The properties of Mineral Trioxide Aggregate and how it can be manipulated

Acknowledgements

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Bioceramics & Hydraulic Dental Cements

MTA and MTA like cements are often called ‘bioceramics’. However, this can be misleading as it groups MTA and MTA cements with medical and prosthetic ceramics such as artificial joints and artificial bone-like structures. Medical and prosthetic ceramics are structures which are produced and set in a factory or laboratory. These products are generally unreactive.

MTA powder is reacts with water to for a crystalline structure. A term which is in line with cement technologists is to use the term ‘hydraulic dental cement’ as hydraulic cements are cements which are mixed with water to form a slurry that later becomes a hard material.

Usage and Training

It is commonly believed that cost is the biggest barrier to use. However, a recent survey (yet to be published) of the ASE illustrates that the biggest barrier to use is education on the usage of the material.

Calcium hydroxide & MTA

Ca(OH)₂ paste is the gold standard of endodontic antibacterial medication. Its main antibacterial effect relates to its pH. It takes 7 days for Ca(OH)₂ paste, at pH 12, for the surrounding dentin to reach a pH of 9, where bacterial growth in teeth is inhibited.

Ideal Properties

<table>
<thead>
<tr>
<th>Ideal Properties</th>
<th>Ca(OH)₂ paste</th>
<th>Ca(OH)₂ cement</th>
<th>MTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brands</td>
<td>Calcipulp, Pulpdent, Calyxl</td>
<td>Dycal, MTA Fillapex, Life</td>
<td>ProRoot MTA, MTA Angelus</td>
</tr>
<tr>
<td>Key / Majority Reactants:</td>
<td>As below</td>
<td>Butylene glycol disalicylate + Ca(OH)₂</td>
<td>2(CaO)<em>{3} SiO</em>{2} + 2(H_{2}O)</td>
</tr>
<tr>
<td>Key / Majority Products:</td>
<td>Ca^{+} + 2OH⁻ + Gel-like thickening agent (eg Methylcellulose)</td>
<td>Calcium disalicylate + 2H_{2}O</td>
<td>2[(CaO)<em>{3}SiO</em>{2} • 4H_{2}O] + 4Ca^{+} + 8OH⁻</td>
</tr>
<tr>
<td>State &amp; Handling</td>
<td>Paste</td>
<td>Thick Paste that solidifies into flaky cement</td>
<td>Hard Paste that solidifies into rock like cement</td>
</tr>
<tr>
<td>Immediate pH:</td>
<td>12.5</td>
<td>9-10</td>
<td>12.5</td>
</tr>
<tr>
<td>Antibacterial effect</td>
<td>Strong</td>
<td>Mild</td>
<td>Strong</td>
</tr>
<tr>
<td>Long term state:</td>
<td>Soluble</td>
<td>Semi Soluble</td>
<td>Insoluble</td>
</tr>
<tr>
<td>Promotes healing</td>
<td>✔✔✔</td>
<td>✔</td>
<td>✔✔✔</td>
</tr>
<tr>
<td>Seals the tooth</td>
<td>×××</td>
<td>×</td>
<td>✔✔✔</td>
</tr>
<tr>
<td>Clinical indication</td>
<td>Therapeutic dressing</td>
<td>Liner</td>
<td>Permanent restoration</td>
</tr>
</tbody>
</table>

Ca(OH)₂ resin-cements do not release Ca(OH)₂, they consume it. They contain Ca(OH)₂ in their formulation, however, in their setting reaction, Ca(OH)₂ is consumed in resinous cement. Their pH is therefore less than the other Ca(OH)₂ mediums which do not consume Ca(OH)₂ in the setting reaction.
What is MTA?

Mineral trioxide aggregate (MTA) and procedures
MTA is not a resin cement. It is Portland cement (PC) (calcium silicate) cement that reacts with water to produce Ca(OH)$_2$ as its byproduct and therefore is a setting cement that has the same pH as Ca(OH)$_2$.\(^5\) MTA contains 20% Bi$_2$O$_3$ (w/w) to establish radiopacity as set Portland cement alone is indistinguishable from dentine.\(^6\) Over a period of several months, the pH of the tooth next to MTA progressively drop in alkalinity.\(^7\)

What is Portland cement?
To make Portland cement, stones, are crushed, ground and placed in an oven that reaches temperatures of around 1500 degrees Celsius. The output material is ground further, until it becomes a powder known as Portland cement. This process breaks the bonds that held the stones together so when you add water, the bonds will reform and produce a stone-like cement material.

What is Bismuth oxide?
Bismuth oxide has a high effective atomic number and is therefore radio-dense. It will absorb X-rays and will therefore appear ‘white’ on radiographs. It does not directly react with MTA, however, it provides steric interference in the setting reaction of MTA.\(^8\)

Chemical Reactions in the setting of MTA

<table>
<thead>
<tr>
<th>Reactants</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland Cement</td>
<td>Calcium-silicate-hydrate</td>
</tr>
<tr>
<td>Calcium Silicates</td>
<td>Calcium-aluminate-hydrate</td>
</tr>
<tr>
<td>Calcium Aluminates</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Calcium hydroxide</td>
</tr>
<tr>
<td></td>
<td>Water</td>
</tr>
<tr>
<td>Unreacted Bismuth Oxide</td>
<td>Unreacted Bismuth Oxide</td>
</tr>
</tbody>
</table>

Setting Time of MTA Indentation
MTA Angelus is marketed as taking 15 minutes to set, ProRoot as 4 hours and Biodentine as 12 minutes. However, the testing methodology is different for each company and therefore it can be inaccurate to compare brands if the testing is different.\(^8\)

ProRoot MTA
ProRoot MTA is provided as sachets are intended to be one-use only, however, many clinicians opt to use the sachets multiple times to save on cost-per-use. This is, however, against the manufacturer’s instructions. Their advertised setting time of 4 hours is based on a test to resist indentation by 5MPa.\(^8\) However, clinicians can carefully place other restorative materials above MTA after 10 minutes as the MTA has reached sufficient hardening.\(^9\)

MTA Angelus
MTA Angelus comes in a re-sealable jar, which is easier to store for re-use than ProRoot. Its advertised setting time of 15 minutes is based on a test to resist indentation by 0.3MPa.\(^8\) Therefore it’s frivolous to compare it with ProRoot MTA based on advertised setting time.

Biodentine
Biodentine is provided with powder in a capsule with an aqueous solution must be poured into the capsule prior to mixing. It does in fact set faster than the other MTAs, however, it is not hard enough to be a
conventional restorative material, such as glass ionomer cement (GIC).

<table>
<thead>
<tr>
<th>ProRoot MTA</th>
<th>Biodentine</th>
<th>Who’s better?</th>
</tr>
</thead>
<tbody>
<tr>
<td>75% Calcium Silicates and aluminates</td>
<td>85% calcium silicates</td>
<td>ProRoot is less soluble(^ {10})</td>
</tr>
<tr>
<td>5% Gypsum</td>
<td>10% Calcium Carbonate</td>
<td>Biodentine sets faster(^ {10})</td>
</tr>
<tr>
<td>20% Bismuth Oxide</td>
<td>5% Zirconium Oxide</td>
<td>ProRoot is more radiopaque(^ {10})</td>
</tr>
<tr>
<td>100% distilled water</td>
<td>Water with 15% Calcium chloride and polycarboxylate</td>
<td>Biodentine has a greater hardness(^ {10})</td>
</tr>
</tbody>
</table>

**MTA Fillapex**

MTA Fillapex is essentially dycal mixed with MTA powder. It is a flowable endodontic sealer and should not be used for endodontic repairs of teeth or for pulp therapy. It requires water to diffuse from the dentine to set the sealer and therefore the setting time is uncertain. Furthermore, it higher solubility and greater cytotoxicity than other endodontic sealers (such as AH Plus) and therefore the long-term seal of the tooth can be inferior.\(^ {11-14}\)

<table>
<thead>
<tr>
<th>Property</th>
<th>AHPlus</th>
<th>MTA Fillapex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Success</td>
<td>Many and long studies</td>
<td>Lab studies and pulp caps studies</td>
</tr>
<tr>
<td>Radiopacity</td>
<td>Better</td>
<td>Worse(^ {15})</td>
</tr>
<tr>
<td>Film Thickness</td>
<td>Better</td>
<td>Worse(^ {16})</td>
</tr>
<tr>
<td>Cytotoxicity</td>
<td>Better</td>
<td>Worse(^ {17})</td>
</tr>
<tr>
<td>Bond strength</td>
<td>Better</td>
<td>Worse(^ {18})</td>
</tr>
<tr>
<td>Antibacterial activity</td>
<td>Worse</td>
<td>Better(^ {19})</td>
</tr>
<tr>
<td>Solubility</td>
<td>Better((Less soluble))</td>
<td>Worse(^ {11})((More Soluble))</td>
</tr>
</tbody>
</table>

**TheraCal LC**

TheraCal LC has been reported, and marketed, as having high calcium ion release and as being able to create an alkaline pH,\(^ {20,21}\) however the assays used involved placing the material into water and measuring changes over only a few days. TheraCal is not mixed with water on placement and therefore it cannot be expected to perform as such, in vivo. Compared to Vitrebond and Ultrablend Plus, TheraCal LC has less cytotoxicity, however, it has not yet been compared to MTA.\(^ {22}\)
**Differences between MTA brands and “MTA Brands”**

<table>
<thead>
<tr>
<th>What is it really?</th>
<th>ProRoot MTA</th>
<th>MTA Angelus</th>
<th>Biodentine</th>
<th>MTA Fillapex</th>
<th>TheraCal LC</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC + Bismuth Oxide</td>
<td>PC + Bismuth Oxide</td>
<td>Modified PC + ZrO</td>
<td>Dycal + PC</td>
<td>Flowable resin + PC</td>
<td></td>
</tr>
<tr>
<td>Clinical Uses</td>
<td>Endodontic repair</td>
<td>Endodontic repair</td>
<td>Endodontic repair</td>
<td>Endodontic Sealer</td>
<td>Pulp caps only</td>
</tr>
<tr>
<td>Packaging</td>
<td>One-use only satchels</td>
<td>Re-sealable jar</td>
<td>Manually combined, capsule mixed</td>
<td>Two part mixing paste syringe</td>
<td>Single one component syringe</td>
</tr>
<tr>
<td>Setting speed*</td>
<td>4 hours</td>
<td>15 Minutes</td>
<td>12 Minutes</td>
<td>2 hours</td>
<td>Light Cured</td>
</tr>
<tr>
<td>Evidence base</td>
<td>Very extensive studies</td>
<td>Extensive studies. Chemically almost identical to ProRoot MTA</td>
<td>Mostly small trials and case reports. Promising results</td>
<td>Performance equal to or less than AH26</td>
<td>Mainly anecdotal and lab studies</td>
</tr>
<tr>
<td>Cost to buy</td>
<td>2 grams (4 satchels) $370.51</td>
<td>1 gram jars for $123</td>
<td>5 capsules $92.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per use</td>
<td>$92.63 for one-use only $26.47 for re-using packet</td>
<td>$17.57 per use</td>
<td>$18.48 per use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier</td>
<td>Dentsply</td>
<td>Gunz</td>
<td>Halas</td>
<td>Gunz</td>
<td>Erskine Dental &amp; Amalgadent</td>
</tr>
</tbody>
</table>

**Brands hitting our shores**

The alternative MTA brands seem to be fundamentally the same but they have different particle sizes and some additives so they will handle slightly differently. Nevertheless, they still are cement powder mixed with water.

Some of these contain zirconium which has a lower atomic number than bismuth so they could be less radiopaque. Otherwise, their main ingredients are the same as ProRoot MTA so you should expect similar clinical outcomes.
| Biodentine | y | y | y | y | y | y |
| EndoCem MTA | y | y | y | y | y | y |
| EndoCem Zr | y | y | y | y | y | y |
| EndoSeal | y | y | y | y | y | y |
| MM MTA | y | y | y | y | y | y |
| MTA Angelus | y | y | y | y | y | y |
| MTA Plus | y | y | y | y | y | y |
| Ortho MTA | y | y | y | y | y | y |
| ProRoot MTA | y | y | y | y | y | y |
| Retro MTA | y | y | y | y | y | y |
| Trioxident | y | y | y | y | y | y |

**Other hydraulic dental cements (‘Bioceramics’)**

| BioAggregate RCRFM & DiaRoot RCRFM | y | y | y | y |
| iRoot SP, EndoSequence BC Sealer | y | y | y | y | y | y |
| iRoot BP & EndoSequence (Putty & Injectable RCRFM) | y | y | y | y | y | y |

<table>
<thead>
<tr>
<th>Property</th>
<th>ProRoot MTA</th>
<th>BioAggregate / DiaRoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Success</td>
<td>Many and long studies</td>
<td>Lab studies and pulp cap studies</td>
</tr>
<tr>
<td>Strength</td>
<td>Better</td>
<td>Worse(^2)</td>
</tr>
<tr>
<td>Radiopacity</td>
<td>Good</td>
<td>No studies</td>
</tr>
<tr>
<td>Setting Time</td>
<td>4 hours</td>
<td>4 hours</td>
</tr>
<tr>
<td>Sealing Tests</td>
<td>Good</td>
<td>Good(^2)</td>
</tr>
<tr>
<td>pH / Ca(OH)(_2)</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td>Solubility</td>
<td>Better (Less Soluble)</td>
<td>Worse(^2) (More Soluble)</td>
</tr>
<tr>
<td>Property</td>
<td>AHPlus</td>
<td>Endosequence BC Sealer</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Clinical Success</td>
<td>Commonly used in endodontic literature</td>
<td>Case Reports</td>
</tr>
<tr>
<td>Radiopacity</td>
<td>Better</td>
<td>Worse&lt;sup&gt;26&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sealing Tests</td>
<td>Better</td>
<td>Worse&lt;sup&gt;27&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bacteriostatic</td>
<td>Similar</td>
<td>Similar&lt;sup&gt;28&lt;/sup&gt;</td>
</tr>
<tr>
<td>Push-out Strength</td>
<td>Better</td>
<td>Worse&lt;sup&gt;29&lt;/sup&gt;</td>
</tr>
<tr>
<td>Solubility</td>
<td>Better (Less soluble)</td>
<td>Worse&lt;sup&gt;14&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Part 2. Steps and Preferences**

**Clinical applications**

*MTA - ANGELUS REPAIRING CEMENT*

The treatment for accidents and endodontic complications

**Success Rates**

MTAs success rates are 97.6% in pulp capping, 79% in pulpotomy in permanent teeth and >95% in pulpotomies.<sup>30</sup> In apical barriers the success rate can be expected to be over 90%.<sup>31</sup>

**MTA pulp capping**

Pulp capping is performed for exposures of the pulp where the pulp itself is not expected to be irreversibly inflamed and currently vital. Aseptic technique is mandatory and any burs used on the tooth should be water-cooled to prevent over heating of the pulp. Once the pulp is exposed using handpieces, haemostasis of the pulp should be achieved via sterile cotton pellet soaked in saline. If haemostasis cannot be achieved it is likely that the area of the pulp is inflamed and you should consider extending your preparation until all inflamed areas of the pulp are removed. Therefore, extend the preparation to a pulpotomy or a pulpectomy. And then place MTA or Ca(OH)<sub>2</sub>.

Ca(OH)<sub>2</sub> has been the gold standard for pulp capping, however, it has problems. Ca(OH)<sub>2</sub> is soluble in oral fluids and therefore it can provide an area for bacterial growth once it dissolves. It does not adhere to the tooth and easily dislodges after placement. Instead of Ca(OH)<sub>2</sub>, MTA can be placed. After placing MTA
into pulpal area, place a layer resin-modified glass ionomer cement (RMGIC) over MTA to protect from washing out. Etch the tooth and then wash out the etch. Place prime and bond adhesive and follow with a composite resin restoration. Discussed in more detail in Accorinte.\(^{32}\)

**MTA pulpotomy**

Pulpotomies are performed for deep carious exposures or exposures of the pulp where the pulp is not expected to irreversibly inflamed and currently vital. The clinical procedure is otherwise the same as a pulp cap with the key difference being the removal of the pulpal chamber. Much of the above was taken from Barreshti.\(^{33}\)

**MTA apexification and apical barrier**

The larger the apex the greater the chance that the apical region of the tooth will be inadequately obturated and the more difficult it is for the clinician to length control the obturation material. In the past, multiple appointments to dress the canals with Ca(OH)\(_2\) were utilized. With MTA, this can be done in one visit.

As MTA is antibacterial, sets hard, and promotes bony growth, clinicians can place MTA at the apex with good confidence the tooth is better obturated than if gutta percha (GP) was placed. Teeth with apices wider than a 55 K-file (0.55mm), and/or when apical patency becomes difficult to achieve, the clinician can consider using MTA instead of GP. Place at least 3-5mm thickness of MTA and then restore the rest with GP, resin, or, more MTA.\(^{34}\)

**MTA apicoectomy**

Apical infections that do not respond to conventional and adequate root canal therapy can respond to apicoectomy. This is where the last 3mm of the tooth is removed along with any apical infection and the end of the root canal is sealed with MTA. MTA is used because it has excellent sealing properties and will encourage healing of the bone around it, unlike the historical alternative of amalgam.

**Trends in Australia**\(^{35}\)

ProRootMTA is the most common MTA in Australia, followed by MTA Angelus. Almost all endodontists use MTA while less than half of dentists in the ASE use MTA. MTA is the material of choice by endodontists for perforations, apexifications, apicoectomy and regenerative endodontics.

For apexifications, endodontist generally perform single visit MTA barrier placement while general dentists generally perform multiple visit calcium hydroxide apexification.

Most endodontists prefer to use sodium hypochlorite as their final irrigant prior to MTA placement.

**Staining and MTA**

NaOCl will react with bismuth oxide to produce a dark brown precipitate. Therefore, if MTA is used in aesthetically important areas, the tooth should be adequately irrigated with saline to remove NaOCl residue darkening the MTA.\(^{32}\) Regardless of NaOCl use, darkening of the MTA is expected and Ca(OH)\(_2\) should be considered if the darkening of MTA is not viewed as acceptable.\(^{36}\)

**Part 3. Tips, Tricks and Science**

**Acidic Environments with MTA**

The setting of MTA features alkaline reagents and products which can be attacked by acids resulting in changes in final structure, greater leakage and less adhesion to tooth structure.\(^{9,10}\) Endodontic infections will create an acidic environment which would degrade the MTA. To neutralize the acid environment, dressing the canal with Ca(OH)\(_2\) for 1–2 weeks before MTA placement will improve the properties of the set MTA.\(^{32}\) If placement of Ca(OH)\(_2\) is not feasible, substantial irrigation of NaOCl is recommended to neutralize the acid.\(^{37}\)
Ca(OH)\(_2\) dressings can also impair the properties of MTA as the various additives, such as methylcellulose and carboxymethylcellulose, can retard the setting of the PC in MTA.\(^{16,17}\) Therefore, if a dressing of Ca(OH)\(_2\) paste is used, extensive irrigation should be carried out to ensure that no remaining dressing material is present, as remnants of the cellulose thickener will retard the setting of MTA.\(^{37}\)

EDTA, etch and tooth conditioners must be adequately washed away before MTA placement.\(^{37}\) NaOCl irrigants have pH values above 11 and will neutralize any remaining acids when used to rinse canals.\(^{18}\)

**Fluid contamination effects on MTA**

MTA, when set in the presence of blood, will have reduced compressive strength, reduced micro-hardness and less resistance to displacement.\(^{29-31}\) Hemorrhagic contamination should be minimized as it impairs the quality of the set MTA.\(^{37}\)

**Working time**

As MTA is mixed, water starts to evaporate from the reacting mass as well as being consumed by the setting MTA. Therefore, the workability dramatically changes in a short amount of time. MTA’s working time is 6 minutes.\(^{38}\) A trick to extend the working time is to cover the MTA with wet gauze so less water will evaporate from the setting MTA.

**Mixing Tricks**

The instructions for use state 3 parts power, to 1 part water, by mass. After mixing, if the work time has elapsed, extra water can be added to make the MTA workable again. MTA can be mixed on a glass slab or paper mixing pad, however, paper mixing pads are flimsy and it’s easy to spill the MTA.

To adjust the wetness of the MTA, two cotton rolls can be kept at hand, one dry and one wet. If the mix is dry, squeeze the cotton roll and it will release gently water into the MTA. Ideally, use a Pasteur pipette. If a mixture is too wet, a cotton roll can be used to dab the MTA which will suck up the excess water. The ideal mixture can have amounts lifted with the flat plastic in one whole piece without dripping or crumbling off the instrument.

**Alternative mixing solutions**

MTA should be mixed with sterile or distilled water. In the absence of water, local anaesthetic can be used, however, the reaction is lower and the set material is weaker.\(^{35,36}\) NaOCl solution will accelerate the setting reaction of MTA, however, it will result in a weaker compressive strength.\(^{35,36}\) Chlorhexidine gluconate, as a mixing solution for MTA, should not be used as it completely inhibits the setting reaction of MTA.\(^{37}\)

**MTA Carriers**

Amalgam carriers and normal hand instruments can be used for large restorations. Damp cotton pellets held by tweezers seem easier to use than traditional packers for compacting MTA. For smaller restorations, MTA carriers can be used. Examples include MAP MTA Carrier, MTA Carrier, and the Dovgan carrier. If excess mixed MTA is left within a carrier after the appointment, the tip may become clogged and seemingly unusable. If this occurs, submerge the carrier in vinegar and use sharp-tipped instruments such as probes and K files to scratch the MTA out from the carrier.

**Lee block (Also known as, “MTA Pellet Forming Block”)**

Many clinicians like to insert their MTA as blocks or pillars into a defect. A simple way to shape your MTA into these ideal pillars is to use a “Lee Block”.\(^{39}\) This is a plastic block that has had bur sized grooves. Freshly mixed MTA is placed into these grooves and then pillars of MTA can be lifted out from the base of the groove using a half hollenback or spoon excavator. The pillars can then be inserted into the tooth. This can be bought or self-made using a fissure bur. If several grooves are made and loaded with mixed MTA the clinician can quickly insert several pillars into the tooth without having to stop to insert more MTA into the block.
Compacting MTA down a canal
Some clinicians like to utilize ultrasonics to compress the MTA with the intent to compact the MTA. However, the collisional vibrations on the setting structure of MTA can disrupt the setting structure, reducing micro-hardness and create porosities if ultrasonics are applied for over 2 seconds.

Removing MTA from tooth walls
MTA can be removed from tooth walls using gentle brushing using cotton pellets, micro-brushes, gentle irrigation with water or using irrigation via ultrasonics. Another method is to twist a K file through a cotton roll, which will turn the K file into a long absorbent brush.

Curing MTA
Much of the historic literature on MTA utilizes a method where a damp pellet is placed above the MTA to protect the material as it slowly set. However, temporizing a tooth with cotton pellets delays completion of the restoration and can compromise the quality of the seal. It is now common to gently place GIC, RMGIC or even resin bonding agents onto MTA. Once these materials have set, the clinician can permanently restore the tooth.

Storage: Packets vs Jars
If sachets of MTA are to be used, they should be used as ‘one-use-only’ as attempts to using remnant powder will result in lower reactivity of the remnant powder as it has partially reacted with water from the ambient humidity. If sachets are to be used for multiple cases, it would be prudent to pour the remaining powder into small jars to protect the cement from reacting with ambient humidity. Keeping the sachets within a sterilization pouches is inadvisable as sterilization pouches are designed to enable humidity to pass through the packet.

Temperature effects
MTA should not be stored in the refrigerator as this will result in reduction in surface hardness, greater porosity and leakage.

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Dr Ha is a part time dentist and a part time PhD student researcher in the field of endodontic biomaterials. The focus of his research is the chemical and physical properties of Mineral Trioxide Aggregate, a material used in endodontics and paedodontics. He has articles published in the Australian Dental Journal, Journal of Endodontics and the Journal of the Canadian Dental Association. Dr Ha is the secretary for the QLD branch of the Australian Society of Endodontology, and is a member of Australian and New Zealand Society of Paediatric Dentistry and International Association of Dental Traumatology.

He is also a recreational app developer with two apps on the market. Dental Prescriber, which helps dentists prescribe medications. And, BraceMate, a free app for orthodontic patients wanting to have fun with colours for their braces.

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