Endodontics, why it works!

Root canal treatment has been around since the mid 1800s. Over the last 200 years the treatment has been modernised, but the general premise remains the same. With improvements in technology what we now consider the standard of care has certainly evolved and more than ever we are able to deliver predictable outcomes for our patients, meaning that saving teeth and preventing the need for dentures, bridges, and dental implants a very valid option for our patients. We have all seen the microanatomy of the impressions taken of the root canal system by Hess (1917) and know the challenges of cleaning a root canal system. But how does this seemingly impossible task correlate to such a predictable degree of healing or maintenance of periapical health? A situation we commonly term 'success' in endodontics.

Apical periodontitis

Although root canal treatment was first performed in the mid 1800s, the story of modern, evidence-based endodontics really begins with Kakehashi and his rats. In 1965 Kakehashi et al took two sets of rats, those that were free from bacteria and those that were in a normal environment. Access cavities were made into the pulps of both the germ free and the normal rats. As you might expect after time the rats in the normal environment, had bacterial colonisation of the pulps in these teeth and abscesses occurred. But in the group of rats which were free of bacteria and had been fed germ free food, no inflammation of the pulp nor the periapical tissues (apical periodontitis) were observed. In fact, even though sterilised food had lodged in the pulps of the germ-free rats, dentine bridge formation had occurred. The conclusion from this study was that bacteria which invade the root canal are essential, and the primary cause of apical inflammation (apical periodontitis). Prior to this the cause of apical periodontitis was very much up for debate.

Some seminal articles then were produced by Moller et al 1981 to show that in monkeys making an access cavity into the pulp and its removal did not cause apical periodontitis by itself but that again bacteria were required to produce apical periodontitis. Fabricius et al 1982 went one step further and showed that the microflora in the root canal which cause apical periodontitis are a community of microorganisms and each species relies on the actions of the others. Some of the bacteria involved in late-stage disease which predominated during this phase, were inoculated into sterile canals and were not culturable as time went on. This extremely helpful article was the first one that showed that primary apical periodontitis is related to the group actions of a wide variety of microorganisms rather than a small number of species. Although the Kakeshashi paper gets all the focus when it comes literature reviews, to me the Fabricius article really underlines why despite all the anatomical challenges we face when performing root canal treatment, we continue to deliver predictable outcomes for our patients. We cannot directly debride all the walls of

a root canal, but we certainly can establish an environment which prevents the microorganisms from thriving.

Locating the root canals

So now that we know bacteria cause apical periodontitis, removal of them is the biggest challenge that presents itself. There has been so much research to show that removal of bacteria from the root canal correlates to predictable healing (Sjogren et al 1997). It is well documented that location of the canals shaping them and cleaning are fundamentals of root canal treatment. Filling the canals is an important step, but it is important to note that filling canals is not always required to obtain healing of apical periodontitis (Klevant and Eggnik 1983). Unlocated, untreated, missed canals (however you want to say it) are the primary cause of failure of root canal treatment (Siqueria 2001). There is no doubt that bacteria that remain in the root canal system untouched by our files and irrigant solutions proliferate with time and then their increase in toxin production, which exit the foramina in the roots, elicits the inflammation in the periapical tissues which leads to swelling and pain under the roots, known as apical periodontitis. Canals most often not located are: the second mesiobuccal canal in upper molar teeth, the lingual canal of lower incisor and canine teeth, the second distal canal in lower molar teeth and the middle mesial canal of lower molar teeth, just to name a few! There are also vast anatomical variations in premolar teeth, and I have treated premolar teeth in the past with 3 separate roots.

As I mention to my students and colleagues, who I teach at courses or online via the Specialist Endo Crows Nest- clinical hacks Facebook page: To be able to locate root canals you need the right tools, such as magnification and illumination. Magnification needs to be a minimum of 4 times magnification. When I was in general dental practice, I fell into the trap of using 2.5 times magnification and although this was helpful, I realised that I still was not able to visualise calcified canals. Operating microscopes are a massive advantage for locating canals. But their usefulness is not restricted to just canal location. They aid in posture, eye strain , neck strain and back strain. All operating scopes are not equal, I recently upgraded my microscope and found that the improved optics helped immensely with many of what we consider career related ailments. The other thing an operating scope does is decrease stress of finding canals and importantly the risk of iatrogenic errors which create undue stress for the operator and patient. The literature is also clear on another point, you need the right tools, and you need experience using these tools to be able to get the most out of them. Just having the tools is not enough. My earliest memory of this came in 1983 when as a young kid I watched my New Zealand cricket team face off against Australia in one of the then ‘Benson and Hedges’ One day series finals at the Melbourne Cricket ground. Facing a target of 303 runs to win New Zealand were 6 wickets down with just 45 runs on the board. Put simply, they had lost the match already, but in walked Lance Cairns to the crease. Cairns was a fast medium bowler and lower order batsman, known for his prodigious hitting. He possessed a new type of cricket bat, called Excalibur. The lack of discernible shoulders on the bat made it look more akin to a weapon used by our Palaeolithic ancestors, than a piece of sporting equipment. He then proceeded to hit the best Australian fast bowlers, including the legendary Dennis Lillie for six sixes, during his

innings of 52 runs, before being dismissed. New Zealand lost the match and the finals series, but what ensued was quite remarkable. People from all over the world wanted to buy the famous Newbery Excalibur cricket bat and kids all over the New Zealand attempted to emulate Cairns' feat at their local playground. But they could not do so, because having the Excalibur cricket bat was helpful but knowing how to use it was another skill entirely. The same can be said for canal location, the Stropko paper 1999 shows that during an 8-year period, improvements in technology and experience using this technology increased the number of cases where the second mesio-buccal canal was locate, in both upper first and second molar teeth. My advice to anyone wanting to purchase magnification or illumination, to improve their root canal treatment is, first to think of what they need and get the next magnification level or model up from this. When you use magnification you get used to it and then always want higher magnification.

Shaping of the canals

Shaping of the root canal is a way we create a path to the apex. It serves a few important functions. Firstly, it removes infected dentine and biofilms from the canal walls as we physically debride the root canal wall. Secondly it creates a more uniform shape that can be irrigated with our antibacterial irrigants and thirdly it creates an apical seat for our root filling material which forms a point for the apical seal. In fact, because preparation of the root canal removes both bacteria and their biofilms, as well as their energy source, the pulp tissue. Preparation of the root canal is one of the most important steps to obtaining healing of apical periodontitis. Studies show that approximately 35% or more of the root canal surface area is untouched when we use solid rotary instruments to prepare a root canal (Peters et al 2001). So, whilst it is a particularly important part of the process, the journey to obtaining (healing of apical periodontitis) does involve both shaping, then cleaning with irrigant solutions. There are many instruments that can be used to prepare the root canal system. The traditional convention was to prepare canals to an apical size three sizes wider than the first hand file that bound at the apex. But with the advent of very flexible greater tapered files the focus is less on apical sizes and now on preparing an adequate, but not excessive taper that is in harmony with the preoperative anatomy. We should never try to make the canal fit the files we use. We should always use a file system which will refine the existing anatomy. By doing so, we reduce the chance of excessive removal of dentine, iatrogenic errors such as perforations, ledges, and fracture of files, which reduce our ability to clean the full length of the root canal. There has been a plethora of instrumentation systems released in the last 10 years all promising to be better than the previous generation. In my career I have used 10 different root canal preparation systems. I currently have 6 different preparation systems for different clinical situations. When a new one is released, I follow a simple assessment procedure before introducing these into my practice. The first criteria I use is that I must be able to easily (by doing a simple google search) find out under what conditions the file was made, if the file is made in the most stringent environment then it is always easy to find out by checking online. Most file manufacturers, who make good products like to advertise how the file is made. In much the same way,

when you visit a quality restaurant the kitchen is visible to everyone dining. They are confident and proud of the quality they provide. A root canal file is a precision instrument and if I were having the instrument used inside my root canal, I would want to know it was made under the strictest conditions, so do not compromise on this. The second criteria I prefer is that the instrument is pre-sterilised. This means that the file made in the strictest conditions was also sterilised under these strict conditions. Again, I would want this for my own treatment, so this is what I want for my patients. If files need to sterilised when they arrive from the factory this slows down the rate at which they are available to use clinically and means that staff need to spend time doing this. For this reason, I prefer and recommend pre-sterilised files. I also prefer milled blades for cutting efficiency, that have been specifically cut into the wire to give the desired rake angle. Files that are not milled often unwind under stress and having a straight non-cutting file in some places along the file reduces cutting efficiency. Reduced cutting efficiency increases force on the file during preparation and predisposes the file to fracture. Remember when as a kid you tried to saw a block of wood with a blunt saw. The blunt saw does not cut efficiently and when you try to move it back and forth to cut the wood, the force that you are putting on the saw, is transferred to the saw. The blade begins to flex and after a certain number of flexing cycles the blade of the saw snaps off. The same goes for preparation of canals. We need files that cut efficiently, and we need blades that do not unwind, because unwound blank files do not cut dentine. The same goes for files loaded with dentine debris, which is why we always should clean the debris off the blades when we prepare a root canal. For this reason, I discourage the use of viscous chelators, such as EDTA gel on motorised files, as they attract dentine chips to the file (Shantiaee et al 2014). Motorised preparation should always be done in the presence of irrigants which keep dentinal debris in solution.

The other two things I prefer for a motorised preparation file system is to have matching gutta percha cones and paper points. This just makes filling the canal easier and less technique sensitive. Of course, most dentists who are proficient at root canal treatment can use stock gutta percha cones, but why waste time trying to select a stock cone, when you can get one that fits the finishing file size accurately?

Irrigation

There has been so much work into the instruments that shape the canal that the extremely important step of irrigating the canal is often overshadowed. The classic studies in endodontics show that removal of bacteria within the root canal system can only be accomplished by both a combination of preparation and use of antibacterial irrigants and medicaments (Bystom and Sundqvist 1981, 1983, 1985). It also makes sense that irrigation of the root canal should reach the tip of the root, this has been shown to only be possible when the tip of the irrigating needle reaches 1mm from the apex (Chow 1983). There are other means by which we can move irrigants apically such as activation and use of files during preparation. My preference is to deliver these via an irrigation syringe directly and then activate the irrigants after full preparation of the canal has been done. Sodium hypochlorite and only sodium hypochlorite possesses the most important features of an

irrigant solution. It has antibacterial properties due to its high Ph and production of oxygen when it interacts with bacterial cells. It also possesses the ability to dissolve pulp tissue which is the energy source for bacterial cells and their biofilms, that protect the bacteria from other irrigant solutions. Over the years there have been many attempts to replace the use of sodium hypochlorite as an irrigant solution, due to its toxicity if extruded from the root canal. But none of these can offer both tissues dissolving capacity and antibacterial activity in the one solution.

Ethylene diamine tetracetic acid or EDTA for short, is another commonly used irrigant and it removes the inorganic smear layer, which is present after shaping of the root canal (Mohammadi et al 2013) . This inorganic smear layer which contains dentine chips amongst other things is thought to buffer the action of sodium hypochlorite through interaction with the irrigant making it less effective.

The removal of the inorganic smear layer cannot be done using sodium hypochlorite and this is perhaps one of the few failings of this universal irrigant. So, it stands to reason that EDTA helps to back up the effectiveness of sodium hypochlorite and research seems to agree on the principle that both sodium hypochlorite and EDTA have a synergistic effect (Bystrom and Sundqvist 1985). My preference is to use sodium hypochlorite throughout the procedure and then after the canals have been prepared use EDTA. This ensures that the active ingredients in the sodium hypochlorite are not used up interacting with EDTA during the treatment, at least during the preparation of the root canal.

Medication

Placement of calcium hydroxide paste inside the root canals as a means of aiding disinfection of the root canal system has been a popular practice. It is thought to exert an antibacterial effect due to its high Ph. This Ph denatures bacterial enzymes that aid in DNA replication and the hydroxyl ions interact with the lipid transport protein present on the cell wall. This interaction forms a lipid free radical and destabilises the cell, leading to lysis. Although classic articles extol the virtues of using calcium hydroxide as a means of disinfection (Bystrom and Sundqvist 1985) (Sjogren et al 1991). Some articles have challenged the idea that it significantly aids in disinfection (Peters 2002). A human histological study with a small sample size seemed to show that use of calcium hydroxide as an interappointment medicament improves the possibility of eliminating microbes from the root canal completely (Vera et al 2012). This study was based on another well-known histological paper that seemed to show that single visit root canal treatment was not effective in eliminating all bacteria from the root canal system (Nair et al 2005). Whatever your take is on all this research, even if the less positive findings on calcium hydroxides antibacterial effectiveness turn out to be true (a topic that has been debated in many endodontic meetings all over the world), one thing is almost certainly true. Calcium hydroxide dentures proteins due to its high Ph. Denaturation of protein is of key importance when it comes to improving removal of pulp tissue. Calcium hydroxide makes the tissue dissolving activity of sodium hypochlorite more effective (Hasselgren 1988) Pulp tissue is the

primary energy source of microbes inhabiting the root canal system and without this energy source their ability to thrive is significantly reduced. Perhaps when it comes to use of calcium hydroxide its ability to create an environment which is more akin to a famine inside the root canal is at least or more important than its ability to actively cause cell lysis. In my clinic most of the cases I treat are multiple visits and for this reason my medicament of choice is calcium hydroxide, delivered using a narrow tip so that I can place this medicament to the apex.

Steroid and antibiotic pastes such as Ledermix and Odontopaste are popular choices but I would only consider using these if there was inflamed tissue remaining at the conclusion of the initial extirpation appointment. When I worked in general dental practice treating walk in emergency patients, I did use Ledermix, often to alleviate the inflammation of the hyperaemic pulp, as a means of calming it down till another longer appointment was scheduled. But, with sufficient time and profound anaesthesia, complete removal of any inflamed pulp tissue can occur at this initial appointment, making the use of a steroid and antibiotic paste redundant.

Filling the canals and restoration

Filling of the canals with a sealer and gutta percha is the current standard of care. Gutta percha has been used to fill canals since 1867 and although many people have tried to replace it with other materials there are a few reasons why creating a new material has its problems. Gutta percha has acceptable biocompatibility and even when extruded rarely causes any reactions (Haumann and Love 2003). Any material that could replace it needs to be more biocompatible but also most importantly also not biodegradable. Biodegradable products used within the root canal are simply food for the microbes that have survived root canal treatment and therein lies the biggest problem with replacing gutta percha. There simply is not a material which is significantly better to use instead of it.

The purpose of filling the canals is simply a way of closing root canal space to try and prevent communication between microorganisms, as well as an attempt to show to what dimensions the canal was shaped and to form a rudimentary coronal and apical seal. The science surrounding whether it does form an adequate coronal and apical seal is very debatable. For this reason, there is a significant body of evidence showing that restoring the root filled tooth correctly is both correlated to improved longevity (Aquilino and Caplan 2002), and a significant determinant to improving success of the root canal treatment (Ray and Trope 1995). For this reason, in my practice in Crows Nest I avoid placing a temporary restoration after filling the root canals. Once the canals are shaped and cleaned and this clean environment has been established, I want to ‘lock in’ that environment. There should never be a reason why there may have been some ingress of saliva or more bacteria. Leaving a temporary restoration in the pulp chamber opens the possibility that the patient won’t return to the referring dentist for the core. Filling the canals and sealing the orifices is a way to preserve your hard work. I also quite often fit orthodontic bands, mainly on molar teeth after provision of the core, to reduce the chance of fracture. It is also a good reminder to the patient, when they can see the band that the crown is the last phase to prevent their tooth from fracturing.

Conclusion

Although obtaining or maintaining periapical health by cleaning and filling of the root canal system seems like a difficult task, we have a lot of factors in our favour, in the quest for success. Our aim is to remove microorganisms and the pulp tissue and create a healthy environment within the root canal system. Our modern armamentarium is a benefit for improving efficiency and the standard of care we can provide. If we can establish this clean environment within the root canal system and then seal in this environment, then the research is clear that in most of our patients the remarkable human immune system, will do the rest!

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