CHAPTER 12

Endodontic Management of the Aging Patient

Harold E. Goodis[1] and Bassam M. Kinaia[2]

[1] *University of California School of Denistry, CA, USA; Boston University Institute for Dental Research and Education, MA, USA*
[2] *Department of Periodontology, University of Detroit Mercy School of Dentistry, Detroit, MI, USA*

Introduction

At the turn of the 19th into the 20th century, life expectancy was to the mid 50s in age. In the 21st century, men can live into their late 70s with women's expectancy estimated to extend into the mid-80s. The aspect of living longer does not necessarily mean that people will live better. In dentistry, extension of life expectancy has led to the need for care of the oral cavity using new methods, materials, and technologies. In many instances, this presents clinicians with challenges of care modalities that were not expected (Centers for Disease Control and Prevention, 2012). The dental needs of aging patient in the 21st century appear to be very different and more complex than those experienced by older patients in the mid to late 20th century (Chalmers, 2006a,b). As the population ages, people are taking more medications that may benefit their general health but not necessarily their dental or periodontal health (Ciancio, 1996). Because we are living longer, more people suffer from chronic medical problems and diseases than those whose lives ended in earlier ages. As written in a newspaper opinion piece, treating today's aging patients many times appears as if dentists are attempting to relate to very young children, but without the "giggles and glee" (Fieler, 2012). The writer remembers his father saying that there were parallels between "… caring upward and caring downward on the family tree." Many middle-aged people are caring for their parents, in their own home or in a managed care facility. Emotionally, everything appears to be backward "… taking care of someone who once took care of you." Mr. Fieler concluded with a profound statement, "… the lessons your children don't want to hear from you today are the same ones you don't want to hear from them later." That sentiment causes patients who are aging of attempting to understand the need for procedures that they don't expect nor understand. Therefore, the need for a root canal procedure can be daunting to them. Explaining not only the need for such a procedure but what it entails as far as what is done to a 70, 80, or even a 90-year-old patient may take up more time than one can imagine.

The need for dental care in aging patients is a multiphase situation and those needs grow yearly. Many of these patients will receive necessary care but many won't, primarily because of what occurs in teeth and oral soft tissues that many care providers have never treated. Therefore, this chapter will discuss the treatment regimens used in root canal therapy of older patients, compare, when applicable the form and function of the tooth, dental pulp, and dentin in young versus aging individuals, and the management of this treatment modality in an environment much different than that usually seen in private practice. The reader will find that, in many instances it is impossible to describe either clinical findings or step-by-step procedures. However, references to appropriate, published articles from refereed journals and textbooks will be suggested to supplement the information in this chapter. Thus, the following will be divided into a discussion of the structure of the inner and outer tissues of the tooth and the changes that occur over time, both physiologic and pathologic, that lead to a different

Geriatric Dentistry: Caring for Our Aging Population, First Edition. Edited by Paula K. Friedman.

Companion website: www.wiley.com/go/friedman/geriatricdentistry

way of treating a large group of patients who need what can be considered primary care.

The dental pulp

The developing soft tissue of an adult and aging individual's tooth is a complex tissue surround by relatively hard tissues (Figs 12.1a,b & 12.2a,b). The dental pulp has several functions in a developing tooth, but in an adult tooth the pulp functions in a manner that is protective in nature. The protective mechanism, as in tissues throughout the body, warns us when something is wrong. In the pulp, the peripheral sensory nervous system composed of two types of pain fibers (neurons) and functions in a way that not only warns the individual that there is a problem but leads, in many instances, to proper diagnoses and treatment plans (Hargreaves *et al.*, 2012). These neurons are called the A delta and C fibers and, because they are located in different areas of the pulp, respond to different stimuli. The response is usually one of pain that may differ in length, severity, location, and stimulus (Hargreaves *et al.*, 2012).

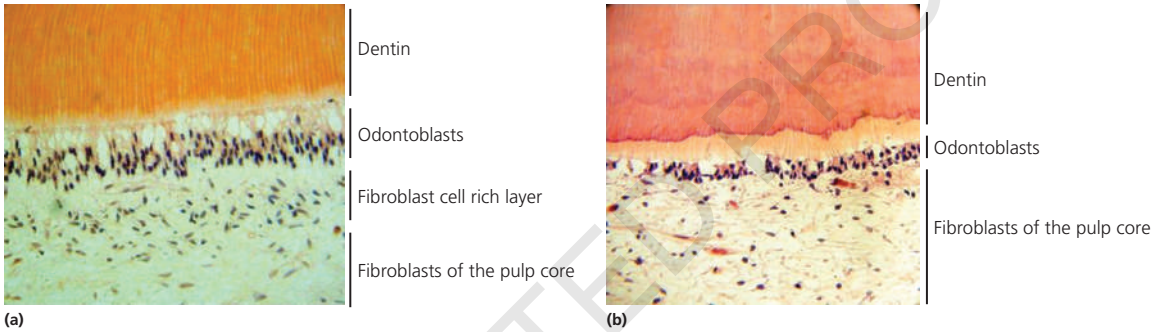


Figure 12.1 (a) Histologic section of the dental pulp complex of a young tooth (15 years old). Note the dense odontoblast and cell-rich zones. (b) Histologic section of the dental pulp complex of a 59-year-old patient. Note the lesser number of odontoblasts present. Figures courtesy of Dr. Peter Murray, Nova Southeastern University.

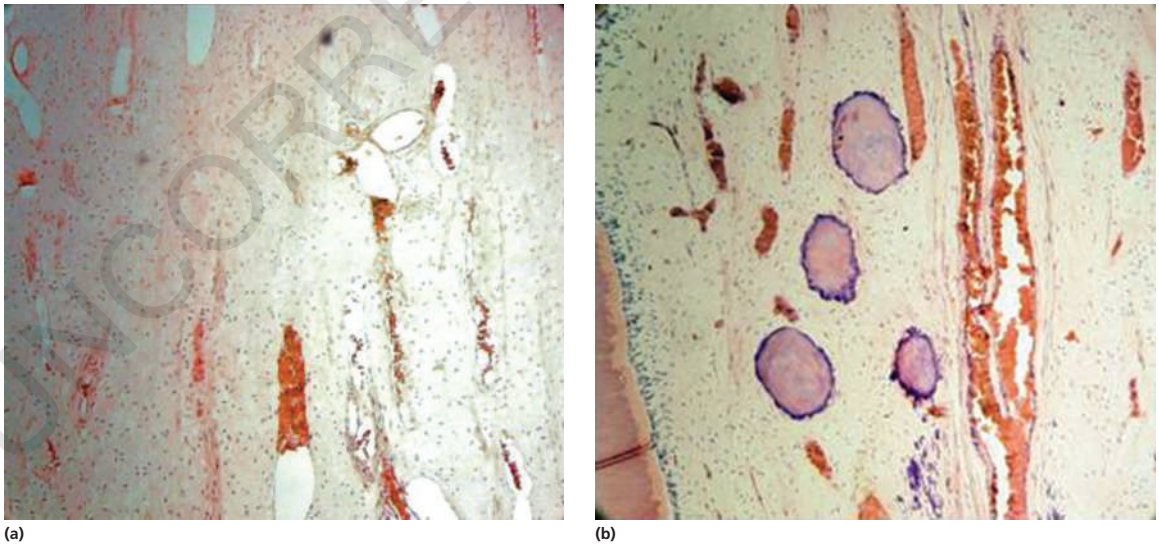


Figure 12.2 (a) Histologic section of the dental pulp complex of a young tooth (15 years old). Note the highly vascularized tissue. (b) Histologic section of the dental pulp complex of a second 59-year-old patient. Note the lesser number of odontoblasts present. Also note the calcifications found in the pulp tissue. Figures courtesy of Dr. Peter Murray, Nova Southeastern University.

The dental pulp has an infinite capacity to heal itself, not an unusual event in the body as many tissues do the same when injured. Pulp tissue submitted for histologic examination demonstrated the effects of multiple challenges to the tooth, including caries (initial and recurrent), marginal bacterial microleakage of restorations, direct trauma, and iatrogenic procedures such as cavity preparation (Bernick & Nedelman, 1975; Hillmann & Geurtsen, 1997; Nielsen, 1983; Stanley, 1961). All affect the pulp, causing an inflammatory response, which will initially be pathologic, but can become physiologic, since the initial inflammatory response can lead to repair with possible regeneration of the pulpal tissue (Cooper *et al.*, 2010).

The dental pulp tissue is considered a low compliance tissue due to its location and the types of tissues surrounding it (Kim, 1985a). First, the pulp is a relatively large volume of tissue with a relatively small vascular supply. The largest artery to enter the pulp is the arteriole and the largest vessel to exit the pulp is the venule; therefore, the vascular system is referred to as a microcirculation. Second, the pulp is a terminal circulation with few, if any, vessel anastomoses. Multirooted molars have demonstrated anastomoses in the root portion of the tooth. Therefore, the ability to shunt blood from and to an inflamed area is not possible and may compromise repair when injury occurs. Last, the pulp is surrounded by relatively hard, unyielding, dentin walls, which inhibits and, in many instances, completely suppresses the ability of the pulp to swell, as occurs in other soft tissues such as skin and muscle (Kim, 1985b). Taken together, the above mitigates toward an adverse ability to be protective in nature as it is designed to be. In sum, the potential for the dental pulp to repair itself is infinite. However, aging individuals have limitations for repair or regeneration of pulpal tissues due to limited blood supply, sensory deficits due to fewer neurons, and reduction of the pulp canal space resulting in less tissue available for repair to occur (Bernick & Nedelman, 1975). Therefore, the evidence points to the need for well-controlled root canal therapy to retain a tooth that may appear to be the easiest treatment rather than the best treatment (Trope, 2008). The potential of the dental pulp for healing is limitless. However, aging individuals have limitations for repair and regeneration. This is due to a limited blood supply, sensory deficits due to fewer neurons, and lesser amounts of pulp tissue due to continued mineralization of the tissue space (Trope, 2008).

Dentin and the odontoblasts

Normally the pulp of the developing and adult tooth, as described above, has the ability to form the matrix that becomes three types of dentin. Primary dentin is formed as the tooth develops with a structure that is tubular in nature. Secondary dentin begins to form as the tooth completes its form and erupts. It also contains a tubular structure with its tubules being continuous with those of primary dentin. The formation of

Figure 12.3 (a) A 9-year-old patient with typically young incisors. Note the size of the root canal systems and the incomplete root end development of the three teeth pictured. (b) A 44-year-old patient with restored maxillary central incisors. Note the great change in the size of the root canal spaces, partially attributed to the mesial and distal deposition of tertiary dentin due to composite placement. (c) Maxillary right lateral incisor and central incisor of a 73-year-old patient. Note the absence of restorations with no history of trauma. When compared to Fig. 12.9, the physiologic deposition of secondary dentin is evident. Figures courtesy of Dr. Franklin Tay, Medical College of Georgia.

secondary dentin continues throughout the life of the tooth and is physiologic in nature, unless there is an injury or challenge to the pulp (Smith *et al.,* 1994, 1995) (Fig. 12.3a,b,c). Tertiary dentin generally occurs in teeth that have been injured in some manner (i.e., caries). It is not tubular in its formation but rather occurs as a solid kind of structure.

The importance of dentin cannot be overstressed. Therefore, it is the dentin that in fact may be considered as the partner to the pulp due to its location adjacent to the pulp (the pulp–dentin complex). Dentin's tubular structure contains pulpal fluid and the projecting arm of the odontoblast, the odontoblast process. The odontoblast is responsible for the initiation of dentin matrix formation that becomes mineralized over time and again acts as a protective mechanism (Holland *et al.,* 1985, 1994). The odontoblasts do not undergo mitosis nor they are replaced, unless the pulp is challenged, and continues to act as stated above. However, given the fact that humans are living longer, it is apparent that continued formation of secondary dentin may begin to narrow the root canal space as individuals age to a point that it may be difficult to perform a root canal procedure. Men will demonstrate narrowing of the root canal space in their 40s and it is not impossible that the entire upper and middle portions of the root canal system may be mineralized (Woo, 2001) (Fig. 12.4a,b,c). This event is a reminder that a completely physiologic process may become a pathologic process due to aging (Fig. 12.5a,b,c). Tertiary dentin is the last form of that hard tissue. It forms in response to an injury to the pulp caused by caries etc. Tertiary dentin is not physiologic but pathologic. Its matrix mineralizes as an atubular structure in response to placement of certain materials next to or over an exposed pulp. Tertiary dentin is of two types: reactionary where the dentin matrix is formed by surviving odontoblasts; and reparative dentin formed by a generation of new odontoblast-like cells, which are cells that may act differently than the original cells (Pääkkönen *et al.,* 2009). The formation of tertiary dentin in response to a stimulating type material, such as calcium hydroxide ($CaOH_2$), also narrows or closes the root canal space, but much more rapidly than secondary dentin. The new dentin formed also may lead to further closure of the root canal space and cause a nonresponse to temperature stimulation.

A normal dental pulp demonstrates its ability to survive throughout life. As mentioned above, the odontoblast, with its process extending into the dentinal tubules, is the cell responsible for formation of the dentin matrix. When caries are present (Stanley, 1977), and initially removed, the odontoblastic processes are cut, effectively causing the odontoblast to die. There are sufficient numbers of odontoblasts so that dentin continues to form. However, repeated placement or replacement of restorations, combined

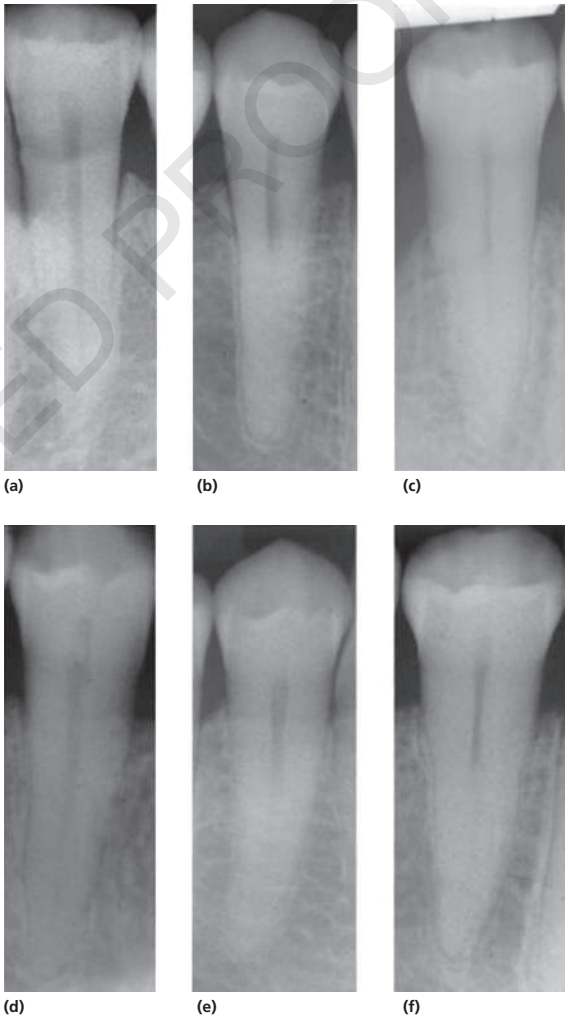
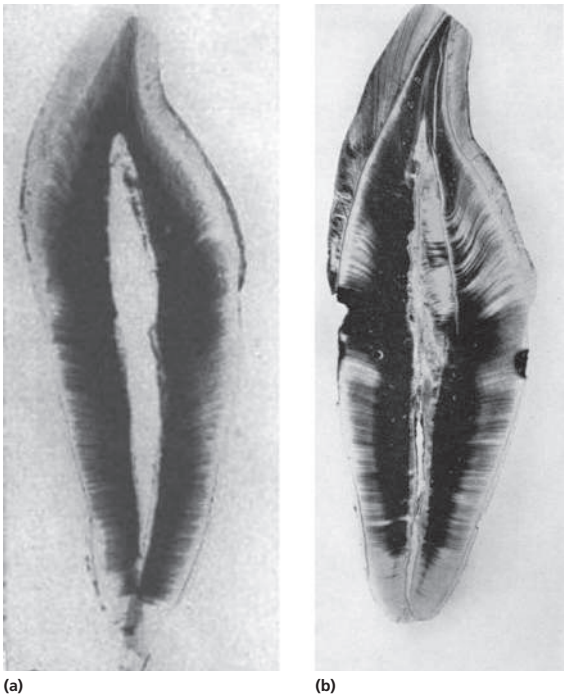


Figure 12.4 Periapical radiographs of a premolar taken of a male patient at three times over a 40-year period. (a) Mandibular first premolar at age 33. The root canal system can be seem to the apex of the tooth. (b) The same tooth at age 52. (c) The same tooth at age 73 years. The same pattern is seen in a second patient at the same time frames (d, e, f). Courtesy of Woo, 2001.



(a) (b)

Figure 12.5 (a) Low power photomicrograph of an unstained root canal space (ground section) of an upper central incisor typical of a 26–30-year-old individual. Note the size of the root canal space (Original mag. ×20). (b) Low power photomicrograph of an unstained root canal space (ground section) of an upper central incisor typical of a over 71-year-old individual. Secondary dentin fills the entire pulp chamber of the root canal space. Note that the secondary dentin formation is tubular as opposed to atubular dentin. Its formation is due to age and not to caries or placement of restorations. Courtesy of Philippas & Applebaum, 1966.

with marginal bacterial microleakage, may cause all odontoblasts in the area to die; therefore, the remainder of the tissue depends on formation of odontoblast-like cells to form a matrix that will result in tertiary dentin (About *et al.*, 2001; Couve & Schmachtenberg, 2011; Couve *et al.*, 2012; Murray *et al.*, 2000). Eventually, the remaining pulp tissue becomes overwhelmed and the remaining tissue becomes necrotic. In these cases, depending on the age of the patient, the patient's ability to sit for a period of time in the dental chair and the condition of the patient's teeth (caries, fractured cusps, lost restorations, periodontal status, and restorability), treatment choices may become overwhelming.

Sensory mechanisms

As mentioned above, the adult dental pulp attempts to function as a protective mechanism. As people age, the root canal space contracts, limiting the number of cells remaining in the pulp to be able react positively to an adverse stimulus. Therefore, aging also leads to decreases in the number of sensory (pain) nerves present in the pulp (Bernick 1962a, 1967a; Fried, 1992; Fried & Hildebrand, 1981; Matysiak *et al.*, 1986, 1988).

The presence of tertiary dentin may be capable of blocking peripheral pain fibers from being stimulated in a manner that will allow the patient to sense pain. Contracture of the pulp space limits the amount of pulp tissue present and can affect those remaining nerves in the body of the remaining pulp tissue, again limiting the ability to respond to an adverse stimulus. These events may compromise patient's responses to tooth testing, especially to applications of testing with cold or heat. The responses occur through stimulation of sensory neurons located in and around odontoblasts and within the body of the pulp. More recent studies appear to indicate that odontoblasts also may have a sensory function (El Karim *et al.*, 2011; Magloire *et al.*, 2010; Okumura *et al.*, 2005; Son *et al.*, 2009). This is an important finding since aging individuals have fewer odontoblasts and, if the pulp has been injured, the odontoblast-like cells may not function as did the original odontoblasts functioned. These studies have expanded the sensory ability of the dental pulp to respond to injury, and indicates that the dental pulp sensory pain mechanisms are much more complex that originally believed.

Since the tissue responds to injury to protect the remaining pulp by formation of odontoblast-like cells, the neural response in these situations may or may not be diagnostic. The formation of tertiary dentin may prevent contracture of dentinal fluid and movement into the pulp through what now may be obliterated tubules; hence, no or weak responses to cold. On the other hand, the atubular dentin may block the ability of a heat stimulus from reaching the body of the pulp to allow increase in temperatures to a level that patients will respond to heat (Zach & Cohen, 1962, 1967). The pulp has a greater tolerance in young people to decreases in temperature, therefore indicating that a coolant must be cold enough to

elicit responses. The tissue is less tolerant to increases in pulp temperatures as responses generally occur with temperatures rising 5–7 degrees (Zach & Cohen, 1962, 1967) same comment as above. Ultimately, the main factor continues to be limitation of root canal space and decreases in the numbers of sensory neurons, lessening the patient's response being realistic.

Vascularity

The same limiting events occur with the vascular supply to the dental pulp. The microcirculation in normal pulp tissue maintains vitality. But as individuals age and the root canal system narrows due to continued secondary or tertiary dentin formation, fewer and smaller vessels are available to allow normal blood flow (Bernick, 1962b, 1967b, 1972). While the radicular vasculature is still effective, the gradual narrowing of the pulp volume indicates a diminished blood flow in the tissue (Domine & Holz, 1991). The metabolic ability of the dental pulp decreases gradually and the capillaries in the subodontoblasts become thinner with aging (Ma *et al.*, 1997). Interestingly, one could say that, of everything being equal, an individual living well into his or her 90s, who presents with what appears to be a completely calcified root canal system, would have been thought to have a perfect root canal without treatment. However, a remnant of pulp tissue remains apically but has no blood supply, and a lesion will be seen apically on a radiograph. Such a case would eventually require treatment, most often surgery. Unlike an event due to trauma, a 90-year-old patient's root canal closure would be due to a normal physiologic event of secondary dentin deposition throughout life. If that patient should require surgery, the situation and management changes and, depending on the health of the patient, treatment becomes more difficult (Eldarrat *et al.*, 2010; Kvaal *et al.*, 1994).

Management considerations

Diagnosis

Tooth testing

The need for a correct diagnosis in any treatment situation is a necessity. Tooth testing can be quite subtle or quite dramatic. The subtlety of endodontic diagnosis is being able to understand pain responses to temperature changes and other stimuli to understand whether the patient presents with a reversible or irreversible pulpitis. For example, a response to a cold stimulus that disappears as soon as the stimulus is removed from the tooth is generally a reversible pulpitis. This indicates that the problem is something other than an irreversible pulpitis, as seen in fractured cusps, caries, or recurrent caries. The key to the diagnosis is that the symptom occurs because underlying dentin has been exposed. Covering the dentin with a new restoration after caries removal or removal of a fractured cusp tip ends the pain. On the other hand, a response to a heat stimulus that lingers for some time or beginning many seconds to a minute or two after removal of the stimulus is indicative of an irreversible pulpitis. In older patients, these responses can be quiet dramatic, with loud and painful responses and a look that will say that the patient believes he or she is in the wrong office.

As stated above, tissues change in the aging patient. While dentists are capable of making a correct diagnosis in older patients, they must remember to be more "patient" with their "patients" who are older. An axiom of tooth testing for pulpal and periradicular diseases, whatever the age of the patient, is to **listen to the patient!** So often, especially in a busy practice, practitioners think that they can take a radiograph and immediately form a diagnosis and treatment plan without patient input. Believe it or not, patients do have a clue as to which tooth is causing the problem. However, with older patients, especially those experiencing pain and with a history of several medical conditions, the dentist must understand the possible difficulty of getting to the "root" of the problem.

First, aging patients tend to be more anxious, thinking that everything touching a particular tooth causes pain. They will try to help by responding immediately to a temperature test when a cotton swab without a stimulant touches their tooth. When asked what they felt, they can't say. Therefore, each and every test used in the diagnostic process must be thoroughly explained to the patient. There have been many older patients who respond to a stimulant placed on the pontics of a fixed appliance. (A not uncommon event in the author's office [H.E.G.].) Second, they ask many questions, sometimes asking the same question several times, either because they

don't understand or have a dementia and don't remember the answers. Older patients also have the need to attempt to dictate what type of treatment they require. It is, therefore, necessary to schedule more time with aging patients than normally would be required for a younger patient. Remember again that an aging patient's responses are not necessarily what a younger patient would report. With the root canal space compromised, either physiologically or pathologically, there may be no response to temperature-testing methods in what may ordinarily be a reversible pulpitis that turned into an irreversible pulpitis, because of recurrent caries or a fractured tooth structure present that can be treated without a root canal procedure. This may complicate the necessary treatment. A necrosis with a sinus tract and radiographic evidence of a lesion may be the easiest diagnosis to make and treat. The use of an electric vitalometer, especially after explaining how the device works, will sometimes frighten an older patient. Because of its limited ability, due to the need to be used only on tooth structure, in routine testing it should not be used for the aging patient. Older patients will always tell their friends how they were "electrocuted" in the dentist's office. A good rule to follow is to never test the suspected tooth first. Test the adjacent, opposing or contra-lateral tooth first, then the suspected tooth last. This not only demonstrates to aging patients that they will not be hurt, it will also be a baseline for the patient's responses.

Once the dental pulp becomes inflamed, the overriding symptom is the onset of pain. Since the volume of tissue in the root canal space of a young individual is relatively large, as opposed to older patients with much less tissue, diagnosis generally does not pose problems. Testing regimens are based on careful questioning of the patient to elicit as much history and information as possible. The input from the patient leads to the type of tooth testing that may be necessary to properly diagnose the problem. Since pain to temperature, either hot or cold, is a cardinal symptom of a pulpitis, this may be the best place to start. This, of course, occurs after a full intraoral and extraoral examination.

In many instances, symmetry of facial areas will have changed due to internal swelling in the mouth. Therefore, the testing begins with the easiest and most common tests prior to other, more complicated tests. When a necrosis is suspected and the pain complaint comes from chewing hard food or swallowing, with normal occlusion, the use of a mirror handle to gently percuss teeth is enough to cause a response. Differentiating between pain when percussing in a vertical direction, for periredicular pain, and in a bucco-lingual direction helps in understanding the possibility of a periodontal problem rather than an endodontic problem. (Don't forget to take periodontal gingival sulcus readings.) Biting on a wet cotton roll, use of a Tooth Sleuth, or percussing individual cusp tips may disclose the presence of a hard tooth structure fracture that certainly will change the diagnosis and may change the prognosis. The use of the ball of the index finger in the palpation test can pick up disease quickly and effortlessly; slight pressure in the cul-de-sac area is used to define sensitivity.

Since presence of vital tissue is necessary in the crown of the tooth for a response to temperature testing, a problem exists with a nonresponse in older patients. With gingival recession and closure of the root canal system, the remaining pulp tissue may be well below the cervical area of the tooth; hence, a possible nonresponse from an older patient. There is a possibility of periodontal recession that exposes dentinal tubules which curve down and then up to reach the pulp, the hot or cold stimulus may be placed somewhat lower towards the gingival crest of the tooth in an attempt to have a response. Care must be taken in these cases not to involve the soft tissue of the gingival crest which will result in a false positive. If radiographs disclose no periodontal ligament thickening or a radiolucent lesion and pain is the only symptom or sign, difficulties increase as to making a correct diagnosis. Keep in mind the difficulty of attempting to pulp test a child 3–5 years of age. That will make one understand the difficulty of testing that child's aging grandparents, who are brought to the dentist by the child's mother or father. A retrospective study concluded that general practitioners were able to detect radiographic changes when they are extensive, but they miss periodontal ligament widening and lamina dura changes (Sherwood, 2012). Remember that loss of restorations, secondary or recurrent caries, and fractured cusps, among other coronal conditions must be intercepted early enough to either prevent a pulpitis from occurring or from suffering the sequelae of a necrotic tooth.

Radiographs

The above is predicated on the fact that properly angled and exposed radiographs have been taken. This part of diagnosis is placed here as, while radiographs are incredibly important, too often dentists will take them first, glance at them when developed or if digital, and never look at them again. Hence, the placing of a radiographic discussion here after the discussion of tooth above is important. The dentist must return to view the radiograph after the information of listening to the patient, extraoral and intraoral examinations completed, with tooth testing having been generated. Ordinarily, the presence of a radiolucency at the apex of a tooth that doesn't respond to testing indicates a necrotic pulp with extension to the periradicular area. That is particularly true in a younger patient but not necessarily true in an aging patient. Being able to diagnose between a lesion of endodontic origin (LEO) and other pathologic entities can be delicate. Obviously, younger patients will present with a greater ability to represent their symptoms and dental history than an aging patient. Simply put, more than one radiograph needs to be taken at a different angle (mesio-distal) after the fully parallel position of the first film. If the lesion moves in the angled film, it's probably not a LEO. If the pulp tests are normal and there were no symptoms, the lesion will be a lesion other than a LEO; this is true in young and aging patients. Additionally, the angled film may better describe the number of roots present or dilacerations of roots not seen in the first film.

There is a very subtle situation that causes dentists to err in a diagnosis. It is referred to as a thickened periodontal ligament (PDL). Most dentists have never heard of or have forgotten that this entity exists. For example, a young patient will present with radiographic evidence of a thickened PDL. Confounding to the dentist – who believes that the symptoms indicate a pulpitis, which is confirmed by the tooth-testing results being positive to cold but with symptoms not lingering – an irreversible pulpitis is diagnosed and the dentist immediately begins a root canal procedure. As presented above, stimuli responses to cold are expressive of a reversible pulpitis, with exposure of dentin. To have this response in an older person with radiographic evidence of coronal closure of the root canal system may indicate that a deeper fracture is present that extends to the lower lever of the pulp tissue. The subtly of a thickened PDL comes from knowing that it generally indicates a reversible pulpitis (find the exposed dentin, treat it), not an irreversible pulpitis. Remember that conventional radiographs used for diagnosis and management of endodontic problems result in limited information because of the two-dimensional nature of the images produced or the geometric distortion produced by the angulation. (Patel *et al.*, 2009) (The reader is referred to Berman & Hartwell, 2011, and other endodontic texts for a more detailed discussion of endodontic radiographs.)

Other methods of radiographic examination are presently being suggested to increase the ability of the dentist to make a correct diagnosis. Laser Doppler flowmetry (LDF) measures the presence or absence of blood flow in the pulp tissue. The device passes a laser beam through tooth structure that interacts with the red blood cells. The interaction causes a signal to bounce off of the blood cells, that are picked up by a receiver device. The resultant value is automatically converted to a number that indicates flow. The use of this device is limited as the laser beam will not go through metallic restorations and must be carried out in complete quiet with little or any type of airflow. In some instances, someone walking near the device will cause deviations in the values generated. The blood flow from gingival tissues also can cause marked deviations in the readings. However, when the environment is controlled, LDF can be used for research. One study tested 8–75-year-old participants' pulpal blood flow (PBF) at different ages. Resting PBF decreased with increasing age, indicating a smaller mass of tissue with fewer vessels. When cold was applied to the crown, all blood flow decreased with significant in aging patients (Ikawa, 2003; Jafazadh, 2009). Laser wavelengths also may become the method of choice for cleaning and shaping root canal systems, but the science still in not quite there. Lasers are suggested for treating sensitive dentin and other clinical methodology (Stabholtz *et al.*, 2004).

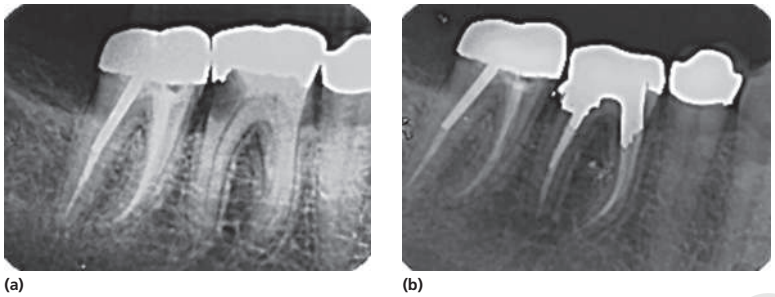
Cone beam computed tomography (CBCT) is presently being tested as having the ability to image oral structures (soft and hard tissue) three-dimensionally. Tests using extracted teeth or other models mimicking the mandible or maxilla with human teeth in place, demonstrated that ability (Gani & Visvisian, 1999; Hassan *et al.*, 2009; Ozer, 2010; Wang *et al.*, 2011). Patel and colleagues were able to detect periradicular

pulpal disease before the disease process had perforated either cortical plates of bone when the lesion could not be seen by periradicular radiographs (Patel, 2009; Patel *et al.*, 2009). This has been increasingly utilized in the oral cavity (Agematsu *et al.*, 2010; Kaya *et al.*, 2011; Maret *et al.*,2011; Silva *et al.*, 2012). CBCT has not become standard of care in endodontics as the ability to see apices in most devices is not acceptable and it does not justify the extra expense. However, use of micro-CT devices in research (not clinically because of increased radiation and cost) demonstrated that decreases in interpulpal space due to secondary dentin in extracted teeth were higher in women than men. Space decreases occurred more often in older men in their 50s and 60s and in women in their 40s and 50s (Agematsu *et al.*, 2010). CBCT has greater utility for imaging maxillofacial areas (Maret *et al.*, 2011). Others suggest the use of CBCT to evaluate changes in root canal anatomy and morphology as individuals' age, which may allow more teeth in aging patients to be treated (Kaya *et al.*, 2011). *In vitro* studies compared the use of CBCT between periapical radiographs and CBCT in detection of artificial perforations in extracted teeth (Tyndall & Kohltfaber, 2012; Tyndall & Rathore, 2008). For the detection of periapical pathoses, Patel *et al.* (2012) found that CBCT demonstrated a lower healing rate for primary root canal therapy than that seen in periapical radiographs, particularly in molars. In teeth with existing preoperative periapical radiolucencies, CBCT images showed more failures (14%) compared with periapical radiographs (10.4%) (Patel *et al.* 2012).

Treatment methods

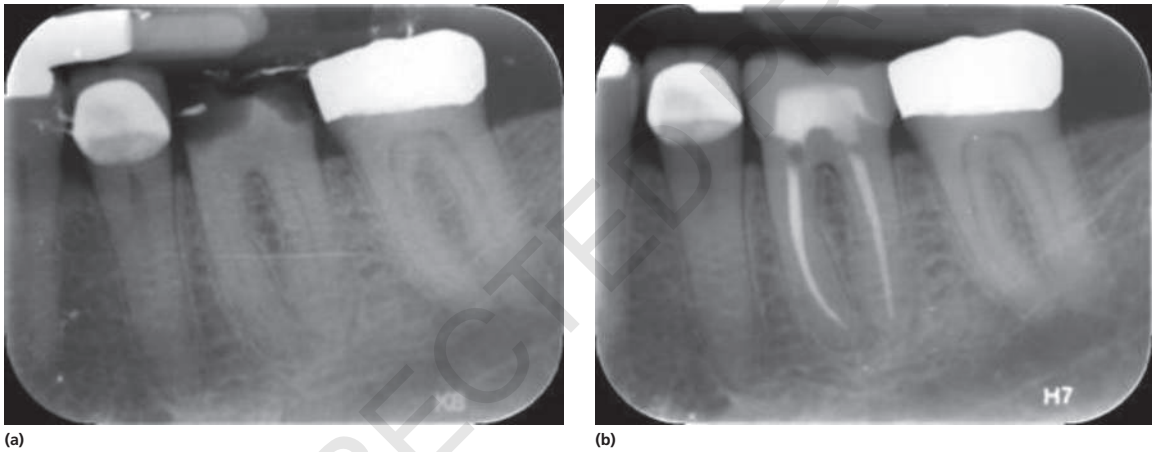
The late 20th century onwards has seen new treatment methods and materials brought to the market place. The advertising of these products implies that, if used as directed, time will be saved and procedures will be much easier, quicker, and better. This will allow the practitioner to see and treat more patients, earn a better income, and live the good life. While many of the products and devices (operating microscope, rotary instruments), when used correctly, may lower the stress levels of practitioners, they are not the new wonders of the modern world. Endodontists will say endodontics is labor intensive. The endodontist knows that he or she must sit at the chair, anesthetize a patient, and access, clean and shape, and obdurate the root canal systems of the tooth to be treated. There are no short cuts. The new materials and devices certainly help, but each generation has its own new instruments and materials and endodontics remains a labor-intensive treatment modality. A successful root canal procedure connotes that diseased tissue has been removed from the root canal system and the tooth, with proper restoration, can be returned to original form and function (naturally, if it is periodontally sound or can be made so). This is a noble objective but not necessarily true, especially when treating aging patients on a regular basis. Goodis *et al.* (2001) surveyed Diplomates of the American Board of Endodontics in the changing demographics of their practices, with emphasis on the ages and numbers of the patients referred to their practices. Respondents reported that smaller root canal spaces more commonly occurred as the aging numbers of patients referred increased. The change in the size of the canals did not, however, compromise the success of their treatment (Figs 12.6a,b,c & 12.7a,b). Rather, it was the poor condition of the aging patient's teeth that caused the most problems. While acknowledgment was made to the greater difficulty in locating and treating smaller canal systems, most respondents spoke to the need of more studies that would lead to treating patients earlier using materials that would not cause closure of those same canal systems, and to the breakdown in dentitions and periodontal tissue breakdown that would require these procedures in aging individuals (Goodis *et al.*, 2001). The treatment of an aging patient in many instances may not necessarily be more difficult than treatment in a younger patient. It just may take more patience and time to complete treatment successfully.

As the US aging population has increased, other studies over the past 25 years have examined management considerations in this population (Galen, 1990). In the 19th century, and well into the 20th century, treatment consisted of removal of all the teeth that possibly could have been saved and their replacement with dentures. "If it was good enough for my father and mother, it's good enough for me." As reported by Walton (1997), the biologic and anatomic differences in the dental pulp and dentin between young and aging individuals must be understood and considered in the diagnosis, treatment planning, and actual treatment. Older patients are



(a) (b)

Figure 12.6 (a) Radiograph of a lower left first molar with little or any coronal structure remaining in a 67-year-old male patient. The patient's dentist suggest the tooth's removal and placement of a crown-restored implant. Note the thinness of the root canal systems, probably due to tertriary dentin formation. (b) Radiograph of the same tooth after endodontic therapy and placement of a crown. Courtesy of Dr. Franklin Tay, Medical College of Georgia.



(a) (b)

Figure 12.7 (a) Radiograph of a lower right first molar in a 71-year-old male patient. Note the large carious lesion at the distal gingival margin below the restoration with successful root canal therapy in the second molar. (b) The caries has been removed and packed with amalgam and the tooth has a second root canal treatment. This case was seen by a periodontist who told the patient that it could not be retained and a crown restored implant would be a better treatment.

more likely to have complex medical histories (strokes, heart disease, diabetes, dementias). This also is a product of living longer. One or another, by itself, may be daunting in successfully completing care (Quantrough & Mannocci, 2011). The dentist today must be willing to vary how he or she treats the aging patient in relation to number of visits, different chair positions for the patients and the practitioner to accommodate physical disabilities, and working more closely with caregivers. It may be necessary to travel to homebound individuals to provide adequate care, which, in most instances, is the most difficult of conditions, requiring portable equipment, supplies, and room to deliver proper care.

Emphasis must be placed on the retention of teeth in order to maintain the ability of patients to properly chew for normal mastication. The knowledge that older patients' teeth may be badly broken down and/or heavily restored makes treatment extremely challenging (Allan & Whitworth, 2004; Qualtrough & Mannocci, 2011). The authors stress the need for strategic treatment planning and preservation of key teeth, even when diseased, to protect and retain natural teeth and associated soft tissue and bone. Age-related changes in the structure of dentin and pulp occur that require knowledge of new endodontic procedures and new instrumentation (Burke & Samarawickrama, 1995).

Endodontic therapy of aging patients

Appointments

Endodontics mostly has become a one-appointment discipline, with root canal system cleaning, shaping, and obturating the root canal space. Obviously, the time scheduled for an aging patient is dependent on the patient being able to sit in a normal dental chair and be reclined when required. If needed, more time can be scheduled, which may ease the patient's ability to sit for treatment. Aging patients will present with canes and wheelchairs, and offices must be designed to handle slower walking or walking-assisted patients. This includes the dental chair, hopefully equipped with fold-down arms to allow ease of movement from a wheelchair or a walker to the dental chair.

Diagnosis

The first part of a diagnosis is listening to the patient. This is not actually a test, since all that is required is attention of the operator to what the patient is saying and the answers to questions asked by he or she. Listening to the patient applies both to young and aging patients. In most cases, absent senilities, the patient to be treated will have an idea as to where the problem is originating and what causes sensitivity.

Diagnosis involves the use of testing devices to elicit patient responses. Further, visualization of the surrounding soft tissue and underlying structure is required to locate pathoses. Devices to augment radiographs (digital films, CBCTs) will be useful in detecting radiolucent lesions associated with abscessed teeth. Accurately angled films are a must and their exposure is the second aspect of making a correct diagnosis.

Endodontic diagnosis depends both on external tooth testing devices applied to either natural tooth structure, or in many instances, to an artificial crown (metallic, ceramic, or combination). Use of percussion and palpation is an easy way to introduce an aging patient to tooth testing. The use of a mirror handle or the finger tip of the index finger is all that is needed. Percussion is a gentle tap to the crown of the tooth in an apical direction, keeping in mind to percuss each cusp of a posterior tooth. In many instances, sensitivity to the test will indicate a fracture, and a hard tap is not necessary (any tooth can be made to hurt if the stimulus is too strong). Biting on a wet cotton roll or on the Tooth Slooth also detects fractured cusps. Tapping in an apical direction and in a bucco-lingual direction distinguishes periradiular from periodontal disease and pain. Palpation is the easiest of tests as only the ball portion of the index finger is used. With the cheeks held away from the periodontium, the fingertip is moved anterior to posterior in the cul de sac above the apices of the teeth. Again, pressure applied should be very light. If slight swelling is present, the patient will indicate sensation much different than that on normal, not involved tissue. The use of a periodontal probe also may be used to differentiate between periapical and periodontal diseases.

Next in the testing hierarchy is the use to temperature testing. Contrary to some beliefs, natural tooth structure in not necessary to test for sensitivity to a stimulus in the environment of the oral cavity. Patients generally present for treatment complaining of pain. The pain is usually caused by temperature change to liquids or food, biting on various foods, or just swallowing, causing opposing teeth to occlude. Included in tooth testing, is the use of hot and cold applications whether an artificial or restored crown is present. If a patient presents with sensitivity to heat or cold while at home, that, in and of itself, tells the dentist that the pulp is involved. The temperature is transferred through the crown but if the tooth is already sensitive, that's the next test. In using temperature tooth testing stimuli, hold the stimulus on the middle third of the buccal surface, away from the gingival crest. The stimulus should be held for five seconds and the heat or cold should not be overly hot or cold. Do not use liquid nitrogen for cold testing nor overly hot, smoking gutta percha for heat testing.

A good rule to follow using these tests, is to test other teeth considered to be normal before testing the suspected tooth. Test adjacent, contralateral, or opposing teeth before testing the suspected tooth. Another test that can be used include application of a dye to locate crown fractures. The reader is referred to Berman and Hartwell (2011) for a more complete discussion of tooth testing.

Since the radiographs or other visual aids were previously taken, now is a good time to revisit those films. The rule now is to coordinate all information generated, including radiographs. While periapical radiographs are the principle means of "looking

inside" the soft tissue and bone, they can be augmented by use of three-dimensional imaging. The CBCT device or other such devices allow for a more complete diagnosis. Much as it has been used in periodontics, the three-dimensional micro-CT devices can be used in endodontics to find separated instruments, perforations, dilacerlations, and hidden root systems not easily demonstrated on peripical radiographs, especially from the standpoint of both bucco-lingual and mesio-distal views. Morse and colleagues (Morse, 1991; Morse *et al.*, 1993) detailed aging changes of the dental pulp and dentin, finding that normal teeth underwent root canal space loss as patients aged. While endodontists knew of these occurrences, not everyone remembered the process. A more recent study (Oginni *et al.*, 2009) found root canal space obliteration using the periapical index and radiographs in developing a positive treatment plan for aging patients. Needless to say, older patients should respond to these tooth tests routinely everything else being equal. However, the reduction to canal space may not allow temperature changes to move fluid through the absent dentinal tubules (a delta response) or raise or lower temperatures in the core of the pulp (C-fibers) to evoke a response. The proper angulation of a radiograph with a second film at either a mesial or distal angulation is needed, including a bitewing to gauge the height of the pulp chamber in posterior teeth.

Medical history

There are common diseases in aging individuals that must be disclosed to the operator. If it appears that they are not complete, a telephone call to the patient's physician should clarify the medical history. The physical and mental problems may affect the success or failure of a particular treatment result. Borderline diabetes (type 2) in aging patients may not be understood nor have been diagnosed by the patient's physician. Inability to swallow from lack of saliva, pain in the left arm, radiating to the mandible, shortness of breath, pain in the chest, high blood pressure, and other conditions mirrored in a patient's face and mouth should be noted. There are many signs and symptoms of disease in other areas of the body that will be manifested in and around the oral cavity first, such as diabetes. A remark of an aging patient that he or she is always thirsty may trigger a visit to their physician.

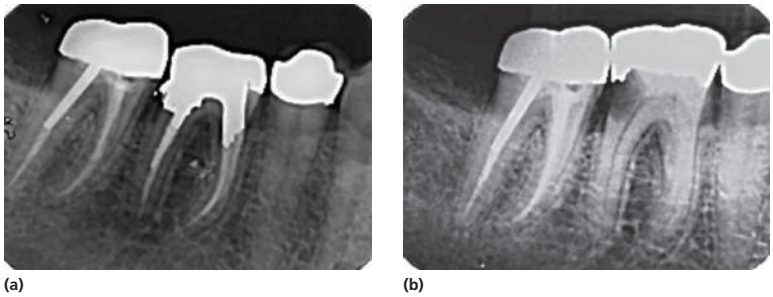
Diagnosis is built upon a series of questions, answers, examinations, testing, and past dental and medical histories. The drugs older patients are taking also may affect success or failure, especially in the case of senilities. Careful attention to the patient's ability to know what is being taken is as important as when it is to be taken. Failure to know or understand these and other conditions were, are or will be; may not cause just failure of oral treatment, but great harm to the aging patient.

Treatment plan

Simply put, proper diagnosis leads to a proper treatment plan. Not all patients can be treated endodontically successfully, especially older patients. However, the dentist should not consign a difficult endodontic procedure to the removal of a tooth just because of age. The treatment plan should be based on the relationship between the general dentist and the endodontist and with other specialists, if required. The advent of successful use of implants with osseous integration has changed the thinking of many practitioners, both generalists and specialists. Teeth that can be successfully treated endodontically may be removed because the dentist offers a dental implant instead. And teeth are treated that should be removed, again because the dentist doesn't know how to place implants. Managing the treatment of an older patient is not as simple as "just" doing a root canal procedure or removing a tooth. The treatment plan is a complex endeavor with any patient, no matter what age.

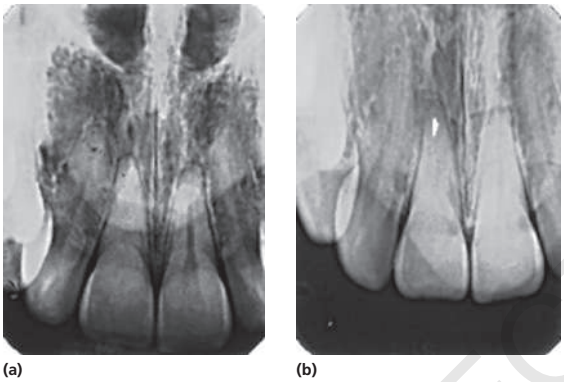
Endodontic treatment

Endodontists see a wide range of situations that may influence their ability to successfully complete a toot canal system procedure in older individuals. The first part of actual treatment is placement of a rubber dam. In optimum circumstances, placement of a rubber dam may be difficult (Fig. 12.7a,b). In an aging patient it may be close to impossible. The first rule is not to give in to older patients saying they won't be able to breathe or swallow with the dam in place. Older patients' tongues will wander more that younger patients and a dam in place will inhibit the tongue from being overly active. Without the dam, and the movement of the tongue, it will be easier to dislodge



(a) (b)

Figure 12.8 (a,b) Radiographs of an upper right central in a 55-year-old female patient. The root canal system appears to be completely calcified. The patient reported tenderness to percussion and biting. There were no responses to tooth testing other than percussion and biting. When surgery was first suggested, the patient was somewhat leery and asked for a few days to think about it. She appeared the next day and the tooth was treated surgically.



(a) (b)

Figure 12.9 (a,b) Radiographs of a 73-year-old male patient. Note the almost complete calcification of the root canal systems of the maxillary second premolar and first and second molars. The premolar became sensitive to percussion and biting (Tooth Slooth). Endodontic surgery was carried out with placement of a reverse fill amalgam rather than remove the crown.

an instrument and swallow it. Again, it becomes a reversion of the patient to early childhood where the tongue is also very active. To ease breathing, cut the dam away from the nose. Four-handed assisting also aids in keeping the patient happy, and usind a saliva injector is necessary. Use a smaller rubber dam that only covers a quadrant with the mouth essentially clear. The use of the dam may be the most difficult aspect of treating aging patients endodontically. Successful root canal treatment depends on being able to isolate the tooth, as cotton rolls will not work,

There are a wide range of treatment modalities in enddontics, including the use of conventional (Fig. 12.7a,b), surgical (Fig. 12.8a,b) (Figure 12.9a,b), or combined treatments. Suffice it to say the success rates in endodontics are about 95% (Allley, 2011). The use of operating microscopes, micrometer instrumentation, rotary instruments, digital and three-dimensional radiographs, new materials to obturate root canal systems, as well as patience with the aging patients lead to such a high success rate and lead to greater numbers of teeth being retained by older individuals. Changes brought about with new instrumentation, enhanced vision enhancement, and new packing materials hasn't appreciably changed the face of endodontics. Success, either with conventional or surgical treatment is labor intensive. The operator must sit at the chair and properly access, clean and shape, and obdurate conventionally or incise, expose, prepare, and fill root apices surgically. There are no shortcuts.

Access openings and cleaning and shaping

After the battle of rubber dam placement, access to the pulp chamber to develop straight line access is performed. Proper access should mirror the orifices of the root canal systems. However, the opening should only be as large as necessary to be able to manipulate the mouth mirror in a manner that each orifice is seen in its entirety and be accessed. Remember that all root canal systems have curves; therefore hand instruments can be curved for easier entry. Nickel–titanium (NiTi) instruments are softer than stainless steel hand instruments and they follow the curve of the system; therefore, they are not curved. They also are able to be centered in the canal

system leading to a more round preparation, which is easier to obdurate. There is a tendency to undershape systems with these instruments since they are not as sharp as hand instruments.

The objective remains that a preparation should be developed as a continuous, funnel-like, tapering preparation which can be packed three-dimensionally. Gates–Glidden burs may be used to augment the upper third of the preparation (Schilder, 1974) before other rotaries are introduced. Manufacturers claim that NiTi instrumentation is all that is needed in root canal system preparations. However, a hybrid methodology had been developed at the University of California School of Dentistry that uses NiTi files to within 3–4 mm of the apex with stainless steel hand instruments used to the radiographic orifice. The use of the stainless steel hand instruments ensures confinement of the apical portal of exit in its same position spatially. This results in a shape of the root canal system of the narrowest potion at is narrowest part of the canal at the apex and largest at the orifice of the orifice of the canal system. This is a great method that avoids over-enlargement of the apical portion of the system.

As with all cleaning and shaping regimens, irrigation after the use of each instrument is a major part of the protocol. Irrigation regimens and solutions generally disinfect the root canal system rather than sterilize it. Many studies have generated data that indicates that combinations of irrigants may result in sterilization within the root canal. Therefore, a method of irrigation should be used that will rid the system of debris, both inorganic and organic. The regimen recommended consists of the use of sodium hypochlorite (NaOCl at full strength: 6%) with ethylenediaminetetraacetic acid (EDTA: 17%). NaOCl dissolves organic debris while EDTA is used for inorganic debris (Siquiera *et al.*, 1998). A smear layer is created during cleaning and shaping, and there is great controversy as to whether or not to remove it through use of irrigants. The recommended irrigants may be used in an alternating manner, with the last application being NaOCl. The use of these solutions is another good reason to apply a rubber dam, which will stop any leakage into the oral cavity (Bystrom & Sundqvist 1985; Lottanti *et al.*, 2009; Rossi-Fedele *et al.*, 2012; Siquiera *et al.*, 2007; Zehnder, 2006).

A final word about the use of calcium hydroxide in an attempt to sterilize the canal systems. Many years ago, patients were treated over three appointments as endodontists believed that it was necessary to accomplish complete removal of microorganisms. The first appointment was for cleaning and shaping, the second to take a culture, and the third to obturate. If the second appointment culture was negative, the belief was that sterilization had occurred. The problem with this was that the wrong culture media was used and operators were culturing for aerobes instead of anaerobes and, thus, culturing was generally discarded. This eventually led to the elimination of multi-appointment procedures and one-appointment procedures became the treatment of choice for a great many practitioners. However, some studies used calcium hydroxide $(CaOH)_2$ placed in the root canal system after the first appointment, leaving it in place for at least a week if not two weeks. (Siquiera, *et al.* 2007). This regimen required multi-visit treatments and caused a great deal of discussion as to the need of at least two appointments and the value of sterilizing root canal systems. There has been no resolution of this issue. There is an old saying in endodontics that precedes completion of root canal therapy: "What is taken out of the root system is more important than what is put back into the system." The phrase is somewhat apocryphal but has been repeated many times over the years. It is certainly proper to take out the contents of the system as thoroughly as possible, but it may eventually lead to three-appointment endodontics and culturing before obturation.

Obturation

Over the years, many discussions in endodontics concerning the use of gutta percha (GP), spoke to its advantages and disadvantages as an obturation material. From the standpoint of cleaning and shaping, there appeared to be more disadvantages than advantages. This "dissonance" occurred due to how the material was used to end up with a very dense material. When used cold with spreaders, auxiliary cones were placed laterally around the master cone, the spreaders were inserted and the material distorted in an effort to completely pack the system space. The advent of warm GP changed

the manner in how the material was packed (Langeland, 1974; Schilder, 1967). Studies found the removing increments of GP with warmed instruments softened the material ahead of the heated instruments and, when the removal reached 5 mm from the apical portal of exit, the remaining GP was now warm and could be pushed the last 0.5 mm to "cork" the apical opening. Flat surface pluggers engage the warmed GP and are able to move it apically in order to obtain a three-dimensional pack within the system. The ability move GP apically allowed the cleaning and shaping process to reach the radiographic apex.

Needless to say, examinations of well-prepared root canal systems demonstrated that the dentin surfaces were not entirely smooth. Therefore, together with GP, a sealer needed to be placed to fill any voids. The sealer also filled the many portals of exit (lateral or accessory canals) found in the apical 5–5 mm. The preferred sealer used with GP is a zinc oxide-eugenol (ZOE) -based sealer that is easily mixed and placed and allows sufficient working time. The use of Resilon® with a resin sealer can be used as GP and its sealer are used and give the operator another choice of a packing material. The material can be warmed and packed ad is GP.

The success of surgical operating microscopes increased the success of surgical procedures as their use disclosed more apical anatomy. They were first thought to increase the success rate of conventional treatments but seem to have somewhat less success than conventional treatments. The isthmus between mesio-buccal and mesio-lingual apical openings in lower molars and between MB 1 and MB 2 in upper molars also can be viewed (Del Fabbro *et al.*, 2007; Hannahan & Eleazer, 2008; Naito, 2010; Ng *et al.*, 2011; Seltzer *et al.*, 2012).

Retreatment

Treatment modalities presently used in endodontics utilize methods that allow teeth once treated to be retreated conventionally. Retreatment has become the treatment of choice before surgical intervention in these situations and appears to be more successful than surgery (Barnes & Patel, 2011; Ng *et al.*, 2011; Torabinejad, 2009; Wong, 2004). In aging patients, both retreatment and surgical options can be used to retain essential teeth.

Lastly, the introduction of dental implants offers another treatment option. However, their use should not become the be-all, end-all choice of a treatment modality. The easier route for these patients would be conventional and retreatment therapy. This can occur when the "team" approach to older patients is utilized. This allows the older patient to receive complete information as to the different treatment options, the better to make an educated decision. That approach also will prevent an endodontic procedure that will not succeed and prevent the loss of a tooth that can be successfully treated.

Vital pulp therapy

No discussion on endodontic treatments would be complete without consideration of vital pulp therapy. Most clinical investigations concerning direct or indirect pulp capping tend to be carried out in young to early middle-aged patient. (Bjorndal *et al.*, 2010; Willershausen *et al.*, 2011). A few studies have been classified as examining aging to elderly individuals 65–85 years of age or older. Therefore, the success or failure of pulp capping in aging patients has not thoroughly been examined. An early study evaluated the success of pulp capping in 148 patients aged 10–67 with a 3-year follow-up. The author found an 88% rate of clinical success with the older patients having a similar success rate (Weiss, 1966). A later study evaluated the success of pulp capping in 149 patients aged 8–74. There was a minimum 5–10 year follow-up. There was a similar success rate (Haskell *et al.*, 1978). Barthel *et al.* (2000) found the same findings in a cohort of patients aged 10–70 when followed for 5–10 years. A slight trend towards failure was found when comparing patients over age 40 to those over 60 years of age (Matuso *et al.*, 1996).

The above studies indicated that age as a prognostic factor didn't appear to play a decisive in success or failure of pulp capping, However, there were no reports as to the extent of remaining pulp tissue in the root systems. In one retrospective study, authors reported that teeth pulp capped in 60-year-old patients showed significantly lower favorable outcomes (Dammasche *et al.*, 2010). A second study found that the success rate in pulp capped teeth

decreased as age increased (Auschill *et al.*, 2003). Neither result is surprising due to the changes previously described as occurring in the dental pulp and dentin of aging patients.

Regenerative endodontics

The future of endodontics will embrace the field of soft tissue regeneration. Several studies have reported the formation of a new pulp-like tissue forming in adult teeth with incompletely formed apices. These cases include dens in dente, traumatized teeth, teeth with necrotic pulp tissue, and periradicular lesions (Banchs & Trope, 2004; Bose *et al.*, 2009; Ding *et al.*, 2009). The interest of in regenerative endodontics began with the pulp capping procedures earlier in the 20th century. Today's research identifies a group of primitive cells (progenitor, stem cells) necessary to develop new odontoblast-like cells, dentin, periodontal ligament, and bone. However, studies to date have taken place in test tubes/plated laboratories and in animals. If, however, pulp capping procedures can succeed in some older patients, regenerative protocols also may be successful. With life expectancies continuing to increase, the field may lead to protocols that, rather than treat a tooth through a root canal procedure, a regenerative pulp procedure may be an approach that older patients would embrace as a treatment procedure that could be easier than a root canal or surgical procedure.

Periodontal considerations

Since periodontics and endodontics essentially treat the attachment apparatus of the tooth and may affect the success of procedures in the two specialties, a brief review is included of the effects of aging occurring in the adjacent periodontal tissue. The notion that age leads to periodontal disease progression has been a controversial topic over the past few decades. Early evidence shows increase in periodontal disease prevalence and severity with older age (Johnson *et al.*, 1989; Van der Velden, 1984). Epidemiologic studies demonstrate that there is a significant increase in periodontal attachment loss, alveolar bone loss, and tooth loss with age. However, the effect of age on increase in periodontal probing depths appears to be nominal (Albandar, 2002). Although early studies demonstrated such effects of aging on the periodontium, age alone does not lead to severe periodontal attachment loss in elderly patients (Huttner, 2009). Therefore the notion that periodontitis is an expected outcome of again has been questioned (Papapanou *et al.*, 1991). Current evidence suggests that severe periodontal disease among elderly patients is not as common as thought of earlier (Burt & Eklund, 1999). Periodontal disease progression as seen in increase in attachment loss, increases with age in elderly patients. However, this is due to the time factor of successful aging rather than pathology (Locker *et al.*, 1998). Thus, it is expected that changes in the oral cavity hard and soft tissue, such as the periodontium, will occur, but is due to the cumulative effect of time rather than the susceptibility of older patients to periodontal disease. This aspect of periodontal disease increase may occur due to inadequate manual dexterity to allow older patients to take care of their teeth and supporting oral structures.

Conclusion

This chapter has reviewed, as much as space permits, the tenets of endodontics in aging patients. A review of the biology of the dental pulp preceded a review of the treatment modalities. In most cases, older patients should be treated the same as younger patients, with the expectation of the same degree of success if correct treatment principles are followed before, during, and after treatment. But, as described in this chapter, in many instances the biology of older patients' pulp tissue and surrounding dentin undergoes changes that, if not recognized, will lead to mistreatment and loss of teeth. The changes that occur have been recognized for several years, yet the greater body of dentists will treat all their aging patients exactly as they treat their younger patients.

A final word: life expectancy appears to increase every decade. No one knows if these increases will continue or not. In either case, aging patients deserve the best care available, which means that dentists and endodontists must be aware of older patients' dental needs.

Case study 1

Mrs. Ethyl Smith is a new patient. She is 79 years old, walks with either a cane or a metal walker with wheels, has been diagnosed with type 2 diabetes, high blood pressure, osteoporesis and arthritis, and is somewhat frail. However, she appears to be mentally sharp with no history of a dementia. The patient is not capable of sitting upright for long periods of time. She is well-dressed, neat, and speaks to you quietly clearly. She admits to be nervous in a dental chair and is concerned that she will lose her teeth as she grows older.

Complaints

Pain on biting in the lower right quadrant and sensitivity to putting on her make-up at the outer lower right cheek area adjacent to the lower premolars and molars. All posterior teeth in her mouth have been restored with PBM crowns and the posterior areas appears to be calculus build-up. She presents with radiographs taken 4 months ago by another dentist. She claims that the other dentist frightened her with his treatment plan.

Case study questions: diagnosis and treatment planning

A Describe the methodology used to make the patient comfortable, both physically and mentally.
B What questions might you ask to put this patient at ease and comfortable in the chair? What questions might you ask concerning the patient's symptoms?
C List the diagnostic tests and the tooth testing needed to make a proper diagnosis. Discuss the rational of the tests used and what responses would possibly be forthcoming.
D What area of a tooth might you describe to the patient? What would you tell the patient to put her at ease during treatment?

(Up to this point the answers to each area above are rather generic. The dentist should now focus on the areas of treatment to be rendered based on his or her knowledge. Therefore, the review of these questions are based on specific knowledge known to the provider consistent with the answers to the following discussion questions.)

DISCUSSION QUESTIONS

1 Describe the tooth structures that normally protect the dental pulp.
2 Identify the various types of dentin in a tooth and the stimuli that causes them to form.
3 What is the role of the dental pulp in an adult tooth?
4 Describe the function of native odontoblasts.
5 What are the main reasons for older patients responding to tooth (pulp) testing?
6 What type dentin forms in response to caries reaching the pulp?
7 Why may treatment of an aging patient take take two or more appointments to complete treatment?
8 Discuss the treatment modalities used in contemporary endodontics and the materials used to complete treatment successfully.

References

About, I., Murray, P.E., Franquin, J.C., *et al.* (2001) The effect of cavity restoration variables on odontoblast cell numbers and dental repair. *Journal of Dentistry,* **29**(2), 109–17.

Agematsu, H., Someda, H., Hashimoto, M., *et al.* (2010) Three-dimensional observation of decrease in pulp cavity volume using micro-CT: age-related change. *Bulletin of the Tokyo Dental College,* **51**(1), 1–6.

Albandar, J.M. (2002). Global risk factors and risk indicators for periodontal diseases. *Periodontology 2000,* **29**, 177–206.

Allen, P.F. & Whitworth, J.M. (2004) Endodontic considerations in the elderly. *Gerodontology,* **21**(4), 185–94.

Alley, B.S. (2004) A comparison of survival of teeth following endodontic treatment performed by general dentists or by speicialists. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics,* **98**(1), 115–18.

Auschill, T.M., Arweiler, N.B., Hellwig, E., *et al.* (2003) Success rate of direct pulp capping with calcium hydroxide. *Schweiz Monatsschr Zahnmed,* **113**(9) 946–52.

Banchs, F. & Trope, M. (2004) Revascualrization of immature permanent teeth with apical periodontitis: new treatment. *Journal of Endodontics,* **30**(4), 196–200.

Barnes, J.J. & Patel, S. (2011) Contemporary endodontics – part 1. *British Dental Journal,* **211**(10), 463–8.

Barthel C.R., Rosenkranz, B., Leuenberg, A. & Roulet, J.F. (2000) Pulp capping of carious exposures: treatment outcome after 5 and 10 years: a retrospective study. *Journal of Endodontics,* **26**(9), 525–8.

Berman, L.H. & Hartwell, G.R. (2011) Diagnosis. In: *Pathways of the Pulp* (eds. K.M. Hargreaves, S. Cohen & K. Keiser), 10th edn., pp. 2–39. Mosby, St. Louis.

Bernick, S. (1962a) Age changes in nerves of molar teeth of rats. *Anatomical Record,* **143**, 121–6.

Bernick, S. (1962b) Age changes in the blood supply to molar teeth of rats. *Anatomical Record,* **144**, 265–74.

Bernick, S. (1967a) Effect of aging on the nerve supply to human teeth. *Journal of Dental Research,* **46** (4), 694–9.

Bernick, S. (1967b) Age changes in the blood supply to human teeth. *Journal of Dental Research,* **46**(3), 544–50.

Bernick, S. (1972) Vascular and nerve changes associated with the healing of the human pulp. *Oral Surgery Oral Medicine oral Pathology Radiology Endodontics,* **33**(6), 983–1000.

Bernick, S. & Nedelman, C. (1975) Effect of aging on the human pulp. *Journal of Endodontics,* **1**(3), 88–94.

Bjorndal, L., Reit, C., Bruun, G., *et al.* (2010) Treatment of deep carious lesions in adults: randomized clinical trials comparing stepwise vs. direct complete excavation, and direct pulp capping vs. partial pulpotomy. *European Journal of Oral Sciences,* **118**(3), 290–7.

Bose, R., Nummikoski, P. & Hargreaves, K. (2009) A retrospective evaluation of radiographic outcomes in immature teeth with necrotic root canal systems treated with regenerative endodontic procedures. *Journal of Endodontics,* **35**(10), 1343–9.

Burke, F.M. & Samarawickrama, D.Y. (1995) Progressive chages in the pulpo-dentinal complex and their consequences. *Gerodontology,* **12**(12), 57–66.

Burt, B.A. & Eklund, S.A. (1999) *Dentistry, Dental Practice, and the Community*. Saunders, Philadelphia.

Bystrom, A. & Sundqvist, G. (1985) The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. *International Endodontic Journal,* **18**(1), 35–40.

Centers for Disease Control and Prevention (2012) *Health, United States 2012*. National Center for Health Statistics, Hyattsville, MD, pp. 106–7.

Chalmers, J.M. (2006a) Minimal intervention dentistry: part 1. Strategies for addressing the new caries challenge in older patients. *Journal of the Canadian Dental Association,* **72**(5), 427–33.

Chalmers, J.M. (2006b) Minimal intervention dentistry: part 2. Strategies for addressing restorative challenges in older patients. *Journal of the Canadian Dental Association,* **72**(5), 435–40.

Ciancio, S.G. (1996) Medications as risk factors for periodontal disease. *The Journal of Periodontology,* **67**, 1055–9.

Cooper, P.R., Takahashi, Y., Graham, L.W., *et al.* (2010) Inflammation–regeneration interplay in the dentine–pulp complex. *Journal of Dentistry,* **38**(9), 687–97.

Couve, E. & Schmachtenberg, O. (2011) Autophagic activity and aging in human odontoblasts. *Journal of Dental Research,* **90**(4), 523–8.

Couve, E., Osorio, R. & Schmachtenberg, O. (2012) Mitochondrial autophagy and lipofuscin accumulation in aging odontoblasts. *Journal of Dental Research,* **91**(7), 696–701.

Dammaschke, T., Leidinger, J., Schäfer, E. (2010) Long-term evalutation of direct pulp capping – treatment outcomes over and ave rage period of 6.1 years. *Clinical Oral Investigations,* **14**(5), 559–67.

Del Fabbro, M., Taschieri, S., Testori, T., *et al.* (2007) Surgical versus non-surgical endodontic re-treatment for periradicular lesions. *Cochrane Database and Systematic Reviews,* **18**(3), CD005511.

Ding, R.Y., Cheung, G.S., Chen, J. *et al.* (2009) Pulp revascularization of immature teeth with apical periodontitis: a clinical study. *Journal of Endodontics,* **35**(5), 745–9.

Domine, L., & Holz, J. (1991) The aging of the human pulp–dentin organ. *Schweizer Monatsschrift für Zahnmedizin,* **101**(6), 725–33.

Eldarrat, A.H., High, A.S. & Kale G.M. (2010) Age-related changes in AC-impedance spectroscopy studies of normal human dentine: further investigation. *Journal of Material Science and Materials in Medicine,* **21**(1), 45–51.

El Karim, I.A., Linden, G.J., Curtis, T.M., *et al.* (2011) Human odontoblasts express functional thermo-sensitive TRP channels: implications for dentin sensitivity. *Pain,* **152**(10), 2211–23.

Fieler, B. (2012) 'The father is child of the man'. *The New York Times,* July **29**, 2012.

Fried, K. (1992) Changes in pulpal nerves with aging. *Proceedings of the Finnish Dental Society,* **88** (Suppl 1), 517–28.

Fried, K. & Hildebrand, C. (1981) Pulpal axons in developing, mature, and aging feline permanent incisors. A study by electron microscopy. *Journal of Compendium Neurology,* **203**(1), 23–36.

Galen, D. (1990) Endodontics and the elderly patient – management considerations. *Journal of the Canadian Dental Association,* **56**(6), 483–7.

Gani, O. & Visvisian, C. (1999) Apical canal diameter in the first upper molar at various ages. *Journal of Endodontics,* **25**(10), 689–91.

Goodis, H.E., Rossall, J.C. & Kahn, A.J. (2001) Endodontic status in older US adults. Report of a survey. *Journal of the American Dental Association,* **132**(11), 525–30.

Hannahan, J.P. & Eleazer, P.D. (2008) Comparison of success of implants versus endodontically treated teeth. *Journal of Endodontics,* **34**(11), 1302–5.

Hargreaves, K.M., Goodis, H.E. & Tay, F.R. (2012) *Seltzer and Bender's Dental Pulp,* 2nd edn. Mosby Elsevier, St. Louis.

Haskell, E.W., Stanley, H.R., Chellemi, J. & Stringfellow, H. (1978) Direct pulp capping treatment: a long-term follow-up. *Journal of the American Dental Association,* **97**(4), 607–12.

Hassan, B., Metska, M.E., Ozok, A.R. *et al.* (2009) Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. *Journal of Endodontics,* **35**(5), 719–22.

Hillmann, G. & Geursten, W. (1997) Light-microscopic investigation of the distribution of extracellular matrix molecules and calcifications in human dental pulps of various ages. *Cell and Tissue Research,* **289**(1), 145–54.

Holland, G.R. (1985) The odontoblast process; form and function. *Journal of Dental Research,* **64**, 499–514.

Holland, G.R. (1994) Morphological features of dentine and pulp related to dentine sensitivity. *Archives of Oral Biology,* **39** (Suppl), 3S–11S.

Huttner, E.A., (2009) Effects of human aging on periodontal tissues. *Special Care in Dentistry,* **29**(4), 149–55.

Ikawa, M., Komatsu, H., Ikawa, K., *et al.* (2003) Age-related changes in the human pulpal blood flow measured by laser Doppler flowmetry. *Dental Traumatology,* **19**(1), 36–40.

Jafazadh, H. (2009) Laser Doppler flowmetry in endodontics: a review. *International Endodontic Journal,* **42**(6), 476–90.

Johnson, B.D., Mulligan, K, Kiyak, H.A. & Marder, M. (1989) Aging or disease? Periodontal changes and treatment considerations in the older dental patient. *Gerodontology,* **8**(4), 109–18

Kaya, S., Adiguzel, O., Yavuz, I., *et al.* (2011) Cone-beam dental computerized tomography for evaluating changes of aging in the dimensions central superior incisor root canals. *Medicina Oral Patologia Oral y Cirugia Bucal,* **16**(3), e463–6.

Kim, S. (1985a) Regulation of pulpal blood flow. *Journal of Dental Research,* **64**, 590–6.

Kim, S. (1985b) Microcirculation of the dental pulp in health and disease. *Journal of Endodontics,* **11**(11), 465–71.

Kvaal, S.I., Koppang, H.S. & Solheim, T. (1994) Relationship between age and deposit of peritubular dentine. *Gerodontology,* **11**(2), 93–8.

Langeland, D. (1974) Root canal sealers and pastes. *Dental Clinics of North America,* **18**(2), 309–27.

Locker, D., Slade, G.D. & Murray, H. (1998) Epidemiology of periodontal disease among older adults: a review. *Periodontology 2000,* **16**, 16–33.

Lottanti, S., Gautschi, H., Sener, B. & Zehnder, M. (2009) Effects of ethylenediaminetetracetic, etidronic and peracetic acid irrigation on human root dentine and the smear layer. *International Endodontic Journal,* **42**(4), 335–43.

Ma, Q., Hu, X. & Yu, P. (1997) [Studies on aging enzyme activities of the human dental pulp blood vessels]. *Zhonghua Kou Qiang Yi Za Zhi,* **32**(2), 81–3.

Magloire, H., Maurin, J.C., Couble, M.L., *et al.* (2010) Topical review. Dental pain and odontoblasts: facts and hypotheses. *Journal of Oral Pain,* **24**, 335–49.

Maret, D., Peters, O.A., Dedouit, F., *et al.* (2011) Cone-beam computed tomography: a useful tool for dental age estimation? *Medical Hypothoses,* **76**(5), 700–2.

Matuso, T., Nakanishi, T., Shimizu, H. & Ebisu, S. (1996) A clinical study of direct pulp capping applied to carious-exposed pulps. *Journal of Endodontics,* **22**(10), 551–6.

Matysiak, M., Dubois, J.P., Ducastelle, T. & Hemet, J. (1986) Morphometric analysis of human pulp myelinated fibers during aging. *Journal de Biologie Buccale,* **14**(1), 69–79.

Matysiak, M., Dubois, J.P., Ducastelle, T. & Hemet, J. (1988) [Morphometric study of variations related to human aging in pulp unyelinated and myelinated axons]. *Journal de Biologie Buccale,* **16**(2), 59–68.

Morse, D.R. (1991) Age-related changes of the dental pulp complex in relationship to systemic aging. *Oral Surgery Oral Medicine Oral Pathology, Radiology and Endodontics,* **72**(6), 721–45.

Morse, D.R., Esposito, J.V., Schoor, R.S. (1993) A radiographic study of aging changes of the dental pulp and dentin in normal teeth. *Quintessence International,* **24**(5), 329–33.

Murray, P.E., About, I., Lumley, P.J., *et al.* (2000) Human odontoblast cell numbers after dental injury. *Journal of Dentistry,* **28**(4), 277–88.

Naito, T. (2010) Surgical or nonsurgical treatment for teeth with existing root filings? *Evidence Based Dentistry,* **11**(2), 54–5.

Ng, Y.L., Mann, V., Gulabivata, K. (2011) A prospective study of the factors affecting outcomes on non-surgical root canal treatment: part 1: periapical health. *International Endodontic Journal,* **44**(7), 583–609.

Ng, Y.L., Mann, V., Gulabivata, K. (2011) A prospective study of the factors affecting outcomes of non-surgical root canal treatment: part 2: tooth survival. *International Endodontic Journal,* **44**(7), 610–25.

Nielsen, C.J. (1983) Age-related changes in reducible cross-links of human dental pulp collagen. *Archieves of Oral Biology,* **28**(8), 759–64.

Oginni, A.O., Adekova-Sofowora, C.A. & Kolavole, K.A. (2009) Evaluation of radiographs, clinical signs and symptoms associated with pulp canal obliteration: an aid to treatment decision. *Dental Traumatology,* **25**(6), 620–5.

Okumura, R., Shima, K., Muramatsu, T., *et al.* (2005) The odontoblast as a sensory receptor cell? The expression of TRPV1 (VR-1) channels. *Archives of Histology and Cytology,* **68**, 251–7.

Ozer, S.Y. (2010) Detection of vertical fractures of different thicknesses in endodontically enlarged teeth by cone beam computed tomography versus digital radiography. *Journal of Endodontics,* **36**(7), 1245–9.

Pääkkönen, V., Bleicher, F., Carrouel, F., *et al.* (2009) General expression profiles of human native odontoblasts and pulp-derived cultured odontoblast-like cells are similar but reveal differential neuropeptide expression levels. *Archives of Oral Biology,* **54**(1), 55–62.

Papapanou, P.N., Lindhe, J., Sterrett, J.D. & Eneroth, L. (1991) Considerations on the contribution of ageing to loss of periodontal tissue support. *Journal of Clinical Periodontology,* **18**(8), 611–15.

Patel, S. (2009) New dimensions in endodontic imaging: part 2. Cone beam computed tomography. *International Endodontic Journal,* **42**(6), 463–75.

Patel, S., Dawood, A., Whaites, E. & Pitt Ford, T. (2009) New dimensions in endodontic imaging: part 1. Conventional and alternative radiographic systems. *International Endodontic Journal,* **42**(6), 447–62.

Patel, S., Wilson, R., Dawood, A., *et al.* (2012) The detection of periapical pathosis using digital periapical radiography and cone beam computed tomography – part 2: a 1 year post-treatment follow-up. *International Endodontic Journal,* **45**(8), 711–23.

Philippas, G.G. & Applebaum, E. (1966) Age factor in secondary dentin formation. *Journal of Dental Research,* **45**(3), 778–89.

Qualtrough, A.J. & Mannocci, F. (2011) Endodontics and the older patient. *Dental Update,* **38**(8), 559–62.

Rossi-Fedele, G., Doğramaci, E.J., Guastalli, A.R., *et al.* (2012) Antagonistic interactions between sodium hypochloride, Chlorhexidine, EDTA, and citric acid. *Journal of Endodontics,* **38**(4), 426–31.

Schilder, H. (1967) Filling root canal in three dimensions. *Dental Clinics of North America,* **4**, 723–44.

Schilder, H. (1974) Cleaning and shaping the root canal. *Dental Clinics of North America,* **18**(2), 269–96.

Seltzer, F.C., Kohli, M.R., Shah, S.B., *et al.* (2012) Outcome of endodontic surgery: a meta-analysis of the literature – part 2: comparison of endodontic microsurgical techniques with and without the use of higher magnification. *Journal of Endodontics,* **38**(1), 1–10.

Sherwood, I.A. (2012) Pre-operative diagnostic radiograph interpretation by general dental practitioners for root canal treatment. *Dentomaxillofacial Radiology,* **41**(1), 43–54.

Silva, J.A., de Alencar, A.H., da Rocha, S.S. *et al.* (2012) Three-dimensional image contribution for evaluation of operative procedural errors in endodontic therapy and dental implants. *Brazilian Dental Journal,* **23**(2), 127–34.

Siquiera, J.F., Jr., Batista, M.M., Fraga, R.C. & de Uzeda M. (1998) Antibacterial effects of endodontic irrigants on black-pigmented gram-negative anaerobes and facultative bacteria. *Journal of Endodontics,* **24**(6), 414–16.

Siquiera, J.F., Jr., Guimarães-Pinto, T., Rôças, I.N. (2007) Effects of chemomechanical preparation winth 2.5% sodium hypochlorite and intracanal medication with calcium hydroxide on cultivable bacteria in infected root canals. *Journal of Endodontics,* **33**(7), 800–5.

Smith, A.J., Tobias, R.S., Cassidy, N., *et al.* (1994) Odontoblast stimulation in ferrets by dentine matrix components. *Archieves of Oral Biology,* **39**(1), 13–22.

Smith, A.J., Cassidy, N., Perry, H., *et al.* (1995) Reactionary dentinogenesis. *International Journal of Developmental Biology,* **39**(1), 273–80.

Son, A.R., Yang, Y.M., Hong, J.H., *et al.* (2009) Odontoblasts TRP channel and thermo/mechanical transmission. *Journal of Dental Research,* **88**(11), 1014–19.

Stabholz, A., Sahar-Helft, S. & Moshonov, J. (2004) Lasers in endodontics. *Dental Clinics of North America,* **48**(4), 809–32.

Stanley, H.R. (1961) Traumatic capacity of high-speed and ultrasonic dental instrumentation. *Journal of the American Dental Association,* **63**, 749–66.

Stanley, H.R. (1977) Management of the aging patient and the aging pulp. *Journal of the California Dental Association,* **5**(5), 62–4.

Torabinejad, M. (2009) Outcomes of nonsurgical retreatment and endodontic surgery: a systematic review. *Journal of Endodontics,* **35**(7), 930–7.

Trope, M. (2008) Regenerative potential of dental pulp. *Journal of Endodontics,* **34**(7 Suppl), S13–17.

Tyndall, D.A. & Kohltfarber, H. (2012) Application of cone beam volumetric tomography in endodontics. *Australian Dental Journal,* **57**(Suppl 1), 72–81.

Tyndall, D.A. & Rathore, S. (2008) Cone-beam CT diagnostic applications: caries, periodontal bone assessment, and endodontic applications. *Dental Clinics of North America,* **52**(4), 825–41.

Van der Velden, U. (1984). Effect of age on the periodontium. *Journal of Clinical Periodontology,* **11**(5), 281–94.

Walton, R.E. (1997) Endodontic considerations in the geriatric patient. *Dental Clinics of North America,* **41**(4), 795–816.

Wang, P., Yan, X.B., Lui, D.G., *et al.* (2011) Detection of dental root fractures by using cone-beam computed tomography. *Dentomaxillofacial Radiology,* **40**(5), 290–8.

Weiss, M. (1966) Pulp capping in older patients. *New York State Dental Journal,* **32**(10), 451–7.

Willershausen, B., Willershausen, I., Ross, A., *et al.* (2011) Retrospective study on direct pulp capping with calcium hydroxide. *Quintessence International,* **42**(2), 165–71.

Wong, R. (2004) Conventional endodontic failure and retreatment. *Dental Clinics of North America,* **48**, 265–89.

Woo, S.P. (2001) *Secondary dentin formation and root canal occlusion in middle-aged to elderly men in a VA dental logitudinal study.* Master of Science thesis, University of California, School of Dentistry, CA, USA.

Zach, L. & Cohen, G. (1962) Thermogenesis in operative techniques. *Journal of Prosthetic Dentistry,* **12**, 977–84.

Zach, L. & Cohen, G. (1967) Pulp response to externally applied heat. *Oral Surgery Oral Medicine Oral Pathology Radiology and Endodontics,* **19**, 515–30.

Further reading

Alian, A., McNally, M.E., Fure, S. & Birkhed, D. (2006) Assessment of caries risk in elderly patients using the cariogram model. *Journal of the Canadian Dental Association*, **72**(5), 459–63.

American Association of Endodontists; American Academy of Oral and Maxillofacial Radiology (2011) Use of cone-beam computed tomography in endodontics. Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology. *Oral Surgery Oral Medicine Oral Pathology Radiology and Endodontics*, **111**(2), 234–7.

Cooper, P.R., McLachlan, J.L., Simon, S., *et al.* (2011) Mediators of inflammation and regeneration. *Advances in Dental Research*, **23**(3), 290–5.