Title: Root Canal Position Paper

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Abstract

This paper examines root canal treatment (RCT), including the history, materials used, health implications, re-treatment considerations, and practical recommendations for biological and holistic dentists. Emphasis is placed on the toxicology of root filling materials, the biological reactions to gutta percha and other sealers, and systemic health concerns. The document highlights research gaps in understanding the full systemic impact of RCT and provides protocols for extraction and site management for failed root canal-treated teeth. The goal is to provide an in-depth review for clinicians seeking a more biologically informed approach to endodontic care.

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1. Introduction

A root canal treatment is a dental procedure that aims to eliminate infection in the root anatomy of the tooth. The hope is to maintain the physical tooth in the oral cavity rather than remove the whole tooth from the jawbone (Mamat, 2023). A root canal procedure typically has several steps, including access, irrigation, instrumentation, obturation, and the placement of coronal restoration. This procedure is often referred to as a "root canal." Even though RCT (root canal treatment) is a common procedure, there is controversy surrounding its efficacy, health and toxicity concerns.

Root canal teeth and/or their associated treatment chemicals and materials have been linked to cytotoxicity, endotoxemia, bacteremia and mutagenicity (Borges, 2013; del Rio, 2019; Eleazer, 1978; O'Donnell, 1992; Torabinejad, 1995; Pussinen, 2022; Kaur, 2015; Lewis, 1981; Sidhu, 2001; Parahitiyawa, 2009; Niazi, 2022). Root canal treated teeth have also been connected with systemic disease via focal infection, neuronal interference, allergies and toxin-related reactions to root canal materials (Gammal, 2022). Much of it has been published in peer-reviewed endodontic, periodontal, dental, and medical journals, and has even reported in daily newspapers. According to the American Association of Endodontists, "There is no valid, scientific evidence linking root canal-treated teeth and disease elsewhere in the body. A root canal is a safe and effective procedure" (American Association of Endodontists, n.d.). At first glance, this statement seems to settle the issue once and for all. But where are the facts to back it up?

2. Evaluating the Success of Root Canals

2.1. The Definition of Success

Endodontic treatment has supposed success rates up to 86–98% (Kumar, 2016). Success can have different meanings in the literature and to the dentist clinically (Mehta, 2025). Accepted goals for success generally mean that there is functional retention of the tooth and that there is healing or prevention of apical periodontitis, a type of root canal related infection (Mehta, 2025; Alves, 2022). Other definitions include no clinical signs of disease and absence of symptoms (Mehta, 2025). However, there is no consistent definition of "success", or even "failure", in the literature to support that claim (Kumar, 2016). The absence of visible apical inflammations and a seemingly normal x-ray does not equal an non-problematic tooth (Lechner, 2015).

2.2. Complexity of Tooth Sterilization

Is it possible to completely disinfect a tooth in order to remove or prevent infection? The literature supports that it is not possible to do so, even though some methods have better results than others. It doesn't matter what technique, chemicals or instrumentations are used, there will often be a part of the root canal space that remains untouched (Lin, 1991; Siqueira, 1997; Siqueira,

2001). During root canal treatment, it has been estimated that as much as 50% of the canal wall may be un-instrumented and the resulting necrotic tissue remnants can be a source of nutrition for the remaining bacteria in the dental tubules (Journal of the Australian Dental Association, 2007; Athanassiadis, 2007; Love, 2001; Peters, 2004). If a root canal tooth cannot be completely disinfected, then bacteria can remain the root canal system (Siqueira, 2001). Therefore, there is a constant risk that peri-radicular inflammation can occur (Siquiera, 2001).

Even some teeth that are considered "well-treated" still can fail (Alves, 2022; Siqueira, 2001). A common reason these "well-treated" teeth still fail is usually due to inaccessible bacteria in the complex tooth anatomy (Alves, 2022). There are many difficult to access areas within tooth anatomy such as isthmuses, dens invaginatus, recesses, canal and root curvatures, additional roots and canals, lateral canals, apical deltas and dentinal tubules. These anatomical structures are where most of the persistent infections reside. To consider the complexity of tooth anatomy, a single-rooted tooth can contain about 3 miles of tubing, and some teeth can have 3-4 roots (U. Schellenberg, 1992). The persistent infection due to complex anatomy is well accepted as the main reason why root canals fail (Alves, 2022; Mehta, 2025). If there is bacteria in the peri-radicular areas in particular, disinfection procedures will not be able to access these areas (Mehta, 2025). It is essential for root canals need to be completely sterilized in order to be successful (Grossman, 1972, Australian Dental Association, 1996).

2.3. Inaccuracy of Radiographs

Radiographs are the standard method for screening for root canal infections. After root canal treatments are performed, some teeth can show "peri-apical healing" radiographically, which many people argue equals success. Even though peri-apical "healing" can occur if the microbial burden is reduced under a certain threshold, it cannot completely eliminate the microorganisms. It is possible that even though the root canal filling can seem to be accurate, untouched areas of necrotic tissue and bacteria can still exist, despite it's radiographic appearance (Nair, 1990; Lin, 1991; Siquiera, 2001). A "well-done" root canal-treated tooth on an x-ray does not equate to proper filling of the root canal and/or disinfection of the root canal system (Nair, 1990; Lin, 1991; Siqueira, 2001; Lechner, 2015,). As *Chandak* states, "total canal sterilization is still a pipe dream today" (Gomes, 2022; Chandak, 2022).

3. Early Research on Root Canal Toxicity

Early in the 1900s, a group of medical and dental researchers independently saw an unmistakable connection between systemic disease and various bacteria. These pathogens seemed to originate from oral sources in and around periodontally involved teeth, infected teeth, root canal-treated teeth, and extraction sites. Some early, important researchers in this area include:

• Dr. Charles Mayo, founder of the Mayo Clinic
• Dr. Frank Billings, past President of the American Medical Association and creator of the Council on Medical Education, "which brought about the standardization of medical education in the United States" in the early 1900s..(AGN & Billings, 2017)
• Dr. Weston Price, founder of the research institute of the National Dental Association (which became the American Dental Association) and chair of the NDA from 1914 to 1928 (Price, 1948; The Nebraska State Medical Journal, 1925; British Journal of Dental Science, 1928)
• Dr. Edward C. Rosenow, a prolific researcher who consistently produced well- documented works, nearly 300 articles between 1902 and 1958

Rosenow in particular built upon two venerable medical concepts: (a) the concept of oral focal infection, whereby distant and/or generalized diseases have been attributed to the dissemination of microorganisms or their toxins through the bloodstream from an oral "focus" or reservoir; and (b) the ability or perhaps even tendency of microorganisms to exist in different phases as a result of dissociation or mutation, depending on environmental conditions (Shakman, 2017). All four of these clinicians, three physicians and a dentist, independently conducted thousands of experiments implanting extracted root canal teeth from patients who suffered from a multitude of diseases. In every case, the experimental animal (rats or mice) became ill with the same disease the patient had suffered.

Perhaps the most famous research was done by Dr. Weston Price. After a 16-year old boy had died of endocarditis two weeks after Price had performed root canal therapy, Price successively implanted that same tooth into two hundred rabbits. All died with endocarditis. The 16-year old boy was his son. Dr. Price worked furiously to find a way to make root canals safe. This research was summarized in his two volume work, Dental Infections, Oral and Systemic and Dental Infections and the Degenerative Diseases. After 25 years of research, he concluded that there was no viable way to sterilize a root-canaled tooth.

This research was performed before the advent of antibiotics, which prevented infections from spreading and killing the advancing organisms causing the disease. Unfortunately, we do see these organisms express themselves over time, but not always in the patient's mouths.

In the 1930s, approximately three years after Price's death, Dr. W. L. Holman wrote an article to dismiss all the research of Price, Billings, Mayo, and Rosenow, doing so without performing any bacteriological research or experiments himself. Holman's dishonest treatment of Rosenow's work in particular was clearly self-motivated and wrong (Kulacz, 2014). The wholesale dismissal of Dr. Rosenow's in no small part seems attributable to a clearly fraudulent misrepresentation of his research results (Holman, 1915; Holman, 1928).

4. <u>Root Canals and The Oral Systemic Link</u>

4.1. Root Canal Microorganisms and Disease

Root canal related disease can cause microorganisms to travel from the root canal teeth to the systemic environment (Niazi, 2022). Research supports the connection between apical periodontitis, a root canal disease, and other diseases such as high blood pressure, diabetes, skeletal infections, adverse pregnancy outcomes and coronary heart disease (Niazi, 2022). Periodontal diseases and endodontic diseases have some of the same pathogens, biological pathways and inflammatory mediators (Niazi, 2022). Studies link periodontitis to Parkinson's Disease, pneumonia, chronic obstructive pulmonary disease, osteoporosis, Alzheimer's disease and kidney disease (Niazi, 2022).

In his book Six-foot Tiger, Three-foot Cage, Dr. Felix Liao states the case for connecting the oral cavity to the rest of the body, with and without endodontic care. The book supports the perio-endo-systemic connections:

- A 2016 study in PLoS Medicine showed the link between periodontitis (gum disease) and memory decline. "The presence of periodontitis at baseline," it said, "was not related to baselinecognitive state but was associated with a six fold increase in the rate of cognitive decline…." (Ide, 2017)
- Bacteria from the mouth have been shown to spread to the rest of the body. For instance, people with periodontal disease have double or triple the risk of having a heart attack or stroke (Bale, 2013)
- Oral bacteria have been found in heart attack clots. "Dental infection and oral bacteria, especially viridans streptococci, may be associated with the development of acute coronary thrombo-sis," wrote researchers in the journal *Circulation* (Bale, 2014)
- One study found that DNA from endodontic (root canal) bacteria was found in 56% of 36 samples of heart attack clots. Periodontal bacteria was found in 47% of those samples. The authors concluded that "dental infection could be part of pathophysiology in intracranial aneurysm disease [stroke]" (Pessi, 2013)
- Bacterial DNA was detected in 21/36 (58%) of specimens. A third of the positive samples contained DNA from both endodontic and periodontal bacteria. DNA from endodontic bacteria were detected in 20/36 (56%) and from periodontal bacteria in 17/36 (47%) of samples. Bacterial DNA of the Streptococcus mitis group was found to be most common (Pyysalo, 2013)

It can be argued that root canal infections can be more dangerous than general periodontitis due to the lack of an epithelial barrier between a necrotic tooth and the periapical granulomatous tissue. The peri-apical area has many inflammatory markers and is highly vascularized, permitting an ideal environment for inflammation and translocation of microbes (Niazi, 2022).

4.2. Bacteraemia

Root canal procedures and infections can increase the risk of bacteraemia (Niazi, 2022; Parahitiyawa, 2009). Some people have better defense mechanisms against bacteremia if they are healthy, while others can be more susceptible to it (Baumgartner, 1973). In healthy individuals, most bacteria that enter the blood are rapidly taken care of by the bloodstream (Parahitiyawa, 2009; Pollanen, 2012). Antibiotics are prescribed for certain susceptible groups of individuals if there is a risk for bacteremia at the time of dental surgeries. This is because it is well known that bacteremic spread from the oral cavity can impact other organs (Parahitiyawa, 2009). The following statement explains some serious general consequences of bacteraemia:

"Patients with rheumatic heart disease, congenital heart disease, heart valvular prosthesis, or patients with an inadequate defense mechanism are susceptible to severe consequences if they are subjected to bacteremia, inadequate defense mechanisms to resist bacteremia may result in cases of debilitation or dehydration, diabetes, cancer, blood dyscrasias, malnutrition, vitamin deficiency, leukemia, multiple myeloma, diseases of the liver or kidney" - (Baumqartner, 1973; Strauss, 1971; Schiff, 1969; Bailey, 1974)

However, there is a difference between acute bacteremia and chronic bacteremia and biofilms can play a large role in the process (Parahitiyawa, 2009; Pollanen, 2012). Since the biofilm establishment is permanent and therefore chronic, this demonstrates how bacteremia from root canal teeth bacteria are not only "transient during the procedure" (Parahitiyawa, 2009; Pollanen, 2012). Biofilms can permanently attach to the outer tooth surfaces in the periodontium, for example, at the dentogingival junction. Many bacteria that reside in these subgingival biofilms are the same species as root canal infection bacteria (Parahitiyawa, 2009; Pollanen, 2012). Any disturbance to the biofilm can allow bacteria to enter the bloodstream, potentially causing bacteremia (Parahitiyawa, 2009).

The extent of bacteremia can depend on factors such as the degree and/or extent of bacteria/infection, trauma to the area from surgeries, brushing, flossing and even chewing can disrupt the biofilm and trigger bacteremia (Parahitiyawa, 2009). After a trigger or disruption to the biofilm, bacteremia can persist for an average to 30 minutes to 60 minutes (Parahitiyawa, 2009). It is plausible that multiple disruptions throughout the day can lead to numerous episodes of bacteremia.

The amount of bacteria persisting in root canal teeth depends on the individual situation, but research shows it can range from low levels to high levels of quantifiable bacteria (Rocas, 2008). Even low levels of bacteria can be harmful, depending on the ecological role of the bacteria and specific bacterial profiles, which vary from individual to individual (Rocas, 2008).

Weakened host defenses can leave more opportunity for bacteria to flourish (Pollanen, 2012). Dentistry has standards of care to prescribe prophylactic antibiotics for certain individuals for acute exposures, but in general, chronic bacteremia prophylaxis is disregarded, even though it has been proven that bacteria can persist after root canal treatments. What constitutes weakened defenses is not clearly defined with regards to chronic exposures and can have variability. Also, while the bacteria themselves are important in regards to bacteremia, the impact of the release of metabolites and toxins from bacteria is rarely discussed, which can be problematic (Suprewicz, 2020).

4.3. Inflammation and Root Canals

Microorganisms from root candled teeth can travel systemically and can result in immune responses that can impact other tissues and organs (Niazi, 2022). When apical periodontitis, a type of root canal infection, is present in the tooth, it can cause an increased risk of bacteria, inflammatory mediators, haemostatic factors and soluble compound traveling to the rest of the body and can contribute to systemic inflammation (Niazi, 2022). This is of concern because it can result in inflammation and infection systemically (Niazi, 2022).

There is increased systemic inflammation and burden associated with apical periodontitis, a type of endodontic root canal-related infection (Mehta, 2025; Niazi, 2022). Some inflammatory markers that have been shown to have increases are IL−1β, IL−6, IL-10, IL-12, MMP−8, E−selectin, tumour necrosis factor (TNF-α), FGF−23, hs−CRP, ADMA, hs−CRP, matrix metalloproteinases (MMP-8 and MMP-9), soluble vascular cell adhesion molecule 1 (sVCAM-1), endothelial leukocyte adhesion molecule (E-selectin), intercellular adhesion molecule (ICAM), Immunoglobulin (Ig) A, IgM, IgG, asymmetric dimethylarginine (ADMA) and complement-C3 levels (Bakhsh, 2022; Niazi, 2022). This oral and root canal inflammation, along with local micro-environmental disturbances, can also allow unbalanced host-microbiome interactions (Suprewicz, 2020).

4.4. Autoimmune Disease and Root Canals

There are possible links between autoimmune diseases and microorganisms from root canal-treated teeth (Bakhsh, 2022). Both apical periodontitis and the overall prognosis of root canal treatment can be impacted by the altered immune response and even immune-modulatory therapy (Bakhsh, 2022).

There are several studies showing a higher prevalence of apical periodontitis in autoimmune disorders such as Rheumatoid Arthritis (RA) and IBD (Bakhsh, 2022). Similarities between apical periodontitis and these conditions include high levels of inflammatory cytokines IL-1, IL-6, IL-17, IL-23 and TNF-α (Bakhsh, 2022). The RANK-L osteoprotegerin pathway (OPG) is con-

nected in the progression of both apical periodontitis and RA (Bakhsh, 2022). *A. Actinomycetemcomitans,* a bacteria linked to arthritis, and can be found in some root canal treated teeth (Barboso-Ribiero, 2020; Looh, 2022).

Some medications used for autoimmune conditions such as the family of Disease-Modifying Anti-Rheumatic Drugs (DAMRDs) have been shown to have a relationship to root canal teeth (Bakhsh, 2022). The medications target the inflammatory process including cytokines (TNF-α, IL-6, and IL-1); RANKL-induced nuclear factor kappa β activation pathway; and T or B cell receptors (Bakhsh, 2022). There are several studies in the literature showing a relationship between bDMARD's (biologics), autoimmune disorders and apical periodontitis. Two studies show that there was a higher prevalence of apical periodontitis for patients with autoimmune disorders taking these medications (Bakhsh, 2022). Another study showed patients taking these medications had "faster healing" of apical periodontitis, which suggests that these meds may influence root canal treatment outcomes (Bakhsh, 2022).

In his book, oncologist Joseph Issels stated that thioethers, an odontogenic toxin from root canals, have been associated with "non-self" proteins and auto-aggression reactions. Thioethers have the ability to denature natural proteins in the body and the denatured proteins become "non-self", leading to extensive cellular damage (Issels, 2005).

4.5. Focal Infections

Modern medicine as a whole generally accepts that an infection in one part of the body that is left untreated can spread systemically (Gammal, 2022). Despite overwhelming evidence supporting bacteria's and even fungi's ability to travel from one part of the body to another and cause infection and harm elsewhere, currently, general dentistry only considers this concept to be a theory called "focal infection theory" (Debelian, 1998). It has been repeatedly proven that dental infections can cause bacteria to travel to places such as the heart and cause problems.

Three proposed mechanisms that explain the link between oral bacteria and systemic spread throughout the body include 1) bacterial antigens forming immune complexes causing both acute and chronic inflammation at the bacterial accumulation site locations 2) Bacteremia metastatic infections when the immune system is bypassed, allowing them to colonize in a particular location 3) Bacterial endotoxin and protein damage to host cells (Suprewicz, 2020).

Root canal microoorganisms have been proven to travel systemically (Gammal 2022; Marciano, 2023; Lewis, 1981). It has been demonstrated that bacteria from a root-canal treated tooth have been found in the blood both during and after endodontic treatment (Debelian, 1996). This may be attributed to several factors. For example, compared to the vital teeth, non-vital teeth are less resistant to bacterial invasion into dentinal tubules (Jacobi-Gresser, 2015).

4.5.1.Dental Foci, Root Canals, Cancer and Disease

The AAE (American Academy of Endodontists) states that there is no valid scientific evidence connecting root canal treatment to cancer or systemic disease" (AAE, 2025). However, modern research will argue otherwise.

Josef Issels, a world famous oncologist and researcher, said that the development of cancer is linked with foci in many ways and "there is no dental root treatment that does not inevitably produce foci" (Issels. 2005). Issels states that untreated head foci can be a contributing factor in the development of neoplasia and tumor development (Issels, 2005). Issels said that there are four main mechanisms by which dental foci can lead to disease: "Neural, toxic, allergic and bacterial."

4.5.1.1.Neural Connection

The foci and toxins can travel in mesenchyme and neural structures such as neural ducts and central nervous system control cells and can impact the polarization of nerves. Certain conditions can trigger neural dystrophy and degeneration (Issels, 2005).

4.5.1.2.Endotoxin "Toxic" Concerns

There are several toxins and toxic metabolic byproducts that can stem from bacteria that reside in root canals. Some are referred to as VSC's, or Volatile Sulfur Compounds. The most dangerous VSC's that can reside in root canal treated teeth are methyl mercaptans, hydrogen sulfide and thioethers such as dimethylsulfide and diethyl sulfide (Gammal, 2022; Jacobi-Gresser, 2015; Lechner, 2015; Lechner, 2020). The bacteria that produce these VSC's can reside in necrotic pulp tissue in root canal treated teeth and can trigger an inflammatory cascade and can also stimulate the immune system (Jacobi-Gresser, 2015). The immune response in relationship to VSC exposure is associated with both local and systemic inflammation responses (Jacobi-Gresser, 2015). Exposures to VSC's can lead to Type IV immune responses, and are one cause of chronic inflammation (Lechner, 2015).

The main species of bacteria that can generate these toxins include *Porphyromonas gingivalis, Veillonella alcalescens, Prevotella intermedia, Fusobacterium nucleatum, Treponema denticola,* and *Porphyromonas intermedia*. Anaerobic, sulfate reducing bacteria that produce methyl mercaptan, dimethylsulfide, and diethylsulfide are mainly produced by Porphyromonas gingivalis and Fusobacterium and can be found in root canal treated teeth (Lechner, 2015).

The bacterial endoxins can travel systemically and Issels argues that the most dangerous odonto-

genic toxins are the thio-ethers such as dimethylsulfides (Issels, 2005; Lechner, 2020). The actions and properties of thio-ethers demonstrate their extreme toxic effects:

- The effect and structure of thioethers are closely related to mustard gases and other poisonous gases used in the First World War (Issels, 2005)
- Thioethers, by nature, are soluble in lipids and tend to enrich themselves into lipoid-containing structures such as mitochondria. Thioethers bound to subcellular organelles now have the ability to control and paralyze aerobic metabolism. Otto Warburg, biologist and two time winner of the Nobel Peace Prize, proved that aerobically-blocked cells, (caused by thioethers), can acquire the characteristics of malignant cells. Substances that are capable of inactivating aerobic metabolism and increasing the anaerobic metabolism are usually classified as "carcinogenic compounds" (Issels, 2005)
- Thioethers can also inhibit mitochondrial enzyme activity (Lechner, 2020). For example: Hydrogen sulfides can form thioethers and can bond with iron in mitochondrial cytochrome enzymes and block oxygen from binding, stopping cellular respiration (Lechner, 2020). Because mitochondria play a major role in immune health, energy metabolism, the cell cycle, apoptosis, cell proliferation and autophagy, mitochondrial damage can be a serious threat to health (Lechner, 2020). Mitchondrial damage is known to be linked to cancer development, diabetes, Alzheimer's disease, cardiovascular diseases and Parkinson's disease (Lechner, 2020)
- Thio-ethers are weakly basic and are "electronegative" in nature and tend to bind with "electropositive" cells. Some examples of electronegative cells that thioethers can bind to include transit and defense tissues. They can also interfere with enzyme metabolism, further enhancing some vitamin deficiencies and many other enzyme-related issues (Issels, 2005).
- Thioethers are haptens and partial antigens and have an association with "non-self" protiens and auto-aggression reactions. Thioethers can combine with the natural proteins in the body and denature them and the denatured proteins become "non-self", leading to extensive cellular damage (Issels, 2005)
- Toxins can travel through blood and lymph as a vessel for local and systemic spread. The higher the blood level of foci-related toxins, the more severe the damaging impact can be (Issels, 2005)

Besides being a toxin released from root canal teeth, methyl mercaptan is not only released from decaying organic matter, but it is also manufactured as a jet fuel additive and for use in pesticides (Agency for Toxic Substances and Disease Registry, 2014). Methyl mercaptans have been labeled a toxic substance by the EPA (Science Direct, 2025). It's side effects can depend on dosage and route of exposure, as recorded toxicity exists for large acute exposures, for example, isolated occupational exposures (Agency for Toxic Substances and Disease Registry, 2014). Toxicity issues from methyl mercaptan include pulmonary and breathing issues, headache, dizziness, loss of smell, staggered gait and tremor, memory loss, nervous system damage, coma, methemoglobinemia and acute hemolytic anemia (Science Direct, 2025). However, there is no data available

to the authors knowledge that shows the range of levels of methyl mercaptan that can be released from root canals. In fact, methyl mercaptan still has many unknowns, including what happens to it after entering your body and whether long term exposure can lead to birth defects, reproductive issues and cancer, even at low levels (Agency for Toxic Substances and Disease Registry, 2014). People with heart, lung, blood and nervous system conditions may have an increased susceptibility to the harmful effects of methyl mercaptan (Science Direct, 2025). In addition to other concerns, methyl mercaptan can also lead to collagen damage, increasing susceptibility to permeability (Jacobi-Gresser, 2015).

Hydrogen sulfide can have toxic effects on the central nervous system and in the oral cavity. It can damage epithelial cells and increase mucosal permeability (Jacobi-Gresser, 2015).

Degrading infected root canal teeth can also release cadaverine and putrescine and have been linked to health concerns (Maita, 1990). Putrescine has been directly indicated in the formation of cancers (del Rio, 2019). Cadaverine and putrescine can react with nitrites to produce the carcinogenic compound, nitrosamines (del Rio, 2019). Cadaverine and putrescine are responsible for the foul odor coming from root-canal treated teeth. Putrescine and cadaverine's "death smell" are produced when organic tissues decay after death in decaying human and other animal cadavers (Izquierdo, 2018).

4.5.1.2.1.Non-Cancer Endotoxin Concerns

One hundred percent of infected root canals have detectable endotoxins (Marinho, 2014). They are related to clinical features of endodontic disease and damage to periapical tissues (Marinho, 2014). These endotoxins can live in both periodical and pulp spaces. Endotoxins have been shown to impact the immune system, even at low concentrations (Marinho, 2014). The body does not recognize them and the immune system considers them as foreign (Marinho, 2014). Even after instrumentation and uses of medicaments, it could not completely eradicate the endotoxins (Marinho, 2014).

Endotoxemia from LPS (Lipopolysaccharide), a root canal endotoxin, has been connected to cardiovascular and metabolic disorders (Pussinen, 2022). Endotoxemia is a risk factor for liver diseases, diabetes, metabolic syndrome, neurological conditions, obesity, atherosclerotic cardiovascular diseases and can play a role in other conditons (Pussinen, 2022; Kalyan, 2022). LPS plays a role in the pathogenesis of both local and systemic inflammation (Pussinen, 2022; Kalyan, 2022).

4.5.1.3.Allergic Concerns

Antibodies can be formed against the odontogenic toxins and this can lead to more damage (Issels, 2005).

4.5.1.4.Bacterial Impact

Bacteria from the mouth can colonize in the intestines leading to chronic inflammation (Suprewicz, 2020).

Enterococcus faecalis, (E. Faecalis) is a bacteria that is strongly associated with root canal infections and has been linked to playing a role in the development of colorectal cancer (Suprewicz, 2020). It has been shown to be present in approximately 77% of infected root canals (Suprewicz, 2020).

The proposed mechanisms by which oral bacteria can play a role in the pathogenesis of cancer are (Suprewicz, 2020):

a) inducing chronic inflammation, which can result in mutagenesis and oncogene activation,
b) accelerating cellular proliferation
c) releasing carcinogenic substances
d) aiding in transition from epithelial to mesenchyme (EMT) a method of movement for cancer cells that is implicated in cancer progression. (Suprewicz, 2020)

Three common bacteria found in root canals are *Fusobacterium nucleatum, Porphyromonas gingivalis and Enterococcus facalis* (Gomes, 2023; Barbosa-Riberiero, 2020). These bacteria have been linked to health issues. *P. gingivalis* and *F. nucleatum,* have demonstrated to be positively correlated to cancer development (Bui, 2019). Research on *P. gingivalis* and *F. nucleatum s*hows that they can stimulate tumorigenesis (Bui, 2019). It is thought that oral *F. nucleatum* is able to travel and colonize in the human intestinal tract and trigger inflammation and infection. This pro-inflammatory environment is thought to contribute to the progression of colorectal adenoma-carcinoma (Bui, 2019). *E. Faecalis* is capable of up-regulating pro-inflammation pathways, triggering a large inflammatory response and causing intracellular reactive oxygen species (Strickertsson, 2013). *E. faecalis* has been linked to DNA damage, mitochondrial genome instability and altered gene expression of DNA repair mechanisms and inflammation (Strickertsson, 2013).

Issels discovered another interesting connection between dental foci infections and cancer. Infra-red emissions demonstrate a close relationship between infrared emission of dental foci and neoplasial regions. Removal/treatment of the source of dental foci resulted a decrease in infra-red activity for both the dental foci and the tumor areas (Issels, 2005).

Can the amount of root canal bacteria play a role in cancer? The change from a normal cell to a malignant cell needs a carcinogenic minimum dose of the toxic, carcinogenic substance. The toxic effects of each dose are stored and accumulate, therefore it does not matter if the toxic exposure is a single dose or continual exposure. This toxic accumulation can occur gradually and un-

noticeably until the total quantity necessary for malignisation is attained (Issels, 2005).

If the source of focal infection is kept under control by the body's local defense mechanism, there will not be any focal-induced remote effects. However, if the body's resistance is compromised, remote focal intoxication can increase, thus promoting malignant growths (Issels, 2005).

In addition to cancer connections, bacterial dissemination can lead to thrombosis, thrombophlebitis and even embolism due to the formation of micro-foci and micro-thrombi in veins (Issels, 2005).

4.5.1.5.Non-Bacterial Pathogens in Root Canals

The most common fungal species in infected root canal teeth are *Candida Albicans* (Suprewicz, 2020). Another fungal species that can occur in root canal teeth is *Aspergillus mycetoma* (Gammal, 2022; Liston, 2022; Giardino, 2006; Khongkhunthian, 2001). Candida albicans has been suggested to play an active role in cancer development and cancer risk, especially for oral cancer (Takalpko, 2023).

Viruses such as CMV (Cytomegalovirus) and EBV (Epstein-Barr Virus) can play a role in root canal symptomatic periodical lesions (Suprewicz, 2020). CMV and EBV have been linked to promotion and increased risk of cancer (Cobbs, 2019; El-Sharkawy, 2019)

4.5.1.6.Leaching of Root Canal Cancer-Related Materials

Some materials used in root canal materials have links to cancer. Some of these materials have been proven to leach from the tooth and even travel systemically (Gammal 2022; Marciano, 2023; Lewis, 1981). Formocresol, which contains formaldehlyde, a well-documented carcinogenic material, has been proven to travel beyond local tissue (Gammal, 2022; Lewis, 1981; Friedberg, 1990). Research demonstrates that after endodontic treatment, formocresol was found not only in localized tissue, but also was found in the glomerulus, indicating that the material traveled to the kidney (Lewis, 1981). Another root canal material, epoxy-based root sealers, have demonstrated to be cytotoxic and mutagenic and have also been shown to leach (Hosseinpour, 2022; Graunaite, 2018).

Routes endodontic materials can take when they spread systemically can include the bloodstream via circulation and respiratory system via inhalation (Hosseinpour, 2022). The application site, the tooth, may be different from the location where the effect can be seen, leading to systemic toxicity (Hosseinpour, 2022).

Although it exists, research with regards to cancer-related root canal chemicals and systemic

spread is scarce. However, it is important to note that presently, there is no root canal obturation material that can have a perfect seal and root fillings have the ability to leak (Gammal, 2022; Ayhan, 1996; Peters, 1992; Higa, 1994; Adamo, 1999; Chong, 1995; Holt, n.d.; Yatsushiro, 1998; Torabinejad, 1995; Oliveira, 2011; Fogel, 1977; Tollens, 1979; Khanvilkar, 2023). There are also many components of root canal materials that have been linked to cancers, which is discussed in more detail in this position paper (National Cancer 2001; Dentsply, 2014, Wang, 2020; National Library of Medicine, 2021). The relationship between the systemic spread of root canal chemicals and potential health implications warrants further research.

5. Complications from Root Canal Procedures

5.1. Allergic Reactions to Root Canals

Root canal materials can be allergens in some people. For example, there is a case of recurrent generalized urticaria from formaldehyde exposure from a root canal sealant material and twenty eight cases of immediate symptoms related to formaldehyde use in root canals (Silva, 2016; Siqueira, 2015). Other more serious adverse reactions to formaldehyde include shock and anaphylaxis (Siqueira, 2015; Orstavik, 2005). Zinc oxide allergy is rare and only one case of allergy is reported in the literature. However, the high amount in gutta percha can contribute to toxicity (Siqueira, 2015). Ledermix Paste, an intra-canal medicament, is a combination of triamcinolone (a corticosteroid) and demeclocycline (a tetracycline antibiotic) (Alves, 2013). There has been one reported case of type 1 allergy presenting as fever, general malaise and urticaria after use (Siqueira, 2015; Alves, 2013). The intra-canal irrigant, sodium hypochlorite, can trigger an allergic reaction during endodontic treatment. The case presented as difficulty breathing and burning sensation, but this is rare (Siqueira, 2015; Caliskan, 2012). There has also been one case of iodoform allergy as a result of endodontic treatment. The intracanal medicament triggered shortness of breath and urticaria (Ho, 2025). Two cases of anaphylaxis to PEG (polyethylene glycol) from root canal treatment, one severe and one unfortunately fatal, are mentioned in the literature (Wang, 2024; Nolan, 2014).

5.2. Nerve Damage

Root canal procedures can cause nerve damage. One form of physical damage includes over-instrumentation with files and instruments, which can perforate the interior of the tooth and lead to irritants leaching out into the bone and nerve. Mechanical compression can happen when instruments or other chemicals perforate the apex of the tooth. Some of the chemical irritants can be neurotoxic and damage can range from inflammation to even irreversible blockage of nerve conduction. Sensations reported from root canal induced nerve damage include, numbness, itching, burning, altered sensations, complete loss of feeling and pain (Moore, 2004; Reddy, 2014; Gupta, 2016).

5.3. Tooth Fractures

It is estimated that over 80% of people over the age of 40 have at least one fractured or cracked tooth (NYC Endodontics, 2003). The treatment of tooth fractures can involve a wide variety of approaches and there does not seem to be a true consensus for universally accepted protocols (Sun, 2022). The literature has many conflicting points and most of the studies are observational and lack long-term, high evidence based results (Sun, 2022).

The literature categorizes the "positive" outcomes of endodontically treated cracked teeth as "survival" and "success" rates (Sun, 2022). With regards to tooth fracture, it has been said that some author's results should be "interpreted with extreme caution" due to the wide spectrum of what is deemed as "successful" (Sun, 2022). There is even more variability and lack of clarity for what is defined as "success" (Sun, 2022). For example, some studies only evaluated success from one or more of the following: disappearing symptoms, smaller (but not completely eliminated) peri-apical lesions, no increase in probing depth or crestal bone loss, no sensitivity to percussion, bite test or palpation, and just the presence of a full coverage restoration (Sun, 2022). The definition of survival in most of the literature consisted of the fractured tooth merely being present in the arch at follow-up (Sun, 2022). Ironically, when reviewing fractured teeth after root canal treatments, "survival" has been advocated as more preferable than "success" because it can be compared to implants (Sun, 2022). It goes without saying that these markers clearly do not automatically equal "health", let alone "success".

Tooth fractures can range in severity, some teeth being non-restorable and some have recommendations to try to repair the tooth. Some research argues that if the pulp is necrotic from a fracture, then it shouldn't be restorable as oppose to other studies showing that pre-operative fractures should not be a prognostic factor for endodontic treatment (Sun, 2022; Berman, 2010; NG, 2011). It is also more likely for an endodontist to "try and save a tooth with a root canal", even if there is deep fractures and plural involvement, than other dentists (Sun, 2022; Alkhalifa, 2017; Yap, 2021).

Not only is the definition of success unclear, but so are the recommendations of how to manage crack lines. There does not seem to be one, generalized accepted recommendation for how to surgically manage crack lines in a tooth fracture (Sun, 2022). The "crack line" is the part of the tooth that is fractured and makes a physical line (Sun, 2022). Some researchers argue it is important to remove the crack line completely while others say to leave it because it can potentially compromise the tooth. However, literature confirms that crack lines from fractures are colonized by bacteria and their biofilms and can invade dentin tubules (Sun, 2022). In addition, for cracks that impact the pulp, periodontal pocketing and complications can arise from bacteria leaching through the crack line (Sun, 2022). Radicular cracks are more likely to result in periodontal de-

fects (Sun, 2022). Is it worth it to do a root canal and "save the tooth" if there is a crack that is unreachable to disinfect it? Pulp survival studies in the form of randomized control trials need to be done because the literature supporting the "successes" are not of strong evidence (Sun, 2022).

Once the tooth has root canal treatment, it is more susceptible to fracture (Stashenko, 2005). As opposed to vital, non-root canal treated teeth, endodontically treated teeth are drier and have collagen cross-linking changes. This makes root canaled teeth more brittle. Excess dentin loss and loss of tooth structure can occur from removing caries, making access preparations and preparations for a crown or final restorative material (Stashenko, 2005; Jones, 2022). Other factors that can make these teeth susceptible to fracture include file/instrumentation type and canal shaping techniques, irrigating solution effects, excessive obturating pressure, and preparing the tooth for placement of posts or re-treatment procedures (Stashenko, 2005).

Medicaments can be used for managing root canal fractures. MTA (Mineral Trioxide Aggregate) has been used for a medicament in managing root fractures and has other uses in root canal treatments (Pan, 2016). Toxicity concerns from MTA include it's presence of heavy metals, tricalciumaluminate, aluminum and bismuth (Pan, 2016; Nguyen, 2025).

5.4. Incomplete Removal of Infections

Complete removal of infection and microorganisms is essential for success. The Australian Dental Association acknowledges this and stated, "The role played by microorganisms has been demonstrated and cannot be emphasized enough. Elimination and destruction of all organisms within the entire tooth is essential for long term success" (Australian Dental Association, 1996).

Complete removal of infection is a major concern when performing a root canal treatment. Before completing a root canal procedure with obturation and placing the final restoration, one would assume that sterility of a tooth would need to be proven to make sure the infection is completely removed. An example of this could be taking a microbial sample and sending it out for laboratory testing. However, this is rarely, if ever performed and is certainly not the standard of care (Gammal, 2022). Instead of obtaining evidence of sterilization, determining when it is time to permanently seal and fill the tooth only includes subjective measures such as lack of pain and/or strong odor, and even just the mere completion of performing the standard procedure steps in the root canal leading up to the point of filling the tooth (Gammal, 2022). In the current model of root canal treatments, sterility is only assumed and not actually proven.

There are several techniques used to attempt to disinfect a tooth in a root canal, which include mechanical instrumentation, intra-canal medicaments and irrigation solutions (Zehnder, 2006). Each of these methods have not been proven to have complete efficacy, which leaves the possibility of leaving some remnants of microorganisms behind (Gomes, 2023; Jones, 2022; Borges,

2013; Jensen, 1999).

Complex tooth anatomy such as isthmuses, lateral canals and apical deltas are difficult to thoroughly mechanically clean and mechanical preparation is unable to remove all of the biofilm (DeGregorio, 2019; Bystrom, 1985; Orstavik, 1990; Gomes, 2023) Chemo-mechanical instrumentation is not able to completely disinfect the root canal system due to the complexity of tooth anatomy and the presence of biofilms. (Gomes, 2023, DeGregorio, 2019) In a necrotic pulp, over-instrumentation can also displace infected dentin or debris into the peri-radicular tissues and maintain inflammation (Siqueira, 2001). Narrow canals can be a hinderance to disinfecting canals for both manual and ultrasonic irrigation, especially when cleaning the apex (Borges, 2013). After irrigation in oval shaped canals and other irregularities, it has been shown that large amounts of dentin debris still is left behind (Borges, 2013). Syringe irrigation is limited with it's efficacy, as it has been shown that irrigants can only progress 1 mm past the needle tip, and increased volume of the irrigant has not been demonstrated to improve disinfection (Borges, 2013).

Extra-radicular infections can happen in root canal treated teeth. Disinfecting procedures will not be successful in eliminating bacteria when a peri-radicular rarefaction is present (Kumar, 2016). The microorganisms in the periradicular tissue are inaccessible to root canal medicaments and disinfectant procedures (Siqueira, 2001). Common microorganisms that may be present in extraradicular infections include *Actinomyces* and *Propionibacterium propionicum* (Siqueira, 2001).

Elimination of bacterial biofilms are of utmost importance for root canal-treated teeth because the infection is biofilm-mediated (DeGregorio, 2019). The EPS matrix (extracellular polymeric substance) and biofilm often protect microorganisms that are deeply embedded within tubules by shielding them from the immune system response and other stressors, despite attempts at root canal treatments. This can lead to ongoing infections (Zehnder, 2006). Mechanical preparation is unable to remove all of the biofilm (DeGregorio, 2019; Bystrom, 1985; Orstavik, 1990). There have been several in-vivo and in-vitro studies that have demonstrated that in more than 80% of all root canal cases, residual bacteria was left, mostly in the apical region (DeGregorio, 2019; Ricucci 2010; Svensater, 2004; Nair, 2005; Paiva, 2013).

There are many different microorganisms that can live in an infected tooth, but *Porphyromonas endodontalis*, *Enterococcus faecalis*, and *Fusobacterium nucleatum* are the most notorious for being resistant to treatments (Gomes, 2023). The most common microorganisms to persist in root canal infections are *Candida Albicans* and *Enterococcus Faecalis* (Gomes, 2023; Zehnder, 2006). *E. Faecalis* is a facultative anaerobic bacterial species that is able to survive extreme conditions and is commonly resistant to antibodies and antimicrobials (DeGregorio, 2019). If *E. Faecalis* is present in the root canal system, it is extremely difficult to eliminate using conventional root canal procedures (Siqueira, 2001). *E. Faecalis* can provide a long-term breeding

ground for subsequent infections (Sedgley, 2005). Calcium hydroxide, an intra-canal medicament, has limited efficacy against biofilm-producing bacteria such as *Enterococcus Faecalis* (Gomes, 2023, Zehnder, 2006). Yeast microorgansims may also be resistant to root canal medicaments (Siqueira, 2001). Periapical actinomycosis has also been documented and is believed to be more common than once believed (International Endodontic Journal, 1996).

Current root canal irrigants include NaOCl (sodium hypochlorite) alone or in combination with chlorhexidine and/or EDTA (ethyl-enediaminetetraacetic acid) (Borges, 2013; Degregorio, 2019). No single irrigant can demineralize the calcified canal walls or dissolve organic pulp material (Borges, 2013; De Gregorio, 2019). Irrigants have limited ability to penetrate biofilms and travel deep into tubules (Haapasalo, 2010). Sodium hypochlorite can be helpful for killing planktonic bacteria, but cannot completely eliminate biofilm (Gomes, 2023; Kumar, 2016) Irrigation solutions such as sodium hypochlorite not only can be toxic, but they also cannot completely penetrate biofilms and dentinal tubules (Gomes, 2023; Zehnder, 2006). Even though it is accepted to do so, chlorhexidine and sodium hypochlorite should not be used in combination for irrigation. Parachloroalanine is a precipate and it is cytotoxic and carcinogenic (Mehta, 2025). EDTA is recommended to remove the smear layer and improve treatment outcomes (Mehta, 2025).

There are two studies that claim to be extremely successful for removing biofilm, but let's break them down:

There is one study that claims to have completely removed the E. Faecalis biofilm using ultrasonic treatment, however, there are several issues with the publication (Bhuva, 2010). The study was done on single-rooted teeth and only a 3 day old biofilm, which is is not a typical situation in reality (DeGregorio, 2019; Bhuva, 2010) The analysis of the results were also done using the SEM method, which is non-specific (Bhuva, 2010; DeGregorio, 2019).

Another study claims to have high percentages of bacterial elimination in root canal treated teeth, however there are many flaws with the experiment (Siqueira, 2018). The in-vitro study design and tooth selection were not accurate for real life situations, including only a 2 week follow-up and only sampling for two strains of bacteria. Also, limitations for the specific culturing technique can underestimate the amount of bacteria present and the "sampling" was not taken in all of the crevices of the root canal tooth (Siqueira, 2018). The authors even admit that paper point sampling, the method used in the study, is not the most accurate way to sample microbes. They also sealed the exterior apical third of the roots with hot glue in order to help prevent contamination from the exterior part of the tooth, which is clearly not modeling in-vivo environments, which bacteria can be present in the adjacent bone. It is important to mention that the study lists one of the authors as having a conflict of interest, "an economic interest" in one of the products (Siqueira, 2018). There was still residual bacteria in the canal for both ultrasonic methods used (Siqueira, 2018).

Even though PUI/ultrasonic activation significantly reduces the number of bacteria after instrumentation and can remove some biofilm, no technique is able to promise complete disinfection (Z, Jensen, 1999; DeGregorio, 2019; Ordinola-Zapata, 2014; Case, 2012; Joy, 2015). Even new technology like the "Gentle Wave" system (Sonendo, Inc., Laguna Hills, CA, USA) does not have studies to date that analyze the complete removal of biofilm (DeGregorio, 2019).

The use of silver nanoparticles and "continuous chelation agents" is being studied and developed as other possible disinfectant strategies (Gomes, 2023).

5.5. Improper Obturation and Sealing

Both over and under extension of a root canal filling can lead to failure (Kumar, 2016). One of the most common surgical errors in dentistry is overfilling of root canals (Yaltirik, 2002). Over-extension of root canal filling material can lead to damage to the surrounding tissue and even nerve damage (Shen, 2016). Most over-extension cases reported have damaged the IANB, but it has also been shown to harm the mandibular canal, bone marrow of the maxilla and the palatal submucosal layer (Shen, 2016). Disabling pain has been reported as a side effect of over-extending root canal filling material (Neaverth, 1989). Over-extension of material can result in contamination from the gutta percha cone (Mehta, 2025). If the root canal procedure is in close proximity to maxillary sinus, the sinus can be adversely impacted and infection with Aspergillus mycetoma can occur (Gammal, 2022; Liston, 2022; Giardino, 2006; Khongkhunthian, 2001).

Another source of bacterial contamination is saliva leakage from improper coronal restoration placement (Alves, 2022). Typically, when a root canal is completed, a temporary restoration is placed. The temporary materials can fall out easily and temporary cements are water-soluble by nature (Siqueira, 2001). Even if saliva contamination occurs over a short period of time, it can be an indication of contamination (Siqueira, 2001). In addition, there can be obturation voids that can be missed on an x-ray that can be responsible for persistent bacterial growth (Siqueira, 2001). Therefore, it can be difficult or virtually impossible to know if there is persistent infection using solely a radiograph. This complicates the diagnosis process for root canal failures.

Another form of overextension of filling materials is referred to as the "puff technique", where root canal sealers extrude beyond the apex in root canal treatment (Hakoma, 2024). There is a lot of disagreement and controversy with "puff", as some dentists believe it indicates a better seal, while others believe it can cause inflammation and can be related to toxicity. Toxicity can occur from several different types of sealers. Toxic byproducts can be released from resin-based sealers when they contact periodical tissues. Zinc-oxide eugenol sealers can also be cytotoxic when extruded from the apex of the tooth. Even bio-ceramic sealers can induce inflammatory reactions when extruded into periodical tissues, even though they are considered to be more biocompatible

(Hakoma, 2024). Endodontists were more likely to be more cautious about overfilling while general dentists seem to have more of an untroubled attitude about it. Evidence-based guidelines need to be established (Hakoma, 2024) and treatment protocols for the puff technique should not be unregulated due to it's potential to cause harm.

Even the standard filling recommendations still come with flaws and doubts. It is accepted that gutta percha should be placed flush with the apex of the root or up to 1mm short of the apex to prevent contamination, future infection and block out bacteria (Gammal, 2022). Leaving 1mm of space according to general standards would still allow opportunity for infection. Even when the obturation material is flush with the apex radiographically, it is actually likely to be overfilled, since the apical foramen is located right at the radiographic apex (Kesel, 1958; Gammal, 2022).

5.6. Foreign Body Reactions

Some root canal failures have been attributed to foreign body reactions (Siqueira, 2001). There are several examples of this in the literature:

Overextension of endodontic material past the apex can result in a foreign body reaction (Mehta, 2025). Some other root filling materials are also thought to trigger foreign body reactions as well (Nair, 1990).

Talc-contaminated gutta percha cones and cellulose containing paper points have caused foreign body reactions (Siqueira, 2001). These foreign body reactions are thought to be due to a chemical or filling material.

There is a case in the literature that links a root canal failure to the presence of cholesterol crystals that are thought to be released from broken-down host cells or circulating plasma lipids (Siquiera, 2001).

Cysts are thought to have an immunological component and different types can persist in relationship to root canal treated teeth (Siqueira, 2001). Cysts related to root canals are not well understood and they may be partially responsible for maintaining infections in even so called "well-treated" root canals (Siquiera, 2001).

5.7. Perforations

A perforation in a root canal is a pathological connection between the surrounding periodontium and the root canal system itself that negatively impacts the prognosis of the tooth (Pascon, 2023). During a root canal procedure, perforations are most likely due to iatrogenic accidents and can be as common as 0.6%-17.6% (Pascon, 2023). This number may be higher because diagnosing per-

forations can be difficult to diagnose due to metallic artifacts and therefore, can be a serious problem (Faria, 2019).

Once a perforation occurs along with irritative restorative materials and/or bacteria is present, healing cannot occur and the tooth is non-restorable (Pascon, 2023). The bacteria can disperse into the surrounding tissues (Torabinejad, 2009). One could argue that since it is impossible to fully disinfect a root-canaled tooth, there is always a possibility that bacteria may be present and therefore, any perforated tooth cannot be restored. However, materials such as cavit, zinc oxide eugenol (ZOE), composite resin, amalgam, glass-ionomer (GIC), mineral trioxide aggregate (MTA), and bioceramic calcium silicate cements have been used for sealing a perforations (Torabinejad, 2009; Faria, 2019). Portland cement is used for root perforations repair and according to it's safety data sheet, it is labeled category 1A for carcinogenicity and also has other toxic impacts (Heidelberg Materials, 2023).

5.8. Tools Left Inside the Tooth

Tools used during a root canal procedure can break off inside of the tooth. Instrument separation is a common occurrence (Chandak, 2022). Ever since nickel titanium rotary instruments were introduced, there has been an increase in instrument breakage, probably because tend to break more frequently than stainless steel (Terauchi, 2022). There is controversy around if an instrument can be left in the tooth or if it should be taken out.

The literature suggests that in some situations, the prognosis of a tooth is unchanged when leaving a fractured instrument inside of a tooth (Ng, 2010). Other literature suggests that there is reduced healing if an instrument is retained in the tooth due to persistent bacteria (Mordeno, 2024;Mehta, 2025).The prognosis of a retained instrument can depend on the location of the tool and the timing of when the tool is broken off during the procedure. It is thought that there should be little concern if the canal is cleaned out before the instrument gets broken off into the tooth (Eleazer, 1991).

One main concern is corrosion of an instrument, and there is not much research to support that it does not occur (Souter, 2013). Metal particles left in a tooth from a separated instrument can lead to corrosion (Chandak, 2022). To the author's knowledge, there is only one report that states that stainless steel fragments are inert and do not corrode over two years, but silver root canal filling cones did corrode (Souter, 2013; Eleazer, 1991). The elements of amalgam were found on the silver points, embedded in the root canal (Eleazer, 1991). It is important to mention that this study only looked at two teeth. Clearly, this is not an appropriate sample size or high evidence study.

Broken instruments can lead to poor prognosis of endodontically treated teeth (Chandak, 2022). In our opinion, if a broken instrument acts similarly to other oral metals, it may pose a corrosive,

foreign body and infection risk dependent on the situation. At the IABDM, we believe the patient has a right to informed consent if an instrument is left behind during the surgery.

Broken instruments can also raise ethical concerns. It is required that if an instrument is broken off, the patient should be informed of the problem (Mordeno, 2013, Chandak, 2022). However, it has been said in the literature that "some patients may be better treated by not being informed, in cases which excessive patient concern has the potential for becoming a psychological problem" (Eleazer, 2021; Mordeno, 2024). Would you feel comfortable not knowing that there was a retained instrument left in your tooth?

5.9. Endo-Perio and Perio-Endo Lesions

The root of the tooth is anatomically connected with the periodontium, or the outside of the tooth. Micro-organisms have been shown to travel in both directions, from the inside of the tooth to the outside and from the outside to the inside, and are referred to as "Endo-perio or "perio-endo lesions". The American Academy of Endodontics acknowledges that the endo-perio relationship is complex (AAE, 2024). Since it is impossible to 100% sterilize and seal off lateral canals, isthmuses, etc during root canal treatment, then there will always be a risk that the bacteria can travel to the outer part of the tooth to the periodontium. The reverse is also true, that if there are pathogenic microorganisms in the periodontal area, it has been shown that they can also migrate into the tooth (AAE, 2024). Cementum damage, furcation canals, root cracks and subgingival plaque at the apical 1/3 of the teeth can increase the risk of perio-endo lesions (AAE, 2024). These communication pathways can be from normal anatomy and also iatrogenic causes from root canal treatments themselves (AAE, 2024). Microbial biofilms from endodontic infections can adhere to enamel, dentin and cementum and are able to spread infection and inflammation (AAE, 2024).

6. Materials Used In Root Canal Treatment

6.1. Introduction to Root Filling Materials

In the 1700's, pulp chambers used to be filled with lead foil (American Association of Endodontists, 2021). One could argue that implanting lead would be an archaic method of treatment. However, it is still commonly accepted to use other extremely toxic root filling materials, such as mercury, in root canal procedures (Bystrom, 2007). Lead is still a contaminant in some cases (O'Donnell, 1992). Materials that have been used as root filling materials include gutta percha, amalgam, silver points, iodoform paste, Hydron® (poly-hydroxyethyl methacrylate) and Resilon (Bystrom, 2007).

It has been shown that root fillings have the ability to leak, to what degree and direction depends

on the location, the filling material itself and other variables (Gammal, 2022; Ayhan, 1996; Peters, 1992; Higa, 1994; Adamo, 1999; Chong, 1995; Holt, n.d.; Yatsushiro, 1998; Torabinejad, 1995; Oliveira, 2011). Presently, there's no single root canal obturation material that can achieve a perfect seal (Gammal, 2022; Yatsushiro, 1998; Fogel, 1977; Tollens, 1979; Khanvilkar, 2023).

6.2. Amalgam

Amalgam fillings contain 50% mercury and can be used for root-end fillings for root canals (Mutter, 2004). The World Health Organization recognizes mercury to be one of the most dangerous chemicals to public health (Bjorklund, 2017). Research confirms that dental amalgams continually release mercury and it can add to the body's mercury load (Mutter, 2004).

6.3. Silver Points

Silver Points have been shown to be toxic (American Academy of Endodontists, 2017). Even the American Association of endodontics has now recommended against their usage (American Academy of Endodontists, 2017). Silver points have been shown to have poor sealing ability and can cause staining and argyrosis. They are also highly corrosive and release cytotoxic byproducts (American Academy of Endodontists, 2017).

6.4. Iodoform Paste

Iodoform paste also has toxicity concerns such as liver issues (Perieira, 2019; Kishen, 2019; Drugbank, n.d). Despite the concerns, it unfortunately is still commonly used for primary teeth (Saricam, 2024)

7. Sargenti Paste

The Sargenti paste, a popular root filling material in root canals, contains paraformaldehyde and they used to contain lead, bismuth and mercury. It can also be known as N-2 Universal, N2, RC-2B White or RC-2B (Gammal, 2022). The paraformaldehyde turns to formaldehyde when water comes into contact with it (Gammal, 2022). Formaldehyde has been a known mutagen since 1946 (Lewis, 1981). Formaldehyde is a known carcinogen and has been linked to other medical problems (Fischer, 2010). It was very popular from the 1920's through the 1990's and declined in popularity due to health concerns, but there is not a specific end date due to there not being a specific ban.

The American Association of Endodontists recommend to not use the Sargenti pastes. Unfortunately, many root canal treatments using the old formulas are still in people's mouths and many are not informed of this (Rojas, n.d.; Hickok, 1976). Two other present day commonly used root filling materials, AH26 and Endomethasone, have formaldehyde as breakdown products as well

(Gammal, 2022; Gomes-Filho, 2007).

8. Russian Red

"Russian Red" is rarely used in Western countries, but is still commonly used in China and other Eastern European/Post Soviet Countries (Schwandt, 2003). It primarily contains formaldehyde and resorcinol, and the glues and resins have toxic side effects (Gammal, 2022; Schwandt, 2003). Barium sulphate and zinc may be added (Gammal, 2022). This "russian red" technique is described as "an RF resin-soaked piece of asbestos or similar material is sealed into the pulp chamber" (Gammal, 2022, Schwandt, 2003). Asbestos exposure has been classified as known human carcinogen and has been linked to mesothelioma, lung, ovarian, laryngeal, stomach, colorectal and pharyngeal cancers (National Cancer Institute, 2021). Asbestos exposure has also been connected to other medical issues such as asbestosis, permanent lung damage, coughing, shortness of breath, pleural disorders such as thickening, plaques, and effusions and other non-malignant lung disorders (National Cancer Institute, 2021).

9. Root Canal Sealers and Medicaments

Calcium hydroxide paste is also used as a root filling material and is significantly biotoxic and have been shown to leak cytotoxic substances (Kaur, 2015). All root canal sealers are toxic when freshly mixed, but it is also considerably toxic when set as well (Kaur, 2015). Calcium hydroxide has been shown to remain in the the hard and soft tissues for a period of time and has been linked to neurological damage if in close proximity to the inferior alveolar nerve (Ahlgren, 2003; Kaur, 2015). Serious health consequences can occur if the material is extruded from the apex including Nicolau Syndrome (NS) damaging connective tissue, thrombosis if displaced into blood vessels, and skin necrosis (Al-sheeb, 2011).

Zinc oxide eugenol sealers are considered to be toxic (Kaur, 2015). Not only has the material been shown to leak, but it's toxic effect continues even after the material sets (Kaur, 2015). This sealer has been shown to harm nerve cell transmission and result in localized inflammation in bone and soft tissue (Kaur, 2015). Zinc oxide eugenol sealer containing paraformaldehyde is mutagenic and cytotoxic (Kaur, 2015).

Epoxy-based root sealers have demonstrated to be cytotoxic and even mutagenic (Hosseinpour, 2022). Root canal sealers with polymers show leakage even after polymerization and a resulting cytotoxic reaction (Graunaite, 2018).

9.1. Apicoectomy Sealers

Pro Root MTA, a form of Portland Cement, is used to seal the end of the root in an apicoectomy procedure. This material is placed directly into the bone along the amputated part of the root. Ac-

cording to the safety data sheet, Pro Root MTA has chemicals known to the State of California to cause cancer, reproductive harm and birth defects (Dentsply, 2014). The manufacturer states that people with pre-existing lung and upper respiratory diseases can be aggravated by exposure to the product and other medical conditions can be caused by exposure to Pro Root MTA (Dentsply, 2014).

MTA has been shown to have micro leakage (Kaur, 2017). Research has found bismuth released from MTA-based sealer into both the surrounding tissue and also into systemic circulation and organs including the blood, kidney, liver, and even the brain (Marciano, 2023; Pelepenko, 2024). Bismuth in MTA has been shown to be less biocompatible over time (Camilleri, 2004). Bismuth has been linked to toxicity of human pulp cells as well as kidney, liver, intestinal and lung cells (Pelepenko, 2024).

Arsenic contamination has been found in Pro Root MTA (Chang, 2011). Arsenic had levels of 1.16 ppm (1.16 mg/L), 116 times more toxic than what is safe for ingestion via drinking water (0.01 milligrams per liter (mg/L) (Chang, 2011; CDC, 2015; Gammal, 2022). Arsenic has been linked to skin disorders, high blood pressure, cardiovascular disorders, neurological problems, endocrine disruption, immune system issues and increased risks for diabetes. Arsenic is a cancer causing substance and has been linked to bladder, skin, lungs, nasal passages, kidney, liver, and prostate cancers (USEPA, 2013; USEPA, 2015; WQA, 2025).

5. Gutta Percha

5.1. History

Gutta Percha, or trans-polyisoprene, has been used since 1656 in Europe and throughout the last several centuries for several purposes such as insulation for underwater cables, cements, musical instruments, carpets, pipes, boats and even sheathing for ships (Kishen, 2019; American Association of Endodontists, 2021). The material has been used in dentistry since the 1840's for several purposes such as softening gold wire, temporary filling material and is currently used as a permanent filling material in the root of a tooth during obturation during root canal treatment (Kishen, 2019; American Association of Endodontists, 2021). When it is processed, gutta percha is derived from South East Asian Palaquium trees and is considered a "natural rubber" (Kishen, 2019). Don't be deceived when someone says that Gutta-percha is "natural". It is not that simple. It becomes a toxic substance when it goes through processing and has other chemicals added to it.

5.2. Allergies and Sensitivities

People with latex allergies should consider avoiding gutta percha use in root canals due to cross reactivity. Gutta Percha material comes from the same botanical family as the rubber tree and is

related to latex (Guttman, 2001; Kishen, 2019). A similar rubber like-substance, gutta-butala, can also be added to gutta percha and sometimes is not reported by the manufacturers. These materials can trigger allergic reactions for sensitive patients when used in root canals (Guttman, 2001; Kishen, 2019).

5.3. Histology of Dental Pulp Reactions to Gutta Percha

There was an experimental study done where gutta percha was inserted into the tooth and some of the teeth were extracted for observation. Some of these included breaks in the continuity of the dental pulp membrane, fibrous encapsulation, calcification, flood of neutrophilic leukocytes, lymphocytes, and odontoblast nuclei. There were also foreign body reactions (Walton, 1992).

These reactions are showing a pathologic, or harmful reaction to the pulp tissue of the tooth. It is also important to note that the article states that the additives on the gutta percha such as coloring agents, age resistants, plasticizers and other additives do not play a large role in influencing the irritational qualities of GP cones (Walton, 1992). When the gutta percha is taken out of the tooth, it can cause cell necrosis (cell death) and local inflammation (Kishen, 2019).

5.4. Added Materials

Many materials can be added to gutta percha for different purposes. Some of these materials can be toxic. Zinc oxide, an additive to gutta percha, has been shown to leech into tissues long-term and cause toxicity (Eleazer, 1978).

In order to make the gutta percha adhere to the inside of the tooth, materials such as resins, glass ionomer resins and calcium phosphate silicates can be added to the gutta percha (Kishen, 2019). Resin materials can also contain BPA and other harmful chemicals (National Institute of Environmental Health Sciences, n.d.). Glass ionomers contain fluoride and have fluoride releasing properties, which can also be toxic to the body (Cheng, 2014). Calcium phosphate silicates can also be toxic and can can have heavy metal with lead, arsenic and cadmium contamination (O'-Donnell, 1992).

Barium is used in order to make the gutta percha "radio-opaque", or show up white on the x-ray in order to help dentists visualize the root canal filling material. Barium is toxic to the heart, the nervous system, and can be toxic if inhaled or there is skin contact. High amounts can cause convulsive tremors, violent diarrhea and muscular paralysis (Rojas, n.d.).

Heavy metals such as mercury and cadmium can be mixed into gutta percha as "salts" or "heavy metal salts". Like the addition of barium, this is also done so that the material can be seen on the x-ray as radio-opaque (Eleazer, 1978). These heavy metals can be toxic to the body (Eleazer, 1978).

Cadmium can come from a byproduct of manufacturing. A study by the IADR (International Academy of Dental Research) found in their study that gutta-percha tips used for root canals contain an average of 0.10 µg in each tip (IADR, 2003). The study claims cadmium toxicity from gutta percha is not a health concern since "FDA allows up to 15 µg/g (ppm) of cadmium in food, and the average person in the U.S. consumes about 30 (micrograms) µg Cd/day" (IADR, 2003). The FDA established a temporary intake guideline for cadmium of 0.21–0.36 micrograms per kilogram of body weight per day and is based on "food consumption" (US Food and Drug Administration, n.d). The IADR study claims that the the average amount found in gutta percha is lower than the "safe" amount, so it is considered to be safe (Dentaltix, 2021).

There are many flaws with this perspective. First, the physiology of food consumption is very different than implanting a heavy metal into the body permanently with continuous exposure every day. Also, the "safe amount" of cadmium in gutta percha is based on an "average" number, so it is important to note that some levels of cadmium can be higher than . 1µg. The study also did not have a large sample size and can lead to bias. (IADR, 2003) In some cases, multiple gutta-percha points are placed within a single canal, and when several teeth are treated, each with multiple roots or canals, this can raise questions about cumulative burden. Cadmium exposure does not only come from food. It can come from other sources such as dental materials, tobacco smoke and industrial waste. Some occupational exposures can occur from work such as soldering or welding (US Environmental Protection Agency, n.d.). Even at low doses, cadmium can be toxic. The EPA states that the greatest concern for cadmium is from exposure to lower doses over a long period of time (US Environmental Protection Agency, n.d.). The FDA states that prolonged exposure to cadmium is associated with adverse health effects. These include kidney and reproductive dysfunction, cardiovascular disease, bone demineralization, and diabetes (US Food and Drug Administration, 2024). The U.S. Department of Health and Human Services determined that cadmium is a probable or suspected carcinogen (a substance that cause cancer) (US Environmental Protection Agency, n.d.). It would be logical to reduce voluntary cadmium exposure whenever possible.

Solvents are used in root canal treatments, mostly to dissolve the gutta percha in re-treatments (Kishen, 2019; Chutich, 1998) The solvents benzene and carbon tetrachloride have been discontinued because of their toxicity (Kishen, 2019). Other solvents include halothane and chloroform (Kishen, 2019; Chutich, 1998). These substances are toxic (Chutich, 1998; National Toxicology Program, 1991). Chloroform has been liked to tumor formation (National Toxicology Program 1991). Chloroform has been banned in cosmetics and drugs by the FDA, but still can be used in dental applications for root canals (Crump, 1984). Halothane has been associated with hepatic necrosis (Chutich, 1998). Halothane, in particular, has toxicity that is not dose-dependent and can happen at any level (Chutich, 1998).

The argument for in-favor usage for these chemicals stems from the claim that the teeth do not leak that much of the chemical out during the procedure, thus it is safe. There was an in-vitro study performed in 1998 showing that there was leakage of the chemicals from the teeth during the root canal procedure, but it is at a "safe level" (Chutich, 1998). There are several flaws with this study and this outlook. First, this study only looked at leakage from the "apical foramen", only one spot on the tooth, completely ignoring the lateral canals. The study also examined the teeth after they were extracted from the mouth, not in the actual environment with other factors such as blood and lymphatic flow. The controls were also not on natural, untouched canals, but on pre-obturated teeth with sodium hypochlorite, which is known to damage tissue (Kishen, 2019; Stanford University Environmental Health and Safety, n.d.). The specimen selection was favorable to minimize the dose leaked out from the tooth. They only used single-rooted teeth. Multi-rooted teeth such as the molars have more surface area and thus more potential for leakage. Also, the apices of these teeth were completely formed without any micro fractures or other malformations and had well condensed gutta percha, which is not always the situation clinically. Even the researchers admit that if the obturation is poor, the chemical exposures could be at greater levels than presented (Chutich, 1998).

5.5. Disinfecting

Gutta percha is sometimes medicated with iodoform in order to help kill some common microorganisms in teeth. It is known to be absorbed through wounds and abscesses (as with root canal teeth) and can cause fatty liver and necrosis (Kishen, 2019; Drugbank, n.d.).

It can also be medicated with calcium hydroxide for antimicrobial effects (Kishen, 2019). Calcium hydroxide can irritate tissues and cause irritation, inflammatory reactions and necrosis (Cheng, 2014). There is also a cancer link with calcium hydroxide. In one study, there was a protein synthesis increase of the epithelial tumor cells with conventional gutta-percha points and with both gutta-percha points containing different calcium hydroxide-based formulations (Balk, 2004). Heightened levels of protein synthesis often indicates cell growth and proliferation and can lead to tumor growth and development (Anantharaman, 2010).

Chlorhexidine is also used used because of its disinfection properties (Kishen, 2019). It can be toxic to not only oral tissues, but also to the kidneys, eyes, ears and liver (Heloisa, 2023; Haapasalo, 2006; Souza, 2017; Lamster, 2012; Fan, 2016).

Nano-diamond gutta percha composite can be embedded with nano-diamond amoxicillin conjugates (Kishen, 2019). Amoxicillin has been linked to liver damage, hypersensitivity reactions and more (Medical News Today, 2023).

Sodium Hypochlorite is used to disinfect gutta percha and can cause tissue damage to the mouth, esophagus and throat (Kishen, 2019; Stanford University Environmental Health and Safety, n.d.).

Glutaraldehyde is also used to disinfect gutta percha (Kishen, 2019). It can contain formaldehyde and is also associated with kidney injuries, hepatitis, blood cancer in rats and more (Wang, 2020; National Library of Medicine, 2021).

Formocresol or parachlorophenol can also be added to gutta percha (Eleazer, 1978). Formocresol contains formaldehyde and that has implications with toxicity to the kidneys and liver (Scientific American, 2017). Parachlorophenol also has been found to have carcinogenic effects and toxic effects to the brain, central nervous system, liver and other organs (Drugbank, n.d.). Formaldehyde is a known carcinogen and has been linked to nasopharyngeal cancer, nasal sinus cancer and leukemias (IARC, 2006).

5.6. Processing Procedure for Gutta Percha

Obach's Technique is used for manufacturing gutta percha (Kishen, 2019; NPAA, 2015). Cold industrial gasoline is used to process the gutta percha and then it is bleached and steam distilled to remove the gasoline. "Final ultra-pure" (white) gutta percha is modified with appropriate fillers to overcome the odor of gasoline and is this is the final commercially available formulation (Kishen, 2019; NPAA, 2015). Gutta percha is then combines with plasticizers, fillers, radiopaque material and other materials and then is available for endodontic use (Kishen, 2019; NPAA, 2015).

6.6 New Alternatives to Gutta Percha

New alternatives to gutta percha have been developed such as brands such as Resilon and Hydron. Resilon is a resin-based filling material made of polyester, bioactive glass, resin sealer, difunctional methacrylate resin and other materials (Dadresanfar, 2012; Deepti, 2010). High-quality research needs to be performed on Resilon. The literature brings up concerns with sealing efficacy and biocompatibilty (Deepti, 2010). Resilon contains Bisphenol A epoxy (Bis-GMA) and that can raise toxicity concerns as well (Pragya, 2019). Another component of resin-based materials, Bisphenol A diglycidyl ether, is classified as mutagenic and may also be cytotoxic (Kaur, 2015). Another filling material, Hydron, had a high failure rate and there are toxicity concerns with un-polymerized HEMA monomer leaching from the root canals (Reid, 1992; Onay, 2006; Kaur, 2015). Incompletely polymerized monomers are more toxic than polymerized sealer (Kaur, 2015).

7. Root Canal Sealers

Root canal sealers, Endomethasone N (Septodont), AH-26 (Dentsply) and Pulpdent Root Canal Sealer (Pulpdent), all have toxicity concerns. AH-26 showed severe toxicity which became mild after one month while Pulpdent Root Canal Sealer showed severe to moderate toxicity (Guatam, 2013; DHP Supply, 2015; Onay, 2006; Septodont, 2023). Apexit Plus's (Ivoclar Vivadent) safety data sheet lists silicon dioxide under carcinogenic categories, yet it is claimed to be the least toxic of all of the sealers (DHP Supply, 2018).

8. Other Root Canal Disinfectants and Tools to Aid in Disinfection

Menthol, camphor, phenol and formaldehyde, all known carcinogens, are used to attempt to disinfect root canals (Gammal, 2022). Antibiotics, calcium hydroxide, chlorhexidine and cortisone have also been used and come with many issues (Gammal, 2022). Although ozone has been considered to be a less toxic option, it has been shown to only penetrate up to .3 mm into dentinal tubules, leaving 2-3 mm untouched and unable to be completely disinfected (Gammal, 2022; Silva, 2019; Can, 2019).

New equipment such as lasers, rotary instruments and endodontic microscopes have also been used to help with disinfection. Lasers and rotary instruments have not been proven to be effective (Jha, 2006; Kreisler, 2003; Vezzani, 2006). Lasers can only penetrate 0.5-1 mm into the dentine and there is no evidence that lasers are better than the standard endodontic treatment, with no demonstration of 100% sterilization (Kreisler, 2003; Bergmans, 2006; Klinke, 1997; Juric, 2014; Asnaashari, 2013). Lasers can also cause cracking in the teeth and other side effects (Mortazavi, 2016). Microscopes can improve visibility, but it does not change the fact that it is still impossible to fully sterilize the tooth (Gammal, 2022).

7. <u>Pediatric Root Canals</u>

Pulpotemies, otherwise known as "baby root canals", are primarily done on primary teeth. It only treats the upper part of the pulp, leaving the root section of the pulp remaining. Common materials used for pulpotemies include MTA, Formocresol, Ferric Sulfate, Biodentine, Calcium Hydroxide and Glass Ionomer Cement (GIC).

Formocresol has been shown to be teratogenic and embryotoxic (Gammal, 2022; Lewis, 1981; Friedberg, 1990). Formocresol contains formaldehyde, a mutagenic and carcinogenic material (Lewis, 1981). A study on pulpotemy teeth treated with formaldehyde demonstrated 30 percent of it spreading systemically (Ranly, 1985). Cresol's is defined as a possible human carcinogen, a possible tumor promoter and can have other harmful effects (USEPA, 2016). See sections 4.5.1.6, 5.1, 6.5.5, 6.7, 6.8 and 6.9 for more information on formaldehyde and cresol.

Ferric sulfate is used in pulpotomies, an endodontic procedure in primary teeth. It's safety data sheet has several health concerns, including target organ damage to the respiratory and gastroin-

testinal tract (Chemtrade Logistics Incorporated, 2023).

For more information about calcium hydroxide concerns, see sections 5.4, 6.5.5, 6.8 and 6.9. For more information about MTA, see section 5.3, 5.7 and 6.9.1.

Glass ionomer cements also have serious health concerns. They have been shown to release fluoride and has been shown to be mutagenic (Sidhu, 2001).

Biodentine has been shown to have leakage of the material and there are still some possible adverse health effects such as airway irritation and gastrointestinal irritation (Ivoclar, 2023). This material seems to be more biocompatible than the other options, but there is still not enough data to draw definitive conclusions (Brizuela, 2024; Kaur, 2017).

Even if there is one material that seems to be "cleaner" than others, the concept of a pulpotemy is still flawed. Part of the pulp is removed, but some is still left over. Similar to adult root canals, there is no definitive way to make sure that the tooth is completely disinfected or that there is no contamination on a micro level. Assumptions are made based on pain levels, lack of visible necrosis, purulence or excessive hemorrhage, but no definitive testing is recommended as the standard of care (AAPD, 2019). Even the American Academy of Pediatric Dentistry acknowledges that the procedure's success rate diminishes over time (AAPD, 2019).

Pulpectomies can still be performed as well. The procedure is similar to adult dentition in that the canals are cleaned and shaped, irrigated and filled with some of the same materials as adult dentition (AAPD, 2019). Sodium hypochlorite and/or chlorhexidine can be used for irrigation, and filling can include zinc/oxide eugenol, iodoform-based paste and/or calcium hydroxide (AAPD, 2019).

8. <u>Re-Treatments</u>

When the first attempt at a root canal "fails", a root canal re-treat is sometimes an option available. The procedure attempts to not only redo the whole root canal procedure itself, but also completely remove all old material and microorganisms, especially those not in the canal itself (Alves, 2022). This becomes complicated because if the old filling materials block access to the pathogenic bacteria, then the infection can persist (Alves, 2022). Once the root canal sealer enters the dentinal tubules, it is impossible to remove it during re-treatment (Alves, 2022). One author commented on root canal re-treatments:

"It is salient to point out that, regardless of the method used for the removal of filling remnants, using or not a supplementary step, virtually all studies demonstrated that the canals are rarely, if ever, completely cleaned after these procedures". - (Alves, 2022)

"The actual impact of the amount of residual filling material on the outcome of root canal re-treatment is unknown". (Alves, 2022)

There has not been a proven re-treatment strategy to predictably remove all of the residual material from the previous root canal treatment (Alves, 2022). Even in a clinical setting or with CBCT, it is still difficult to visualize residual infection and/or materials because the resolution may not be enough to see in the crevices of the teeth (Alves, 2022). Therefore, this always leaves a possibility for infection.

9. Crossing the Research Gap

9.1. Review of General Health and Root Canal Research

To the author's knowledge and to date, there are some studies exploring general health outcomes related to root canal therapy, but many more need to be done. A comparative longitudinal study showed that the subjects with root-canal teeth reported poorer oral health outcomes than other dental treatment groups (Chew, 2019).

What is the current scientific literature, peer-reviewed articles connecting periodontal disease, (Levy, 2017; Legein, 2013) root canal-treated teeth, and ischemic osteonecrotic or chronic avascular necrotic bone lesions connecting these conditions with systemic disease? Today, research on both periodontal disease bacterial microbiology (Siqueira, 2009; Vidana, 2011) and toxicity of root canal-treated teeth (Martinho, 2011) have been published, using advanced biopsy techniques ranging from polymerase chain reaction technique (DNA) to the Limulus amoebocyte lysate (LAL) assay, quantitative kinetic chromogenic LAL assay (KQCL) and kinetic turbidimetric LAL assay (Turbidimetric), with the exception of the histological techniques. (Vidana, 2011; Nobrega, 2013; Siqueira, 2013; Gomes, 2012; Martinho, 2011; Rocas, 2011; Mahendra, 2010; Ott, 2006; Pessi, 2013; Pyysalo, 2016; Louhelainen, 2014; Kostic, 2012)

More research needs to be done on root canals and overall health. There is a lack of peer reviewed articles connecting histological analysis and DNA testing of microorganisms present. In fact, there is very little incentive for researchers to investigate an established dental procedure that generates over $22,900,000,000.00 annually (American Association of Endodontists, n.d.) in the United States of America* for fear of retribution by established dental institutions, whose membership consists of governor-appointed positions recommended by their state dental associations and state dental boards, the American Dental Association, as well as organizations such as: the American Association Of Endodontists, the American College of Oral and Maxillofacial Surgeons, the American Academy of Periodontology, and the American Dental Association.

There are several studies showing that root canals do not impact general health. Besides the fact that these studies are outdated, there are many flaws with them (Bystrom, 2007). Some examples

of this include insufficient stratified data to calculate pooled success rates, only selecting for healthy patients and excluding unhealthy ones, and only using patients with radiation to the head and neck (Bystrom, 2007). Therefore, there is no strong enough evidence to support the claim that root canals are not connected to overall health.

9.2. Pulp-less Tooth: Vital or Non-Vital?

An article in the Journal of Endodontics' January 1982 special issue, as well as a large portion of the dental community today, try to make a case that a pulpless tooth is not a dead tooth. During a root canal treatment, the nerve inside of the canal of the tooth is removed. Here are the arguments:

Argument #1: Teeth still have a definite and vital relationship with the surrounding tissue; the author insists; the life of the tooth depends on the attachment apparatus, i.e., the periodontium and adnexa. In the words of Dr. Grossman and Dr. Marshall, the life of the tooth is dependent upon the integrity of the periodontal membrane and not upon the integrity of the pulp.

This logic of the authors above do not coincide what the American Academy of Endodontists have to say. Necrosis is defined as the death of tissue or an organ in the body (NIH, 2023). For teeth, pulp necrosis equates to the death of the pulp and it can lead to apical periodontitis (American Academy of Endodontics, 2013). Therefore, the tooth is considered to be dead. It is impossible to fully remove infection in the tooth and there will always be some amount of necrosis present.

Argument #2: If a pulpless tooth were a dead tooth, it should be exfoliated since the body does not tolerate dead tissue.

Similar to gangrene, waiting for a necrotic tooth or a digit to exfoliate on it's own is very dangerous to health and can be life threatening (Fikri, 2011; Mayo Clinic, n.d.). There are two ways that the human body can exfoliate a tooth itself. A tooth may eventually fall out on it's own due to breakdown of bone and tissues leading to loosening due to infection spreading into periodontal tissue, although it can take years (Medical Microbiology, 1996). The concept of root resorption can be a body's natural response to infection in the pulp. This process disintegrates the tooth from the root upwards (Piriyakhuntorn, 2025).

Argument #3: They argue that the tooth can't really be dead because patients can feel a tooth being removed if there is no anesthetic used (Shakman, n.d.; Root Canal Therapy Special Issue, 1982; Grossman, 1940)

Root canals and dentistry are somehow exempt from modern medicine's outlook on necrosis. A

gangrenous digit is considered necrotic (NIH, 2025). There is still feeling surrounding the digit right up to the border, even though it is considered dead. For teeth, the PDL is considered the border and it still has feeling, but somehow, it is not considered dead. Surgery/amputation of the digit or antibiotics can be treatment options for gangrene (NI Direct, n.d.). In root canal-treated teeth and teeth with apical periodontitis, antibiotics cannot reach the inside of the pulp since the blood supply to the inner part of the tooth is not viable (Muller, 2024). Logically, the only option left is to "amputate" the tooth, or extract it from the jawbone. However, root canals seem to be exempt from this thought process.

10. Practical Matters for the Biological, Holistic, or Integrative Dentist

Exemplary record keeping is certainly essential for legal purposes. In your records you must list:

1. The patient's chief complaint.
2. Why the patient wants their root canal-treated teeth removed.
3. Any experience of pain, infection, or a systemic-related condition the patient has had.
4. Radiographic (both CBCT and 16 to 18 full mouth series), EAV, and/or quantitative ultrasound (QUS or CAVITAT™) documentation of dental conditions.
5. A signed and dated informed consent form from the patient and a written statement why they want their root canal-treated teeth (past extraction sites and titanium implants) removed.
6. The patient's expression of pain level or statements like "After I had my root canal done, I got sick, and I believe these two situations are related."

Chart the facts: existing conditions, missing teeth, restorations, periodontal health, bone health oral cancer screening, TMJ condition, and sinus health.

Include the condition of each tooth number or area: failed root canal-treated tooth with granulation tissue, cracked tooth, etc.

Note why you recommend extraction. If the patient had persistent pain and discomfort despite root canal treatment and an absence of positive peri-apical findings on radiograph, write it in the record. Why is it a failure? Pain? Suppuration? Mobility? Fracture? Un-restorability?

Record your diagnosis. This is where the board will say they "gotcha" because until the biopsy is returned, you may only give possibilities (i.e., differential diagnosis) and not a formal diagnosis. If you use a DNA biopsy report, many dentists do not get the connection between a histological report or a DNA report.

Therefore, state possible differential diagnoses of
1. AVN (Avascular necrosis)

2. Asymptomatic chronic fibrosis.
3. Failed root canal due to radiolucency at the apex of the tooth, no pain.
4. Abscess present with draining fistula.
5. Non-supportive osteomyelitis.

Upon the arrival of biopsy reports, a diagnosis may be stated or the personal opinion given on the patient's situation. This maybe entered at the time you review patient results or in a letter to the patient, with a copy placed in the patient's chart. There are new insurance dental codes that distinguish between Histological Reports (D7285) and DNA Reports (0422). Always have a biopsy of either type for all surgical procedures that include surgery of avascular necrosis sites, removal of root canal-treated teeth, bone lesions, or soft tissue excisions.

11. Protocol for the Removal of Root Canal-Treated Teeth

For an infected tooth, the alternative to RCT is usually extraction (removing the tooth from the jawbone). In Root Canal Cover-up, Dr. George E. Meinig explains the extraction method he has suggested since 1993. There have been many good suggestions added to his basic protocol, but his lays the foundation for the basics (Bale, 2013). The basic protocol is also recommended for the extraction of non-root canal-treated teeth, but it is not the only way to prepare an extraction site.

Once the tooth has been extracted and tooth, tissues and blood samples have been collected for biopsy, a #8 or #10 round burr is used to remove one to two millimeters of the entire bony socket, including the apex area.

Of course, there are exceptions to every rule. In mandibular third and second molar areas, one should know exactly where the neurovascular bundle is and the mental foreman/nerve. On occasion, one may avoid cleaning the lower one-third of the socket to avoid neurological damage. In the upper arch, the round burr is started in the apex area and brought to the surface, avoiding the possibility of going directly into the sinus. It is very common to extract a failed root canal-treated tooth or abscessed tooth and discover an oral-antral fistula exists into the sinuses. If this happens, a protein rich fibrogen (PRF) or collagen membrane can be inserted into the apex of the socket or in the sinus via the opening and a bone augmentation material, such as artificial bone, cadaver bone, autologous bone, or a beta-tri-calcium phosphate paste may be placed in the sinus area and socket. A similar membrane may be secured in the socket, sutured into place by suturing the tissues in such a manner to secure the healing site. Make sure there is good blood flow into the area by not injecting an anesthetic with epinephrine, unless there is a contraindication.

Whenever a lower third molar appears to be entangled around the neurovascular bundle, always refer that patient to an oral surgeon for removal. If the surgeon encounters a problem, their li-

cense makes it less likely they will be involved in a board complaint or legal action. Never attempt to be a dental hero.

The purpose of removing the first 1 to 2 mm of bone is to perform a partial ostectomy squestrectomy for removal of the periodontal ligament (PDL), non-vital, loose, or sloughed-off dead bone caused by infection or reduced blood supply. aiding healing of the site. As we learned in school; the PLD has four purposes:

- To secure the tooth to jawbone.
- To facilitate fluid flow through the dentinal tubule structures. When the tooth is "depressed" into the socket, it acts as a cushion. When the pressure is released, the tooth moves back to its original position and acts as plunger to the fluids in the dentinal tubules, creating pressure to pull the liquids out from the tooth's inner structures into the PDL and the interstitial spaces.
- To give feeling without pain.
- To prevent bone growth. (Teeth are considered bone by the body.)

Ligaments allow freedom of movement between bones. So if a tooth is removed but the PDL remains in the socket, the body reacts as if the tooth is still present. It prevents the creation of capillary beds which bring in the blood vessels establishing circulation. Without proper circulation, osteoblasts and osteoclasts cannot be generated and no new bone will grow. A lesion is created, and an anaerobic environment is established for bacteria, viruses, and toxins to live in and thrive.

With root canal teeth, endotoxins have been found 100% of the time (Bale, 2014; Pessi, 2013). This means the PDL and adjacent bone were exposed to toxins and should be completely cleaned.

The basic principles of cleaning the jawbone socket are recognized in the American Dental Association's Dental Procedures Codes 2017. The principle of cleaning the surgical sites is the same for a root canal-treated tooth, a non-root canal tooth, and areas of avascular necrotic lesions.

D7140: extraction, erupted tooth or exposed root (elevation and/or forceps removal). [Includes removal of tooth structure, minor smoothing of socket bone, and closure, as necessary.]

D7210: extraction, erupted tooth requiring removal of bone and/ or sectioning of tooth, and including elevation of mucoperiosteal flap if indicated. [Includes removal of tooth structure, minor smoothing of socket bone, and closure, as necessary.]

D7550: Partial ostectomy/squestrectomy [for removal of non-vital, loose, or sloughed- off dead bone caused by infection or reduced blood supply].

While the procedure is being performed, the area should be irrigated with copious amounts of sterile saline water via your surgical hand piece or a separate water syringe.

While cutting the bone, the PDL and toxins are removed and the bone is "perturbed" or stimulated. As the blood vessels are established in the socket or other bony lesions, this perturbation of the bone stimulates a change from osteocytes to osteoblasts. The latter are the cells that generate new bone formation.

After the socket has been cleaned, it is recommended to prepare it. There is no one set method to perform any or all of the suggestions below. Whatever works in the specific, individual case is appropriate.

1. Fill the socket with a non-vasoconstrictor (no epinephrine) local anesthetic. Allow the liquid local anesthetic to set for about thirty (30) seconds, then gently remove most of the anesthetic,leaving a small amount to continue stimulating osteoblastic activity.

2. Irrigate the surgical site with sterile saline water, hydrogen peroxide (and set for 30 seconds), ozonated water (and left to set for 1 minute), or other preferred cleaning solutions.

3. Rinse the site with another antiseptic solution.

Once the surgical site has been cleaned, place your bone augmentation material(s) or PRF/PRP tissues along with primary closure via suturing the site. Each practitioner needs to decide whether to place anything into the surgical site. Materials used by many of our members include: nothing, sterilized cadaver or xenograft materials, synthetic bone; and protein rich fibrogen or plasma rich protein, with or without the addition of homeopathic remedies.

Some biological and integrative dentists will simply clean the site, placing nothing because their patients often suffer from autoimmune conditions. Their experience with this type of patient is less is more.

All surgical sites should be closed as much as possible by suturing the surgical site with an absorbable or Teflon suture for better healing and less build-up of plaques. Addition of homeopathic remedies, PRF, PRPP liquids, ozone, or another product may be added to the sites to aid in healing. For postoperative care, gentle mouth swishing with salt water or a non-toxic mouth wash is recommended.

12. <u>IABDM's Stance on Root Canals</u>

The IABDM does not advocate root canal treatment. However, we do not recommend automatically removing every root canal–treated tooth. We strongly encourage that each root canal tooth be thoroughly evaluated, as a significant number of them may fail over time. Because conventional radiographs often cannot detect root canal issues with complete accuracy, patients may benefit from consulting a biological dentist who can perform a CBCT scan for more precise assessment.

We believe patients must receive full, informed consent regarding potential health and toxicity concerns before undergoing root canal-related procedures. A one-size-fits-all approach is not appropriate for root canals; clinical decisions should take into account individual susceptibilities and overall health. Root canal-treated teeth may not always be fully disinfected, and associated pathogens have been linked to various health problems. Greater awareness of these issues among all medical professionals is also essential.

13. Recommended Reading

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