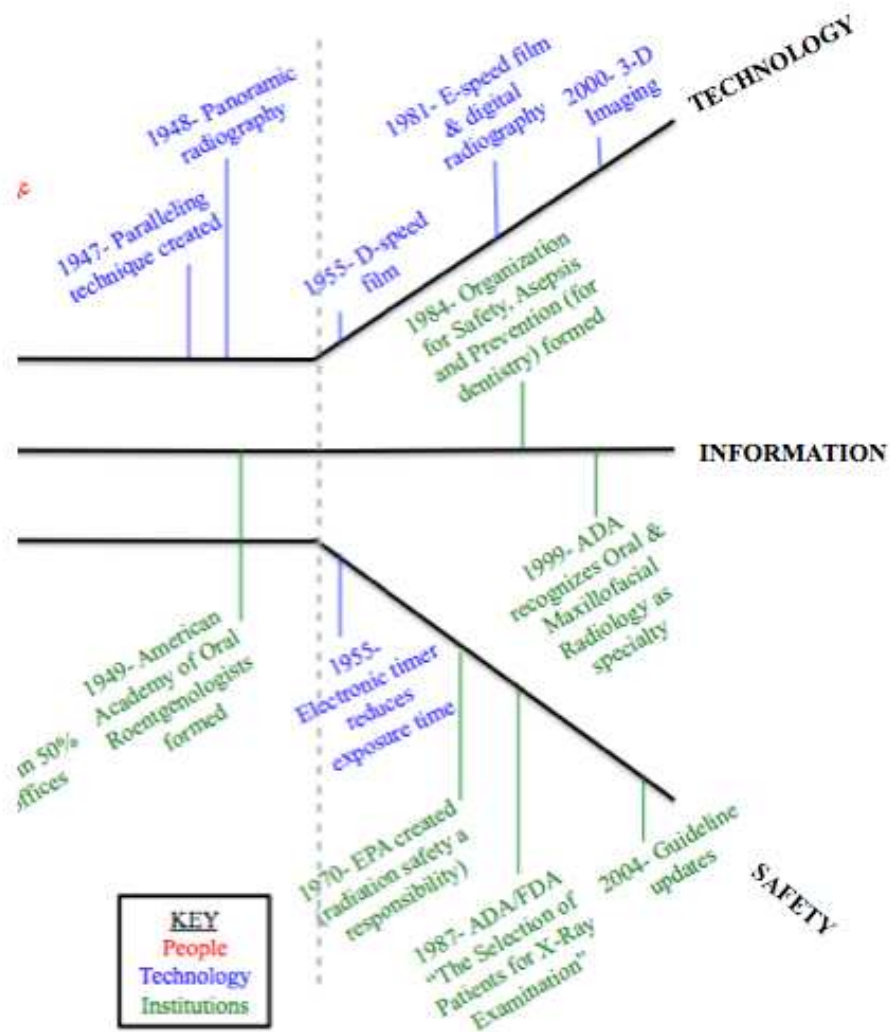


FIGURE 13: A piece of the Figure 1 diagram, this timeline shows important events in the development of dental x-rays from the 1950s forward.

During that time, technology continued to change to meet the needs of dentists. Film speed increased, which further reduced patient x-ray exposure time. In the 1980s, digital radiography was introduced, which decreased the radiograph process because it eliminated the need to develop the film. Computed tomography technology is also making three-dimensional images a reality. Information continues to be spread through groups like the Organization for Safety, Asepsis and Prevention, which is an authority on

safety and sanitation in the dental field. In 1999, the American Dental Association recognized Oral and Maxillofacial Radiology (OMR) as a specialty. Raper's 1915 recommendation for x-ray operators to have basic x-ray knowledge is coming to fruition with the OMR specialty. Safety has also progressed dramatically since Rollins' time. Technologies like the electronic timer reduced x-ray exposure time, while institutions such as the Environmental Protection Agency (EPA), the ADA and the FDA have all distributed responsibilities for regulating and establishing guidelines for the use of dental x-rays. As illustrated by the Oregon Board of Dentistry's inclusion of radiographs in their standard of care, the United States legal system is another important institution in the development of the dental x-ray.

The dental x-ray story is complex and has taken on a "capillary character."<sup>107</sup> This thesis has laid out the groundwork to explain how the x-ray and dentistry have become so tightly integrated with one another. A technology that helps dentists diagnosis, locate and treat oral issues, including impacted teeth and decay, the x-ray is also much more. Linked to this technology are stories of professional development, disease concepts and governmental regulations, all of which could be topics of further exploration.

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<sup>107</sup> "On actor-network theory," last modified 1997.

## REFERENCES

- “About AAOMR,” American Academy of Oral and Maxillofacial Radiology,” accessed March 1, 2013, <http://www.aaomr.org/?page=VisionMission>.
- “ADA/FDA Guide to Patient Selection for Dental Radiographs,” U.S. Food and Drug Administration, accessed January 22, 2013, <http://www.fda.gov/Radiation-EmittingProducts/RadiationEmittingProductsandProcedures/MedicalImaging>.
- Alcorn, Franklin. “Narratives: Radiology in Illinois.” Chicago Radiological Society, accessed February 16, 2013, [http://www.chi-rad-soc.org/crs\\_rad\\_illinois.html](http://www.chi-rad-soc.org/crs_rad_illinois.html).
- American Dental Association Council on Scientific Affairs. “The use of dental radiographs: Update and recommendation.” *The Journal of the American Dental Association* 137 (2006): 1304—12.
- Borden, W. C. “The use of the Röntgen ray by the medical department of the United States military in the war with Spain.” (1898).
- Campbell, D. “A brief history of dental radiography.” *New Zealand Dental Journal* 91 (1995): 127—33.
- Cirillo, V.J. “The Spanish-American War and military radiology.” *The American Journal of Roentgenology* 174 (2000): 1233—9.
- Clark, Charles A. “A method of ascertaining the relative position of unerupted teeth by means of film radiographs.” *Proceedings of the Royal Society of Medicine* 3 (1910): 87—90.
- Codman, E. A. “No practical danger from the x-ray.” *The Boston Medical and Surgical Journal* 144.8 (1901): 197—8.
- Dennis, John. “The roentgen energy to-day.” *The Dental Cosmos* 41 (1899): 853—7.
- Eisen, E. J. “Indications of dental radiography.” *The Dental Cosmos* 55.8 (1913): 782—4.
- Faught, Francis A. “The dentist’s relation to preventative dentistry.” *The Dental Cosmos* 50.1 (1908): 7—12.
- Fig. 2. Kurt Ard, Cover of the Saturday Evening Post. October 19, 1957.
- Forrai, J. “History of x-ray in dentistry.” *Rev. Clin. Pesq. Odontol.* 3.3 (2007): 205—11.
- Gaillard, Frank. “Tooth anatomy,” Radiopaedia, accessed March 1, 2013, <http://radiopaedia.org/images/847>.

- Gittinger, John W. "Radiation and cataracts: Cause or cure?" *The Journal of Archophthalmology* 119 (2001): 112—6.
- Glenner, Richard. "How it evolved: the general dentist- early 1960's." *The Journal of the History of Dentistry* 48.2 (2000): 75—7.
- Glenner, Richard. "80 years of dental radiography." *The Journal of the American Dental Association* 90 (1975): 549—61.
- Graskemper, Joseph P. "The standard of care in dentistry: Where did it come from? How has it evolved?" *The Journal of the American Dental Association* 135.10 (2004): 1449—55.
- Gutmann, James L. "The evolution of America's scientific advancements in dentistry in the past 150 years." *The Journal of the American Dental Association* 140 (2009): 8S—15S.
- Hedley, W.S. "Radiostereoscopy." *The Lancet* 151.3888 (1898): 639.
- Instruction Book Embodying the Use of the Modern Dental X-Ray Unit in Intra-oral, Stereoscopic Extra-Oral, Sinus Profile and Extremity Radiography.* Rochester. Ritter Company, Inc., 1944.
- Jacobsohn, P.H. and R.J. Fedran. "Harnessing the x-ray: Coolidge's contribution." *The Journal of the American Dental Association* 126 (1995): 1365—7.
- Johnson, C. N. "Some of the present problems in operative dentistry." *The Dental Cosmos* 63.10 (1921): 963—7.
- Kathren, Ronald L. "William Rollins (1852-1929): X-ray protection pioneer." *The Journal of the History of Medicine and Allied Sciences* 19 (1964): 287—94.
- Kells, Charles E. "Practical development of dental films." *Dental Items of Interest* 44 (1922): 927—37.
- Kells, Charles E. "Radiograph as a diagnostic aid." *The Dental Cosmos* 63 (1921): 816.
- Kells, Charles E. "Roentgen rays in daily practice." *Items of Interest* 20 (1898):892—3.
- Kells, Charles E. "Roentgen rays in practice." *Items of Interest* 20 (1898): 729—31.
- Kells, Charles E. "Roentgen rays." *The Dental Cosmos* 41 (1899): 1014—29.

- Kells, Charles E. "The x-ray in dental practice: The crime of the age." *The Journal of the National Dental Association* 7 (1920): 241—72.
- Kells, Charles E. "Thirty years' experience in the field of dental radiography." *The Journal of the American Dental Association* 13 (1926): 693—711.
- Kells, Charles E. *Three Score Years and Nine*. New Orleans: C. Edmund Kells. D.D.S., 1926.
- Kevles, Bettyann Holtzmann. *Naked to the Bone: Medical Imaging in the Twentieth Century*. Reading: Helix Books, 1998.
- Latour, B. "On Actor Network Theory: A few clarifications." (1997).  
<http://www.nettime.org/Lists-Archives/nettime-l-9801/msg00019.html>.
- Leopold, Lynne A. *Radiology at the University of Pennsylvania, 1890-1975*. Philadelphia: University of Pennsylvania Press, 1981.
- M. Hoing, R. T. *A history of the ASXT: 1920 to 1950*. Saint Paul: The Bruce Publishing Company, 1952.
- Mackee, George M. "Radiodermatitis following x-ray examination of the teeth." *The Dental Cosmos* 58.4 (1916): 428—9.
- Mackee, George M. and John Remer. "Measurement of the amount of x ray employed in making dental radiographs." *The Dental Cosmos* 56.1 (1914): 35—42.
- Macon, Francis A. "The interdependence of dentists and physicians." *The Dental Cosmos* 64.4 (1922): 441—6.
- Manson-Hing, L. R. "H.R. Raper: dental radiology pioneer." *Oral Surgery, Oral Medicine and Oral Pathology* 46.3 (1978): 447.
- Mayo, Charles H. "Dental research, its place in preventative medicine." *The Journal of the National Dental Association* 3.2 (1916): 167—71.
- "Milestones," The American Association of Oral and Maxillofacial Radiology, accessed on February 26, 2013, <http://www.aaomr.org/?page=Milestones>.
- Mooney, Bernard R. "The importance of the dental surgeon in medicine and the value of radiography in dental practice." *Journal of the Canadian Medical Association* 15.12 (1925): 1245—7.
- Morton, William J. "The x-ray and its application to dentistry." *The Dental Cosmos* 38 (1896): 478—86.

Morton, William J. and Edwin W. Hammer. *The X-Ray or Photography of the Invisible and its Value in Surgery*. New York: American Technical Book Co., 1896.

Pfahler, G. E. "The use of the roentgen rays in dentistry." *The Dental Cosmos* 50.9 (1908): 916—9.

Phinney, Donna J. and Judy H. Halstead. *Delmar's Dental Assisting: A Comprehensive Approach*. Clifton Park: Delmar Learning, 2004.

"Radiographs." *Oregon Board of Dentistry News* 27.1 (2012): 2.

*Radiography in Modern Industry: Fourth Edition*, Rochester: Eastman Kodak Company, 1980.

Raper, Howard R. "Uses and advantages of the x-rays as an aid to dental diagnosis, including the differentiation of the radiographic appearance of normal and abnormal tissues." *The Dental Cosmos* 57.5 (1915): 510—2.

Raper, Howard R. *Clinical Preventative Dentistry: Based on a New Type of X-ray Examination*. Rochester: Ritter Dental Manufacturing Company, Inc, 1926.

Richards, Albert G. "Roentgenographic localization of the mandibular canal." *The Journal of Oral Surgery* 10 (1952): 325—9.

Richards, Albert G. "The buccal object rule." *The Journal of the Tennessee Dental Association* 33 (1953): 263—8.

Rollins, William H. "Notes on x-light: the effect of x-light on the crystalline lens." *The Boston Medical and Surgical Journal* 148.14 (1903): 364—5.

Rollins, William H. "Roentgen-ray notes." *Electrical Review* 32.1 (1898): 12.

Rollins, William H. "X-light kills." *The Boston Medical and Surgical Journal* 144.7 (1901): 173.

Röntgen, Wilhelm C. "On a new kind of rays." *Science* 3.59 (1896): 227—31.

Ruprecht, Axel. "Oral and maxillofacial radiology: Then and now." *The Journal of the American Dental Association* 139 (2008): 5S—6S.

Satterlee, Francis Le Roy. "The x-ray in dentistry." *The Dental Cosmos* 48.3 (1906): 260—7.



- Schiff, Thomas. "Principles of intraoral imaging." *The Academy of Dental Therapeutics and Stomatology* (2012): 2—5.
- Stout, George C. "The borderline between dentistry and laryngology." *The Dental Cosmos* 53.1 (1911): 71—6.
- "The Selection of Patients for Dental Radiographic Examination," American Dental Association and U.S. Department of Health and Human Services, revised 2004.
- "The use of dental radiographs: update and recommendations." American Dental Council on Scientific Affairs, revised 2006.
- "Tooth (Anatomy)," Encyclopedia Britannica Online, accessed February 2, 2013, <http://www.britannica.com/EBchecked/topic/599469/tooth>.
- Tousey, Sinclair. "Recent work with the x-ray and high-frequency currents in the diagnosis of dental cases and in the treatment of pyorrhea and cancer." *The Dental Cosmos* 48.6 (1906): 637—9.
- Tousey, Sinclair. *Roentgenographic Diagnosis of Dental Infection in Systemic Diseases*. New York: Paul B. Hoeber, 1916.
- Van Allen, H. W. "The roentgen ray in dentistry." *The Dental Cosmos* 56.5 (1914): 587—91.
- Wade, Thomas B. "Interpretation of roentgenograms." *The Dental Cosmos* 60.8 (1918): 695— 700.
- Walden, Thomas L. "The first radiation accident in America: a centennial account of the x-ray photograph made in 1980." *Radiology* 181.3 (1991): 635—9.
- White, J. William. "A foreign body in the esophagus detected and located by roentgen rays." *University of Pennsylvania Medical Magazine* 8 (1896): 710—5.
- "William H. Rollins Award for Research in OMR." American Academy of Oral and Maxillofacial Radiology, accessed February 16, 2013, <http://www.aaomr.org/?page=RollinsAward>.
- Woodmansey, Karl. "Stereoradiography and related early radiographic localization techniques." *The Journal of the History of Dentistry* 58.2 (2010): 73—82.
- Wynbrandt, J. *The Excruciating History of Dentistry*. New York: St. Martin's Griffin, 1998. Print.

“X-rays,” Mouth Healthy- American Dental Association, accessed January 23, 2013,  
<http://www.mouthhealthy.org/en/az-topics/x/x-rays.aspx>.

“X-Rays: Dentist Version,” American Dental Association, accessed January 28, 2013,  
<http://www.ada.org/2760.aspx#safety>.

