Introduction to endodontics

- Goal of endodontics
  - Relieve pain and swelling and restore function
  - Treatment of infection and do no harm
- Indications
  - Tooth displays pulpal/peri-radicular pathology – most are good candidates
  - Extraction is contraindicated due to medical reasons
    - Post extraction osteonecrosis and fracture of the mandible
    - IV bisphosphonates and radiation therapy altering ability of bone to heal
  - Prophylactic endodontics is done to avoid almost certain pulpal involvement during subsequent crown fabrication
- Contraindications
  - Non restorable teeth
  - Inadequate periodontal support such that it cannot be corrected by endo/perio therapy
  - Vertical root fractures and options of root amputation vs alternative replacement therapy (FPD, RPD, implant supported)
- Overview of steps in endodontics
  - Preparation: access cavity, working length determination, debridement, cleaning, shaping
  - Obturation: master cone fit, filling, cleaning pulp chamber, remove gutta percha above CEJ, temp filling, final restoration
    - Note: a proper final restoration is a continuum of RCT. Restorative Tx plan must be approved prior to RCT

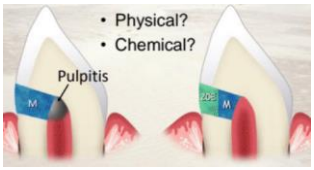
Etiology and pathogenesis of endodontic diseases

- Steps involved in endodontic disease
  - 1. Healthy pulp
  - 2. Pulpitis (reversible → irreversible)
  - 3. Necrosis (can be sterile or infected)
  - 4. Periapical lesion
    - Apical periodontitis
      - Chronic or acute
      - Asymptomatic or symptomatic
      - Periapical granuloma or acute periapical abscess
    - Radicular cyst
      - Apical periodontitis + a cyst
    - Other diagnosis
- AAE recommended diagnostic terminology

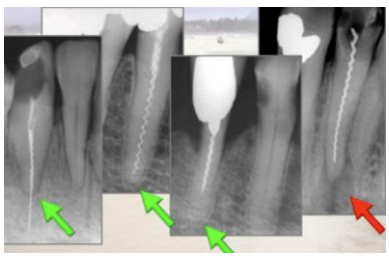
Pulpal	
Normal pulp	-Symptom free and responsive to pulp testing
Reversible pulpitis	-Inflammation of vital pulp that should resolve and go to normal -Clinical Dx made on subjective + objective findings
Symptomatic irreversible pulpitis	-Inflammation of vital pulp is incapable of healing -Clinical Dx made on subjective + objective findings -Descriptors: lingering thermal pain, spontaneous pain, referred pain
Asymptomatic irreversible pulpitis	-Inflammation of vital pulp is incapable of healing -Clinical Dx made on subjective + objective findings -Descriptors: no symptoms, inflammation produced by caries, caries excavation, trauma
Pulp necrosis	-Death of the dental pulp -Non responsive to pulp testing
Previously treated	-Tooth has been previously endodontically treated and canals are obturated with filling materials other than intracanal medicaments
Previously initiated therapy	-Tooth has been previously treated by partial endodontic therapy (pulpotomy, pulpectomy)

Apical	
Normal apical tissues	-Teeth with normal periradicular tissues that are not sensitive to percussion/palpation -Lamina dura intact, root is intact, PDL space is uniform
Symptomatic apical periodontitis	-Inflammation of the apical periodontium causing painful response to percussion/palpation -May/may not be associated with an apical radiolucent area
Asymptomatic apical periodontitis	-Inflammation and destruction of apical periodontium that is of pulpal origin -Appears as a radiolucent area and does not produce symptoms
Acute apical abscess	-Inflammatory reaction to pulpal infection and necrosis characterized by rapid onset, spontaneous pain, tenderness to pressure, pus formation, swelling of associated tissues
Chronic apical abscess	-Inflammatory reaction to pulpal infection and necrosis characterized by gradual onset, little or no discomfort, intermittent discharge of pus through a sinus tract
Condensing osteitis	-Diffuse radiopaque lesion representing a localized bony reaction to a low grade inflammatory stimulus, usually at the apex of the tooth

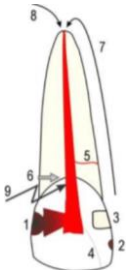
- Etiology of pulpal necrosis
  - More common to see necrotic teeth that are asymptomatic
  - The main underlying etiology is bacterial invasion
    - Study 1
      - Exposed pulps in the teeth of rats in a sterile environment
      - Despite pulp exposure, there was no apical periodontitis until bacteria was introduced
    - Study 2
      - Studied teeth that became necrotic due to trauma in humans
      - Trauma → pulp death → pulp necrosis, but no bacterial invasion → no apical periodontitis
      - Pulp necrosis in the absence of bacteria is called <u>sterile necrosis</u>
      - If there was any bacterial invasion, there was always an apical lesion
    - Study 3
      - Deep restos were frequently associated with pulpitis, so initially was thought that restorative materials were toxic to the pulp
      - However, ZOE (a material known for absolutely leak-free seals) was placed over the restorative material and there was no pulpitis
      - Conclusion: it is NOT the restorative material that irritates the pulp, but it is the microleakage of bacteria around restorations that cause pulpitis



    - Case studies of broken instruments in pulp
      - When instruments break but have a good seal, there is no bacterial infiltration and hence no apical periodontitis (first 3 cases)
      - If there is a pathway for bacteria, then there is an apical lesion (4th case)



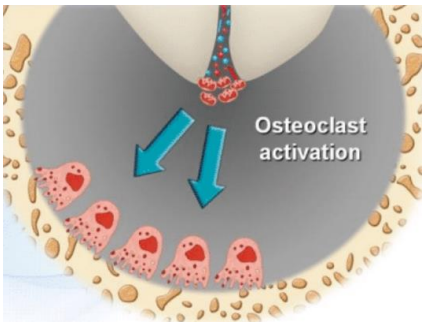
  - What does bacteria do once it gets into the pulp?
    - Bacteria in pulp triggers an inflammatory reaction
    - Leukocytes enter via chemotaxis and phagocytose bacteria
    - If there is too much bacteria, the leukocyte can die
    - Light brown pus may form: contains dead leukocytes and bacteria
  - How does bacteria get into the pulp?
    - Coronally: caries, leakage, hairline fracture, pulp exposure
    - Root: lateral canal, dentinal tubules, vertical root fracture
    - Apex: deep pocket, bacteremia
    - Other: trauma, cracked tooth, invagination, evagination



  - Microbiology of pulpal infection

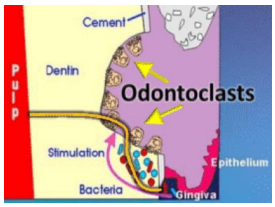
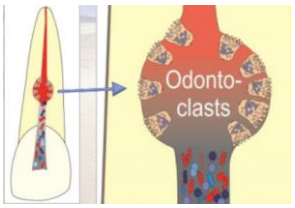
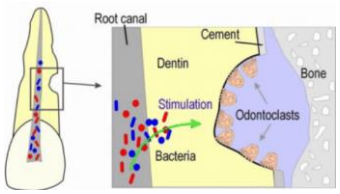
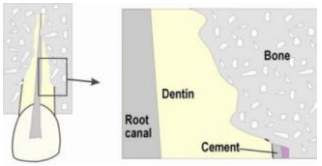
Tooth being RCT'ed for the first time	Previously RCT'ed tooth
-<u>Anaerobes dominate:</u> gram – rods, gram + rods, gram + cocci -<u>Some facultative as well:</u> gram + rods, gram + cocci -Resembles pocket flora -2~10 species per canal -Enterics and yeasts absent	-Dominated by E. faecalis -Also present: Lactobacilli, streptococci, Gram + rods, gram – rods, yeasts -Tougher and more resistant to Abx -Less anaerobic bacteria

- Etiology behind "flare ups"
    - Different strains of bacteria with different virulence factors will cause flare ups unpredictably
    - During RCT, if a file gets pushes beyond the apex, the bacteria being pushed into the periapical space can cause a flare-up as well
        - >5% of patients have increased sensitivity after the first appointment
- Etiology of the periapical lesion



    - Immune system does a good job of keeping bacteria inside the pulp chamber and not into the periapical space
    - However, osteoclasts activate and start resorbing bone around the apex even though there are no bacteria
    - This is a defense mechanism from the body to prevent the bone from getting infected
        - Bone infections require hospitalization and are incredibly hard to deal with
    - The periapical space can now fill with highly vascularized defense tissue
    - A successful RCT will allow this defense tissue to be replaced by normal bone again
    - Since the bacteria is kept in the tooth, it is why most periapical lesions are asymptomatic
    - Periapical lesion also depends on the type of bacteria in the canal space
        - Left = intact molar with a periapical lesion
        - Right = same carious molar with no periapical lesion
        - Reason: the ecology of the pulp chamber changed on the right picture. Nutrients and carbs had direct access to the pulp chamber on the right picture, which likely altered the flora. The new flora doesn't cause a severe periapical lesion

- Etiology of resorptions

Cervical resorption	Internal inflammatory root resorption	External inflammatory root resorption	Replacement resorption (ankylosis)
 			
-Something damages the tooth surface -Triggers osteoclast-like cells called odontoclasts to activate -Starts resorbing the tooth surface -Bone-like structure grows into tooth	-Present in 50% of pulpitis cases and 77% of necrosis cases (often not seen b/c so minimal) -Large visible internal root resorptions are rare	-Trauma to teeth cause bacteria to invade and infect pulp -Stimulates resorption externally -Can be very aggressive in pediatric teeth	-Due to trauma -Tooth structure becomes replaced by bone over the course of years
-Not from pulp -Not from bacteria	-Due to bacteria	-Due to bacteria	-Not from bacteria

Endodontic armamentarium

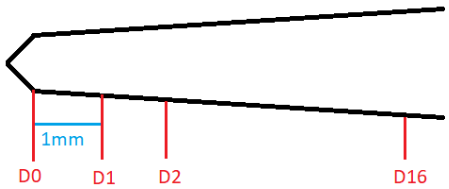
- Endodontic bur block

Carbide burs	Gates Glidden burs	Mueller burs	Lentulo spiral
			
-Mostly high speed -There is 1 slow speed	-Slow speed (500 RPM)	-Slow speed	-Slow speed
-Can be round ended or fissure ended -Used to gain access to the pulp chamber and shaping walls of the access preparation -In porcelain crowns, a diamond bur is used instead -Some burs are safe ended (bur only cuts on the sides and not on pulpal surface)	-Enlarges coronal part of root canal -Removes existing gutta percha filling -Side cutting burs, <u>not end cutting</u>	-Advances into deeper parts of the access preparation -Long flexible shaft for better visualization	-Steel wire that's been twisted to form a spiral -Used to place CaOH and sealer into the prepped root canal space -CaOH is used for inter-appointment disinfection -<u>Handpiece must be set to forward direction</u> (or else risk of breakage)

- Hand files

	K files (SSK, Flex SSK)	Flex NTK (NiTi)	Hedstroem files	Reamer
Symbol (on file)	■	◧	●	▲
Sizing and labelling	-SS = stainless steel -File # = diameter of the file tip -Sizes 6~140 -Length of file can be 21, 25, or 31 mm long, but only the first 16mm are cutting surfaces -Every 1mm away from the tip of the file has a 0.02 mm increase in diameter	-NiTi = nickel titanium -File # = diameter of the file tip -Sizes 30~50 (but says 15~60 in manual?) -Every 1mm away from the tip of the file has a 0.02 mm increase in diameter	-File # = diameter of the file tip -Sizes 15~80 -Every 1mm away from the tip of the file has a 0.02 mm increase in diameter	
Use	-Size 6~25: debrides the canals to working length -Size 15~25 are <u>FlexSSK</u> files, which have a non active tip and are more flexible. This minimizes risk of ledging and transportation -If roots are <u>straight</u>, K files are good to use -If roots are <u>curved</u>, K files are OK to use up to size 25, but any bigger K files are not optimal	-More flexible version of K files -Apical force may result in distortion of helical structure or fracture of the file -Check file for symmetry by rotating it against an even background before using it	-Flares the coronal and middle portions of the canal -Good for final polishing of canal walls after using K files -Should be one size less than K file at WL (if #20 K file was the last file to WL, then use a #15 Hedstroem file) -Less useful if rotary NiTi files are used for instrumentation	Not used
Technique	**Push/Pull** (For size 6~15 files) **Balanced force** (Recommended)	**Balanced force only**	**Push/pull only**	
Cutting angle	-Moderate	-Moderate	-Aggressive	-Low

- Note about file dimensions
  - The tip of the cutting surface is labelled as D0
  - Every 1mm from the tip is labelled D1, D2, D3, etc
  - In a hand file, every increase in D(X) is 0.02mm wider diameter
  - D16 = D0 + 0.32mm
  - For example, a size 6 K file will have 0.06mm diameter at D0. This means at D16, it will have 0.32+0.06 = 0.38mm diameter



- Colour and file size representation (top row for Arash and Calvin)

Pink	Grey	Purple	White	Yellow	Red	Blue	Green	Black
6	8	10	15	20	25	30	35	40
			45	50	55	60	70	80
			90	100	110	120	130	140

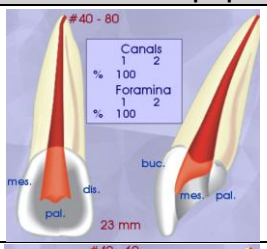
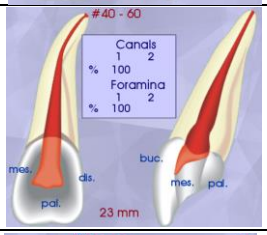
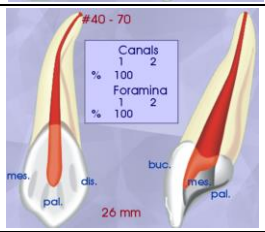
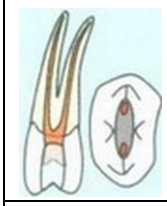
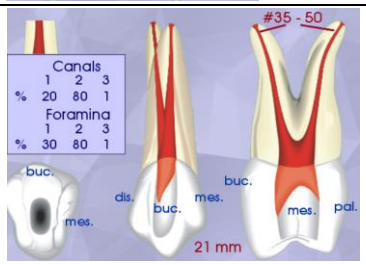
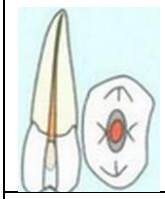
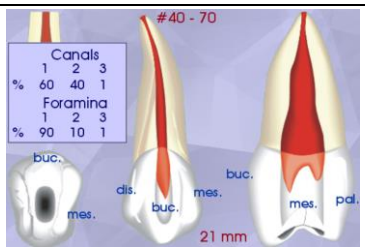
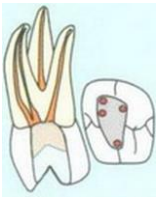
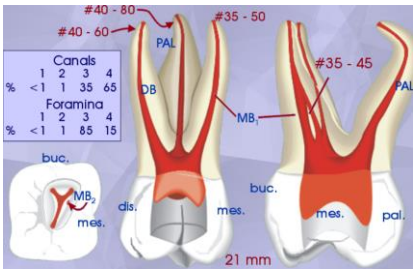
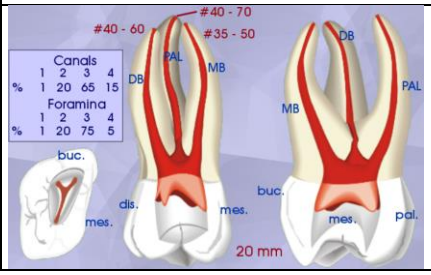
- Hand filing techniques

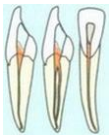
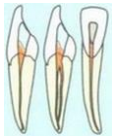
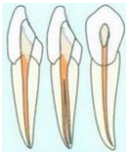
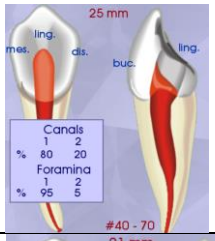
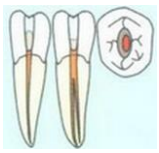
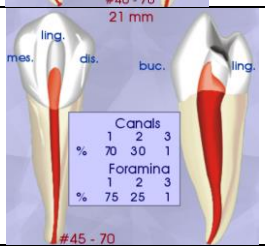
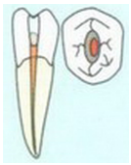
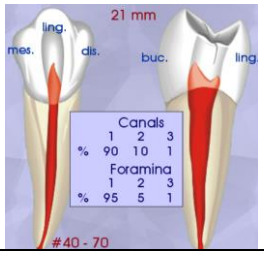
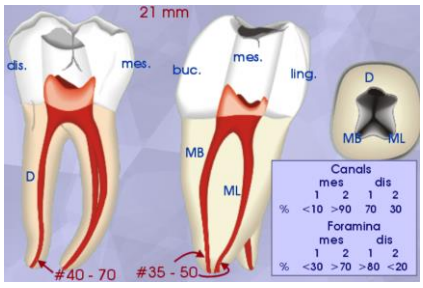
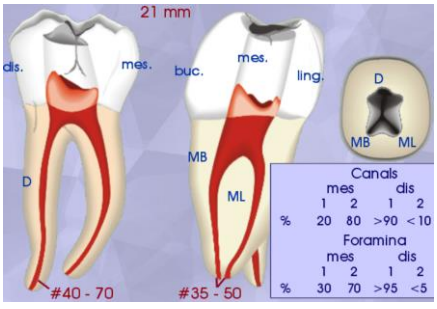
Push/pull:	**Balanced force:**
-Simple push pull motion, with cutting happening during pulling -Larger files can be used this way only if the canal is straight -Done circumferentially -Copius irrigation to prevent debris from being pushed into apex	1. ¼~½ clockwise turn with apical pressure 2. ¼~½ counter clockwise turn with apical pressure (crushing stage) 3. Repeat 2-4x until WL is reached 4. If WL is not reached, pull out of canal with 1~2 non cutting clockwise rotations 5. Clean file with alcohol soaked 2x2 gauze 6. Repeat until file reaches WL without binding 7. Final 2~3 clockwise rotations at WL to remove apical debris

- Rotary instruments
  - Handpiece (X Smart Cordless Motor)
    - Had variable speeds from 150~800 RPM
  - Sx ProTaper file
    - Nickel titanium file size 19 at the tip and 18mm length
    - Instrumented at 300 RPM
    - Used to open coronal portion of the canal
  - Profile VORTEX files
    - Nickel titanium file size 20~40 at the tip and 21/25mm length
    - Taper is 0.04 mm
- Other materials/instruments

DG 16 explorer	-Double ended sharp explorer -Locates the pulp chamber and canals
D11, D11T, #3 spreader	-Single sided with explorer-like appearance -Pushed into canals to make space for accessory cones during root canal obturation using lateral condensation technique
Finger spreaders	-Almost always better than spreaders above -Also used for making space in lateral condensation technique
Glick #1	-Narrow tip end: heated to sear off excess GP -Paddle end: placement of temporary filling
Spoon excavator	-Used for removal of caries, coronal pulp, and cotton pellets which occupy the pulp chamber
Cotton pliers	-Come in locking and non-locking types -Locking pliers facilitate handling of paper points and GP
Steiglitz pliers (looks like scissors)	-Retrieval of small material in pulp chamber or canals (like a silver cone or broken instruments)
File block	-Used to measure file lengths -Lexicon file block is best for placing silicone stoppers accurately on files
Rubber/silicone stoppers	-Placed on all files and Gates-Glidden burs to facilitate accurate measurements -Stoppers are notched to indicate which way the file curves
Paper points	-Used to dry the canal -Coarse size = #35, medium size = #30, fine size = #25
Gutta percha points	-**Master cones**: made in standardized sizes 15~140 with 0.2 tapers (but other tapers now exist to correspond to the taper of rotary files) -**Accessory cones**: made in descriptive sizes (fine, fine-medium, medium etc) -Comprised of ~75% zinc oxide, ~25% gutta percha, and other opaquers/coloring agents -Gutta percha component is what gives the files its flexibility
Sealer	-**Roth™:** zinc oxide and eugenol mixture sealer -**Thermaseal:** epoxy resin based sealer -Other types also exist -Seals the root canal space along with gutta percha

Root canal anatomy and variations

	Tooth	Root structure	Access preparation	Other considerations
Maxillary	Central incisor	-99% Single canal -Possible 2 canals in 1~2 roots -Straight and round cross section		-Be prepared for variations such as invagination
	Lateral incisor	-One root one canal -Possible 2 canals in 1~2 roots -Cross section is oval or round -Root tip often tips distally/palatal/labial		-Dens invaginatus is a common variation -Lingual radicular groove can extend into root and be a pathway for saliva to leak into
	Canine	-One root one canal -Cross section usually oval -Root tips distally/labial -Large canal, but narrow apex and foramen		-Longest and strongest root
	First premolar 	-2 roots 2 canals -Sometimes 1 root, but still usually has 2 canals -10~20%: 1 canal  -1%: 3 canals 3 roots -Tips may curve M/D or B/P directions -Use palatal root for posts b/c buccal root has a furcation groove		-Concave root surfaces on M/D faces -Roots often equal length, but may differ by 1~2mm -Root tips can be extremely fine, susceptible to perforation -Treat easier canal first (palatal)
	Second premolar 	-1 root 2 canals, canals often unite before apex -1%: 3 canals 3 roots -Root normally straight but may tip at the apex, often distally		-If it has 2 canals, they are closer together than first premolar -Bayonet shaped root
	First molar 	-3 roots, 2~4 canals **Palatal root canal:** -Straight until apex, where it tips buccally -Sometimes 2 canals or 1 elliptical canal which leaves as 1 canal in apex **Distobuccal root canal:** -Round and straight, may tip M/D, often D **Mesiobuccal root canals:** -Most challenging -Often tips distally -Usually 2 canals in MB root (MB1 and MB2)		-2 palatal roots have been reported -Pulp chamber is mesially shifted -MB2 usually difficult to find on clinical inspection and radiographs. Usually 1~3mm palatal to MB1 -Palatal root 1~2mm longer than other roots
	Second molar 	-Resembles first molar -3> 4> 2> 1 canals -Rarely has 2 palatal roots -1 buccal root is also possible -MB and DB canal orifices are closer than first molars -Sometimes 2 buccal canals are side by side in M-D dimensions, and can also form a line with the palatal canal		

Mandibular	Central incisor 	-80% one root one canal -20% 2 canals that join before apex -Usually straight root -Canal is wide B-L and narrow M-D, but almost round at the apex		-Lingual canal may be missed unless detected in a pre-treatment radiograph
	Lateral incisor 	-Similar to central incisor -Root is usually 1~2mm longer -Slight distal tip on the end		
	Canine 	-Longer and wider root than incisors -Ovoid root canal is common -80% one root one canal -20% 2 canals in 1~2 roots -Root may tip distally or labially		-2nd longest tooth, only 1~2mm shorter than the upper canine
	First premolar 	-70% one root one canal -30% one root 2 canals -Very rarely molarized (3 canals) -If 1 canal, oval in cross section -If 2 canals, buccal canal easily found but lingual canal may require some bending -Rarely curves, easy to instrument		-2 canals are easily found in pre-treatment radiographs as a suddenly disappearing canal shadow
	Second premolar 	-Usually 1 canal -Lingual second canal occasionally present -Molarization is more common, but still rare -Root canal oval in cross section -Slight distal curvature		
	First molar 	-2 roots with 3~4 canals -2 roots with 2 canals is rare **Distal root** -2 canals that may/may not share an apex -Ovoid or hourglass shaped (never round) -Wider B-L than M-D -Apical 1~2 mm of canal curves up to 90 deg distally. Less severe mesial tilt also possible **Mesial root** -Usually 2 canals, sometimes 3, rarely 1 -Tips distally and B/L, mostly at apex -Isthmus between canals may be present -MB and ML canals curve on whole length, with most curvature near apex		
	Second molar 	-Milder curvature than first molar -Can have 1 root with 1, 2, 3 canals -One or both MB/ML canals can join the distal canal -C shaped canal found in 1% of Caucasians and more frequent in Asians		-Susceptible to vertical root fractures

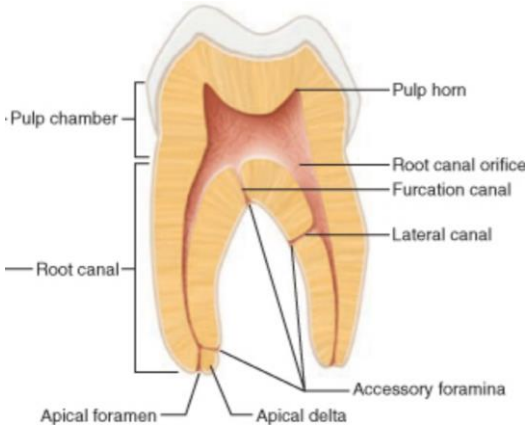
Vertucci's root canal configurations

1 canal @ apex			**2 canals @ apex**				**3 canals**
Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8
							
1 canal from chamber to apex	2 canals from chamber merges before apex	1 canal from chamber splits then merges again	2 canals from chamber into apex	1 canal from chamber splits and leaves as 2 canals	2 canals from chamber, merges in root, splits near apex	1 canal from chamber, splits and rejoined in root, splits near apex	3 canals from chamber, and reaches apex

Endodontic radiology

- Gives useful information regarding shape, size, and position of pulp chambers. Also reveals the crown/root orientation and how the root canal is positioned in the root
- 5 radiographs should be taken for a full RCT
    - 1. Pre-operative film (straight and off angled film may be necessary)
    - 2. Provisional working length film to confirm working length
    - 3. Master apical file after instrumentation, taken on the day of obturation
    - 4. Trial cone film containing 1 master cone and 1 accessory cone to confirm apical seal
    - 5. Final post obturation film
    - #2, 3, 4 require a rubber dam. #1 and 5 do not.
- As roots are often superimposed in 1 radiograph, altering the horizontal angulation may be useful to produce additional radiographs from different angulations
    - Follow the SLOB rule (same lingual, opposite buccal). This means that if a second radiograph was taken directed mesially, the lingual canal will move the same direction (mesially) and buccal will move distally
    - Can use files of different sizes to differentiate from buccal/palatal canal

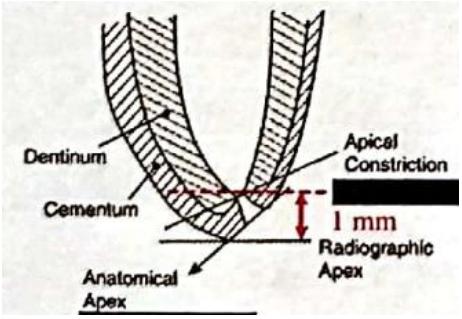
Access preparation



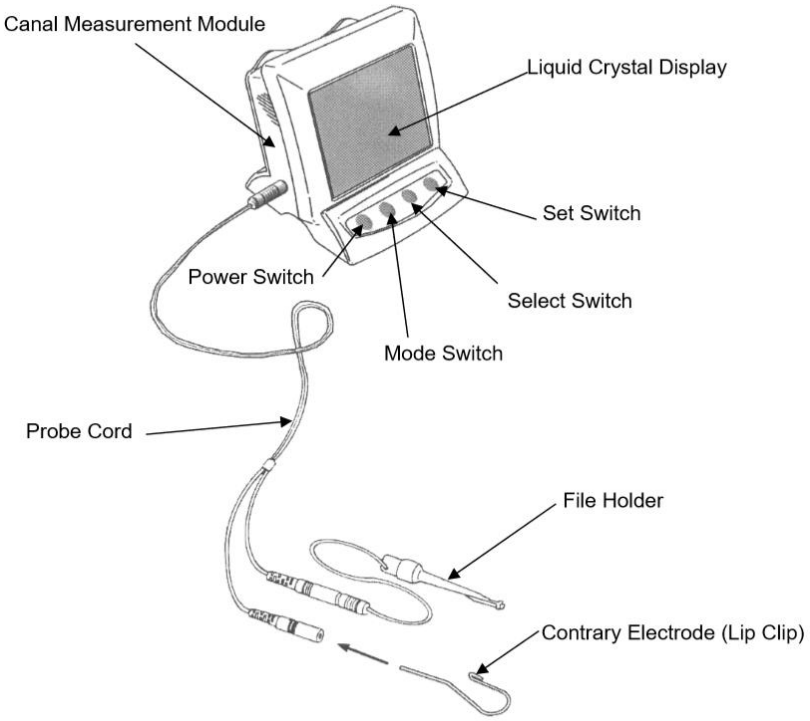
- Purpose
    - Unroof the pulp chamber
    - Remove pulp horns to prevent staining of the crown
    - To obtain straight line access to the apical third of the root canal to aid in cleaning and shaping
    - Conserve tooth structure – less weakening of remaining crown
- Direct access
    - A DG16 explorer should fit unimpeded into the coronal or middle third of each root canal
    - The DG16 explorer can be used to show the operator where enlargement is required
    - "Triangles" of dentin should be removed
    - Access is always done through occlusal or lingual surfaces, never interproximally
    - Restorations overlying canals should be treated and preserved like natural tooth structure unless there is caries underneath OR a thin portion of friable restoration material remains
    - Access without a rubber dam may be allowed if canals are difficult to find (like calcified roots)

- Anterior teeth
    - Draw an imaginary line between the tip of the cingulum to the tip of the incisor
    - Bur will be placed perpendicular to this line on the middle third (M-D and height wise)
        - Divide the lingual surface into 9 squares → aim for the middle one
        - It's like the Gardner grid, except this time it works
    - Drill until dentin is exposed
    - Reorient bur to long axis of tooth to aim for the pulp chamber
    - When the bur reaches the pulp chamber, a drop should be felt and no resistance should be felt
    - Use a DG16 explorer to confirm the pulp has been exposed, and reorient explorer to long axis of tooth
    - Continue drilling to obtain straight line access as guided by the explorer
    - Irrigate chamber
    - Confirm complete removal of the pulp chamber roof
    - Use a spoon excavator to see if it catches on any ledges in the pulp chamber. If present, use a round bur (cutting on withdrawal stroke) or a fissure bur
    - Obtain straight line access using a safe tipped fissure bur or long shank round latch bur. Gates Glidden burs may also be used to modify the lingual wall within the dentin shelf
- Posterior teeth
    - Use a high speed round bur to reach dentin, then a fissure bur to reach the pulp
    - Angulation of bur should be perpendicular to occlusal surface
        - Exception: mandibular premolars have a lingual tilt
    - Drill apically until a drop is felt
    - Extend prep to get direct access to all root canals
    - See page 6+7 for outline form of preps. Preps should be more on the mesial half of the tooth
    - General rule for outline preps:
        - Max premolars: ovoid with widening B-L
        - Max molars: triangular (3 canals) or rhomboid (4 canals), widest B-L and closest to MB cusp tip
        - Mand premolars: ovoid with widening B-L
        - Mand molars: triangular (3 canals) or rhomboid (4 canals), widest M-D
    - Irrigate chamber
    - Confirm complete removal of the pulp chamber roof
    - Use a spoon excavator to see if it catches on any ledges in the pulp chamber. If present, use a round bur (cutting on withdrawal stroke) or a fissure bur
    - Obtain straight line access using a safe tipped fissure bur or long shank round latch bur. Gates Glidden burs may also be used to modify the lingual wall within the dentin shelf
- Errors in access prep
    - Missed canals
        - Most commonly: MB2 on max 6, D2 on mand 6, 2nd canal on mand 1/2/4/5, 3rd canal on max 4/5
    - Constricted access prep
        - Being too conservative, leaving dentin triangles
        - May cause a missed canal, improper removal of pulp horn, and excessive file bending
    - Not removing pulp horn
        - Remaining pulp tissue will break down and the resulting hemosiderin will stain the crown
        - Causes discoloration of tooth
    - Mistaking the pulp horns as canal orifices
        - Floor will appear yellow-white, rather than the gray shadow it typically is
        - Improper access to apical root third
        - Will cause failure of RCT since pulpal tissue still remains
        - Avoid this by measuring pre-operative radiographs and seeing where pulpal floor will likely be
    - Overextended access prep
        - Weakens the tooth and makes it more likely to fracture
    - Access preparation perforation
        - Bur not aligned to long axis of tooth properly
        - Searching for a 3rd or 4th canal in molar preparations
        - Not being familiar with pulpal anatomy

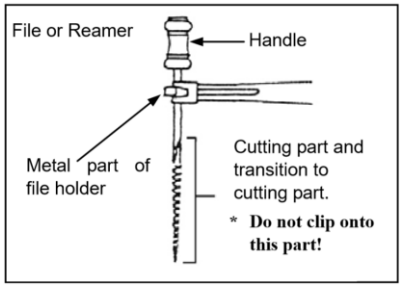
Establishing working length



- Canal preparation and filling should terminate at the cemento-dentinal junction. This site is also referred to as the apical constriction or minor diameter
    - Usually about 0.75mm inside the apical foramen
    - The apical foramen is usually located <1mm of the anatomic apex, but only 30% of apical foramens are located exactly at the anatomic apex
        - Discrepancies as large as 3mm have been found
- Take a preoperative radiograph
    - Visualize the apical foramen
        - Root canal goes to anatomic apex – apical foramen is at the tip of root
        - Root canal ends before anatomic apex – foramen is likely buccal/lingual to tip of root
    - Estimate the tooth length. Measure from fixed points (i.e. cusp tip to root tip)
        - Record tooth length in patient chart
        - Subtract 2mm from this measurement as a safety factor
- After access prep complete
    - Select a file that's long enough to reach the apex, minimum size #15. This is your "trial file"
    - Place a rubber stopper 2mm short of the length of the tooth
    - Pre-curve the apical 4mm of the file
    - Introduce #15 file in a twiddling motion until it binds at or before WL
    - If the #15 doesn't fit, then file the canal wider with a #6 and #8 file until the #15 fits
    - Anything smaller than a #15 will not show on the radiograph for the next step
- Take a provisional working length (PWL) radiograph
    - If file is <1mm from the apex, then no adjustments are required. Proceed to instrumentation
    - If the file is >1mm, <2mm from the apex, then slightly adjust the rubber stopper and proceed to instrument
    - If the file is >2mm from the apex, adjust rubber stopper and retake radiograph to confirm new length
    - If the file is beyond the apex, measure amount of protrusion and add 1mm. Insert a larger file, to this new reference point and retake radiograph
    - **The tip of the file should bind at the working length**. If it doesn't, then the file is too narrow and risks penetrating the apical periodontal ligament
    - Teeth with high incidence of more than 1 canal (mand anteriors) may benefit from a M-D horizontal radiograph
        - If the M-D radiograph shows the file not along the center of the tooth, there is likely a second canal
    - Older patients may have WL 1~2mm short of the apex due to an increased deposition of cementum
- Important terms
    - Debridement: instrumentation and irrigation
    - Instrumentation: planning all walls to loosen debris
    - Irrigation: flushing debris from the root canal
    - Always irrigate between instrument usage and wipe files with EtOH



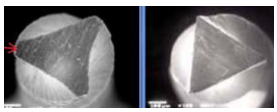
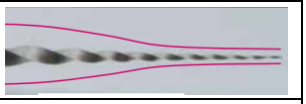
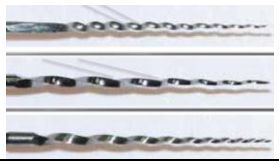
- Apex locator
  - Device that allows working length to be determined without a MAF radiograph. More accurate and efficient
    - Legally, you only need the initial and final radiograph. WL and MAF are not necessary
    - Older people have more cementum deposition in root canal, which can displace the foramen more than 1mm away from the radiographic apex
  - Generation 1+2: sensitive to canal contents and irrigating solutions
  - Generation 3 (current): impedance of the canal is measured via 2 currents of different frequencies → gives a ratio measurement rather than one measurement, called a quotient
    - Example: Root ZX apex locator uses 8kHz and 0.4kHz frequencies to find the quotient
    - Ensure battery is >50% charged, or else it will give an inaccurate reading
    - Values listed on the apex locater are arbitrary, you want to be around 0.25~0.5 on the scale
  - Consult cardiologist before using device on patients with pacemakers
  - Components of an apex locator
    - **Device**
    - **File clip**: clips to the file. Make sure file is long enough to accompany rubber stopper and file clip
    - **Lip clip**: hooked on the patient's lip
    - **2 cords**: one for the lip clip and one for the file clip



  - Technique
    - Hook a file to the file clip
    - Touch the rubber dam clamp with the file. If it reads 0, then you know it's working
    - Push file into canal and refer to device to see how close the tip is to the apical foramen
    - Will make a noise if going too far
    - Most accurate when double checked with a working length radiograph
  - Considerations
    - Do not touch metal, fluid, or blood (contains iron) as it may give a false reading
    - Perforations will give a value of 0
    - You still need to take the initial film to get a rough idea of where the WL will be, especially in calcified canals
      - No apical constriction = no sudden change in impedance for the apex locater to detect
    - Readings are the most accurate when the file fits in the apical region
      - Don't use a size 8 file in the apex that's sized 25
    - Does not work on an immature tooth as the apex is open

Instrumentation

- General principles
  - Direct straight access should be obtained to the apical root third
  - Smooth instruments should precede barbed instruments, and in sequence of size
  - Instruments should be fitted with instrument stops
  - Files and reamers should be discarded as soon as they bend or show signs of fatigue
  - Instrument should not be forced if it binds
  - All instrumentation should be done in a wet canal
  - Debris and instrument tips should not be forced through the apical foramen
  - Do not over-instrument the apex as it ↑ chances of root tip fractures, root perforations, and zipping of canals
  - In multi rooted teeth, treat the easiest canal first
    - Maxillary bicuspid: P → B
    - Maxillary molar: P → DB → MB → MB2
    - Mandibular molar: D → M
  - Take extra caution in areas of thin dentin, where strip root perforations are possible if instrumentation is excessive. These areas are called danger zones
    - **Premolars** have concave root surfaces (as their cross-section is a figure 8), so try to instrument away from the center of the tooth. <u>Push buccal/lingual</u>
    - **Maxillary molars** have a MB canal that's often kidney shaped and a MB root that has a distal concavity. Instrumentation should be done away from the distal aspect of the MB root. <u>Push mesial</u>
    - **Mandibular molars** have a distal concavity on the mesial root and mesial concavity on the distal root. Instrumentation should be done away from the midline of the tooth. <u>Push away from furcation</u>
  - The isthmus between 2 canals contains pulp tissue. It can be removed using a #10 or #15 file through the isthmus
  - Instrumenting curved canals will slightly straighten them out. This may shorten the WL, so confirm the new WL by taking a radiograph with an instrument in place
- Nickel titanium vs stainless steel
  - Nickel titanium (NiTi) has better flexibility and strength than stainless steel
  - NiTi is anticorrosive and does not weaken following sterilization
  - However, stainless steel can undergo more flexion before breakage than NiTi
  - NiTi exists in 2 forms: martensite (lower temp) and austenite (higher temp)
    - Martensite has shape memory, is softer, ductile, and super elastic. This is used in our files
    - Austenite has more strength and hardness
  - Stainless steel is for high torque use, whereas NiTi works best in low torque and passive environment
- Stresses to NiTi files
  - <u>Torsional fracture</u>: tip of a file binds, meaning the rest of the file bends while the tip is stuck → electric motor will stress and tear the file. Electric motors can have torque control, but this is unavailable in air rotor handpieces
  - <u>Cyclic fatigue</u>: rotating around a curve will cause repeated compression and tension
  - These 2 factors will lead to file breakage
  - Instrumenting a calcified canal will cause more fatigue and need to be discarded after 1 use
- File traits

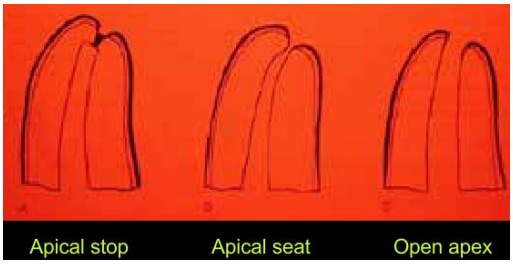
Trait	About	What's used	Image
Cross sectional design	**Passive cutting (U file):** somewhat flattened at the blade tip, forming "radial lands". Seen on left **Active cutting (K file):** sharp and aggressive cutting edges. Seen on right	-Passive cutting used in ProFile instruments (apical prep) -Active cutting used in ProTaper instruments (coronal prep)	
Taper	**Variable taper:** taper increases along the shank of the file **Constant taper:** file is cone shaped	-ProTaper has variable taper -Other files (including ProFile) are constant	
Helical angle	Helical angle is the angle between the cutting edge and long axis of the file **Twisted file:** steep angle, constant **Sequence:** shallow angle, constant **Vortex:** steep @ tip, shallow @ shank	-Constant angles debris to accumulate and are more susceptible to "screwing in" -Varying helical angles are preferred	

- Techniques

	Standardized technique	**Modified step back technique**	**Crown down technique**	**Hybrid technique**
About	-Inferior method, not used	-Goal is to get a funnel/bullet shaped apex -This prevents master cone from passing apex while accessory cones are being packed	-Easier access -Improved irrigation distribution -Uses rotary NiTi files -WL must be >20mm	-Used when crown-down is done on a canal too large (ProFile #35/40 reaching WL right away)
Technique – coronal portion	-Start with small file at WL -Increase file size -Continue instrumenting to WL until criteria for cleaning and an apical matrix are formed -Inferior method and not used	-Insert a #35 file to WL -If the file reaches ½ of WL passively, then it is large enough to prep the coronal portion -If the file doesn't reach ½ WL, then it's too tight and apical prep should be done first -Insert #2 GG bur up to ½ of WL **while spinning** -GG should never stop spinning in canal -Irrigate and work up to #3 and #4 GG burs. #5 can also be used if not enlarged enough	-Instrument up to #20 hand file to WL -Use a ProTaperSX file on a MM324 handpiece at 300RPM -Push in until resistance felt → pull back 0.5mm → push again until resistance → withdraw completely -Do circumferentially in ovoid canals -Clean SX file with alcohol soaked 2x2 and check for distortion -Irrigate canal -Can take WL radiograph before/after doing coronal flaring **Engines for rotary NiTi instruments:** -MM324: air rotor with variable speeds -Aseptico: electric rotor with variable torque settings. Engine reverses if torque passes threshold -Xsmart Easy: cordless handpiece	
Technique – apical portion		-Add 3 sizes from the WL file. This is your **master apical file** (MAF) -Since #15 is the smallest WL file, the smallest MAF file is #30. But if WL file is #50, then #70-#80 may be needed as MAF -Instrument MAF at WL -After MAF, ↑ 1 file size and ↓ 0.5mm WL -Continue this for 5 file sizes -Clean file after use and irrigate canal 0.5~1mL -Recapitulate with MAF (or smaller file) after every file -Take radiograph with MAF -Minimum apical size is #30	-Leave irrigant in canal -Use #40 ProFile Vortex (black, largest) at full speed -Push until resistance → push 1mm more → pull back 0.5mm → advance 1mm more → withdraw completely -Clean and inspect file, like above -Repeat until 1/2~2/3 to WL -Use #35 file to 2/3~3/4 WL -Use #30 file to 3/4~4/5 WL -Use #25 file to 4/5~full WL -Use #20 file if necessary to WL -Switch to hand files→ instrument apex to MAF (min #30) -Irrigate between each file and finish with EDTA rinse	-#35 or #40 file immediately reaches WL -Find a hand file that binds at WL, starting with #35 or #40 -The smallest file that binds at WL + 1 size up is your MAF -Begin the step back technique, sizing up 4~5 times from MAF

- About rotary NiTi files (Crown down technique)
    - Advantages: time saving and no difference compared to hand files in straight and curved canals
    - Disadvantages
        - In 2 canals that join, should only be used up to the point of union
        - In canals with double curved, should only be used up to the first curve
        - Unable to follow abrupt 90 degree curves
        - Overuse and overinstrumentation at apical foramen can cause breakage
- Example scenario of when hybrid technique is used
    - Achieve adequate access preparation and flare coronal portion using ProTaperSX file
    - Take WL radiograph (example: say WL is 21mm)
    - Attempt crown down technique
        - Starting with the ProFile Vortex #40: resistance at 17mm → push to 18 → pull to 17.5 → push to 18.5
        - Then use ProFile Vortex #35: resistance at 19mm → push to 20 → pull to 19.5 → push to 21
        - Apex was reached too early, meaning we need to size up the apex with step back technique
    - Start step back technique
        - If a size #40 reaches WL with resistance, then the #45 becomes the MAF
        - Step back: 50 file @ 20.5mm, 55 file @ 20mm, 60 file @ 19.5mm, 70 file @ 19mm, 80 file @ 18.5mm
        - Recapitulate and irrigate between files

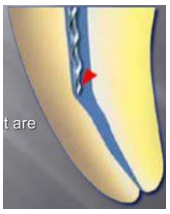
- Types of apical preparations
  - Apical stop: instrumentation short of WL to create a blockage
  - Apical seat: result of the step back method
  - Open apex: overinstrumentation through the apical foramen. Will need to take a new WL film using the largest file that binds at WL and make an even wider apical stop or seat



- Instrumenting a calcified canal
  - Preparation
    - Locating canal: use a DG16 explorer. Keep this instrument straight and sharp
    - Irrigation: irrigate canals copiously to removal all dentin shavings, especially during instrumentation
  - Instrumenting
    - Start with the smallest endodontic file (#10, #08, #06)
    - Once the canal has been negotiated to at least the middle root third, a chelating agent like RC PREP (EDTA) can be used on the tip of the file to negotiate to full WL
    - Using EDTA before reaching the middle root third can soften dentin, creating "false canals"
    - Can come in a gel form, which could be a good lubricating agent
    - It is necessary to instrument up to a #15 before taking a WL radiograph
- Errors in instrumentation
  - Ledge formation

Due to	Solved by
-Lack of straight line access → bent instrument → gouges into wall	-Newer instruments have rounded tips which are non-cutting, decreasing chance of ledging
-Using large stiff instruments in curved canals, usually in maxillary laterals and palatal root of maxillary first molars	-Small flexible instruments with non cutting tips can negotiate these curves

    - Detecting a ledge
      - Instrument no longer can be inserted to WL
      - Change in tactile sensation, feeling the instrument not engaging the walls



    - Dealing with ledges
      - Take a radiograph with the ledged instrument in place
      - Return to a smaller stainless file and curve the tip away from the ledge
      - Insert into canal, with tip pushed away from ledge to WL, and pull out pressing against the ledge
      - Increase file sizes until larger instruments slip by the ledged area
      - Keep area well lubricated, but avoid EDTA as it tends to intensify the ledge
  - Root perforations
    - Cervical: too large an instrument is used, frequently a Gates-Glidden
    - Mid-root: usually due to zipping, frequently in the distal wall of a curved mesial root of mand molars
    - Apical: due to over-instrumentation of the apical foramen, especially in apices that are curved
  - Separated instruments
    - Files and reamers are the most frequently separated instruments, and in the apical third
    - Avoid by not forcing any instrument and inspecting + cleaning after each use
    - Safe rule is to use rotary files only once, but clinically they are used 3 times unless they have been over stressed or distorted (in Alberta, legally you can only use it once)
    - Broken instruments can be removed by a hemostat or using a fine ultrasonic instrument to loosen and float the broken piece out
    - If retrieval fails, they can be bypassed with a successful root filling placed around it
    - If a broken instrument extends out the apex, it should be removed surgically and a retrofilling placed
    - Happened more with stiff stainless steel files, but now nickel titatnium files are used, which adapt to the curvatures more easily with minimal ledge formation, perforations, and canal transportation
  - Canal blockage
    - Can occur during canal enlargement
    - Files compact debris at the apex and shorten the WL
    - Recapitulating the canal (going back to MAF or smaller after every file) can remove accumulating debris
    - Chelating agents (EDTA or RC prep) is helpful

- Irrigation
  - Purpose
    - Reduce friction and lubricate instrumentation step
    - Facilitate elimination of dentinal debris, pulpal tissue, and microorganisms
    - Avoid blocking the canal
  - Technique
    - 27 or 30G syringes are used to irrigate the solution into the canal
    - The tip should fit loosely in the canal, so you don't force solution out the apex
    - Needle can be inserted on an angle, withdrawn if it binds to the canal, use a slight pumping action during irrigation, gentle pressure on syringe, and aspirating
    - There are special side-vented tips that prevent dispensing solution directly into the apex. Insert these into the canal until it stops, withdraw 1mm, then express the solution
    - Sodium hypochlorite (0.5~5.25%) is used during RCT, and final rinse is done with EDTA to remove the smear layer prior to obturation
    - EDTA is left for 3 minutes in the canal
  - Materials

Sodium hypochlorite 0.5~5.25%	-Diluted household bleach, usual irrigating solution of choice -Kills microorganisms and dissolves necrotic tissue
Chlorhexidine gluconate 0.2~0.5%	-Can be used instead of bleach, but worse tissue dissolving ability
EDTA 17%	-Removes smear layer after preparation -Helps prep some obliterated/calcified canals
MTAD	-Tetracycline, citric acid, detergent -Removes smear layer but treats dentin gently -Strong antibacterial activity against root canal bacteria

  - Sodium hypochlorite accident
    - Acute symptoms: severe pain, swelling, bruising
    - Long term symptoms: paresthesia, scarring, muscle weakness
    - Treatment: immediately rinse area with saline. May give antihistamines, ice packs, analgesics, antibiotics. Possible surgery + hospitalization
    - Reassure patient they will get better, but swelling and bruising will be present for the first few days
- Drying canals
  - Use the irrigating syringe and cotton pellets to suction/aspirate most of the fluid out of the canal
  - Then, grasp paper points (MAF size or slightly smaller) using cotton pliers
  - Place paper points in canal for a few seconds, retrieve, then discard
  - Sizes vary from fine, medium, coarse, extra coarse
  - Measure paper points to ensure it's not inserted past WL
    - Residual cellulose that's left in the periapical space can cause long lasting inflammation
    - May induce periapical bleeding
  - If the paper point is bloody, it can mean a few things
    - Vital pulp tissue remains
    - An instrument has been pushed through the apex, and periapical tissues are bleeding into the canal
    - Paper point pushed through apex
    - Root perforation
    - Bleeding from pulp tissue in a lateral canal
    - Vasodilation effect of local anesthetic
- End point for cleaning
  - Glassy, smooth walls
  - Clean dentin shavings
  - Clean irrigation solution
- End point for shaping
  - Apical stop with at least 3 sizes greater than the first file to bind at the WL has been formed
  - Preparation flare is sufficient to allow penetration of D11 or D11T spreaders to within 1~2mm of WL alongside the master cone seated to WL
  - Only when these endpoints are met, can we proceed to drying and obturation

Obturation

- Objective
  - Create a fluid seal between the coronal access to apical terminus
  - Inhibit access of antigenic material from oral cavity to root canal
  - Minimize the hollow tube theory
  - Inhibit growth of periapical tissue into the root canal (which may cause resorption or continue infection)
- Ideal qualities of an obturation material
  - Seals the canal apically and laterally – no change in size after placement
  - Bactericidal
  - Not irritative to periapical tissue
  - Impervious to moisture
  - Sterile or easily disinfected
  - Easy to handle
  - Radiopaque
  - Does not stain tooth structure
  - Easily removed from canal
- Improper obturation can lead to
  - Irritation of periapical tissues from pulpal remnants in the canals
  - Salivary leakage from the oral cavity into the tooth
- Ideal length of obturation
  - Obturation should be at the cementodentinal junction, 0.5~1mm short of the radiographic apex
  - Obturation should be the same as WL, where the apical matrix was prepared
- When to obturate
  - Patient is asymptomatic
  - Tooth is not tender to percussion
  - Pre-existing sinus tract has healed
  - Canal can be dried – no fluid in the canal
  - Negative culture result – no longer applies, but was a criteria in 1970
- Gutta percha
  - Most popular root filling/obturating material, used in conjunction with a sealer
  - GP makes up most of the filling, with sealer filling any gaps and irregularities in the root canal
  - Advantages: plasticity, easy to manage, easy to remove, low toxicity
  - Disadvantages: does not adhere to dentin, so a sealer must be used in conjunction
  - Sizing
    - Standardized cones: matches the 0.02 taper files (25, 30, 35, 40, 45, 50, 55, 60, 70, 80)
    - Accessory cones: narrow tip with a wide body (FF, F, MF, FM, M, L)
    - GP cones are rolled by hand, so there is a wide variation of taper and size and poor correlation to instrument size and cone size
  - Proper fitting
    - Visual criterion: cone should extend to within 0.5~1mm of the WL
    - Tactile criterion: cone should fit tightly enough so there is tug back
    - Radiographic criterion: when above are satisfied, radiograph is taken. No voids should be seen in the apical third and cone should be seated to proper length
    - Radiograph in this step is not needed with more experience. If there is tugback 1mm short of WL, the canal can be filled without a confirming radiograph
- Sealers
  - Fills voids in root canals, fills space between cones, seals lateral canals, seals dentinal tubules, and lubricates cones
  - Thermaseal: zinc oxide eugenol and resin. Mixed from 2 pastes
  - Grossman's sealer: zinc oxide eugenol based. Mixed from powder and liquid. Mix on glass slab for 2~3 minutes until the liquid can draw 2.5cm with a spatula

- Lateral condensation technique with gutta percha
    - Placement of master cone
        - Start with a GP cone same size as MAF or select the cone which fits the canal best within 1mm from WL
        - Use locking pliers to hold the master cone at WL and introduce into canal
        - The cone should have "tugback" at WL – feeling of resistance as the cone engages the canal walls
        - If a GP cone is too small and the next size is too big, you can try other cones from each of the two sizes or trim the apical portion of the smaller cone
            - If you are considering cutting the cone, it should be done perpendicular to the long axis
            - Cutting the cone will flatten the tip, which could give a false positive for tugback. Insert a trimmed cone multiple times to ensure tugback is a true positive
        - Once the right cone is selected, it needs to be adapted to the canal shape
        - Dip the apical half of the cone in chloroform for 1~2 seconds to soften it (bigger cone = longer time)
        - Tamp the cone in the canal to WL 2~3 times to capture an "impression" of the apical third
        - Repeat softening and tamping if needed, to seat the master cone to WL
        - Once the master cone has been adequately formed, coat the apical canal with sealer
            - Use a file one size smaller than MAF (or a lenticulospiral file), and dip the end in sealer
            - Turn the file counter clockwise in the canal to deposit sealer and adapt it to the walls
            - Use a paper point if too much sealer was put into canal
        - Coat apical part of the master cone with sealer as well
        - Insert master cone to WL
    - Placement of accessory cones
        - Introduce the spreader alongside the master cone and press apically until 1~2mm of WL
        - If the spreader reaches WL, the master cone is too narrow
        - Remove the spreader by rotating while pulling coronally
        - A space will remain where the spreader used to be, where an accessory cone can be inserted
            - If the accessory cone is too small, an excessive number of them may be needed
            - If the accessory cone is too large, it could get stuck and create a void, leading to failure
            - The accessory cone should ideally be slightly smaller than the spreader
        - Take a <u>trial cone radiograph</u> after the master cone and one accessory cone has been placed
            - Looking for acceptable length (cones to WL), lack of voids in apical portion, and shape of GP reflecting the shape of the canal
        - If the above criteria are met, then continue packing accessory cones until spreader can only be pushed 4mm below the canal orifice
        - Sear off + compress the cones with a heated Glick #1 instrument so that GP is only in the root canals
        - An alcohol soaked cotton pellet can help clean the pulp chamber
    - Other considerations
        - The end result of obturation should not allow a spreader to penetrate between GP and dentinal wall
        - In multi canaled teeth, fill one canal at a time
    - Take the final radiograph without the rubber dam clamp in place
- Errors in obturation

Error	Description	Prognosis	Management/prevention
Overfilling	-Good apical seal, but master cone pushed beyond WL due to poor apical matrix -May cause transient discomfort	-Slight overfilling usually does not cause failure	-If seen during trial cone radiograph: pull out cones, irrigate canal, size up apex with new MAF to re-create apical seat, and redo step back
Overextension	-Master cone is smaller than the apical matrix, so the cone goes past WL	-Usually results in failure due to poor seal	-If seen during trial cone radiograph: pull out cones, irrigate canal, reobturate with a proper size cone
Underfilling	-GP is condensed short of WL and apical portion harbours bacteria and a chronic inflammatory reaction	-Usually results in failure	-If seen during trial cone radiograph: pull out cones, irrigate canal, reobturate with a proper size cone
Vertical root fracture	-Crunching sound heard during obturation (lateral compaction more common)) -Silent fracture months~years after RCT	-Failure	-Minimize risk by conservatively preparing canals -Avoid excessive pressure during obturation

- Other obturating materials

Category	Material	Radiographic appearance	Etc info
Solids	-Silver cone	-Radiopaque with no voids -Doesn't have striations like a post does	**Removal** -Cotton forceps -Chloroform to dissolve cement and use K files to wedge into canals -Hedstrom files could break (weaker) **Disadvantages** -Toxic to periradicular tissues -Can be pushed apically when creating post space -Difficult and extra time needed for retreatment
Semi solids	-Gutta percha -Gutta core -Thermafil	-Less radiopaque and uniform	**Removal** -Dissolve with chloroform
Pastes	-Sargenti paste N2	-Soft pastes are less radiopaque and likely to have voids -Some pastes are hard-setting, which appear a lot like GP	**Toxicity** -Toxic metallic paste and paraformaldehyde that can cause nerve damage if leaked out the apex **Removal** -For hard setting pastes, an ultrasonic can be pushed down the canal

    - Gutta Core
        - Gutta percha cone with a metal reinforced core in the middle
        - Use: heated in a machine until GP softens, then whole cone is pushed into the canal. GP flows into canal space and adapts to the canal shape
        - Features: subtle, flexible strength, retains shape when heated, radiopacifiers ↑ radiographic appearance
        - Benefit: centrally condenses the surroundings with flowable gutta percha → moves warm flowable GP 3 dimensionally to the apex, and is removed with unprecedented ease
    - Thermafil
        - Gutta percha cone with a plastic core
        - May appear exactly like gutta percha until access is made and the plastic (black) core is seen
- Overview of radiographs to take
    - Initial
    - WL
    - MAF
    - Trial cone
    - Final (without RD clamp and after the restoration is complete)

Restoration after obturation

- Any contamination will lead to bacterial infection and RCT failure. Some sources are:
  - During RCT: no rubber dam, leaky rubber dam, leakage during radiographs
    - Use a plastic rubber dam frame so it's radiolucent on the radiograph. The PSP can be inserted by everting one corner on the rubber dam frame. Don't remove the RD as contamination is likely
  - After RCT: leakage of temp/perm restoration, contamination during post space preparation, fitting, or cementation
  - Restorations must be placed prior to removing rubber dam
- Access temporization
  - Temporary restoration placed to prevent leakage between endo appointments
  - Normally, a cotton spacer is placed below the temporary restoration
    - Makes it easier to re-access the root canal during the next appointment
    - Make sure no cotton strands are sticking out, as they can be sources of leakage
    - Don't use cotton if you need the temp material to be thicker
  - Materials

Cavit	-Pros: has the best seal -Cons: weak strength (needs to be >4mm thick), only for short term temporizatoin (3-4w) -Types: gray (softest), white (medium), pink (hardest) -For more long term temporization, can place composite or GI on top of Cavit -Adding a cotton pellet is optional given space, as mentioned above
IRM	-Pros: better wear resistance than cavit -Cons: not a good seal, difficult to place and retain, longer setting time -Good to place Cavit first then top it up with IRM -IRM contains some ZOE, which may reduce adhesive efficacy, so avoid composite restos

- Permanent restoration
  - Should be placed as soon as possible (ideally the same appointment as finishing the RCT)
  - Within a couple weeks is acceptable, but don't wait a couple of months
  - Tooth is much weaker due to amount of structure lost, so must be protected in addition to preventing reinfection
  - Types

Direct restoration	-Composite restoration is used only when minimal coronal tooth structure is lost -Usually in anterior teeth with marginal ridges and incisal edges intact
Indirect restoration	-Onlay -Full coverage crown (gold, PFM, zirconia, lithium disilicate, porcelain) -Core buildup will also be necessary (amalgam, composite, GI, GI + composite on top) -Cores are usually composite. Amalgam if subg or hard to isolate -Anterior teeth are only crowned if there is structural weakening or discolouring that can't be treated with a veneer -Posts may also be needed, and their indications are listed below

- Considerations in placing crowns
  - 2 main considerations: occlusion and esthetics
  - Full gold crowns should be placed on second molars whenever possible
  - PFM crowns on anteriors, premolars, and molars with a porcelain butt margin where appropriate for esthetics
  - Lithium disilicate on anteriors, premolars, sometimes first molars (case by case), never second molars (too weak)
  - Zirconia on posteriors as an economic alternative to gold. However, it is very hard and may harm the opposing tooth structure or opposing restoration
  - Crown design
    - All margins must be on solid tooth structure and not core buildup material
    - Restoration must completely encircle the tooth
    - At least 2~3mm of ferrule with min. 1mm of tooth structure from crown margin to core buildup margin

Adequate ferrule	**Inadequate ferrule**
-↑ retention, stability, fracture resistance -↑ ferrule/tooth structure = ↑ restoration longevity	-Catastrophic crown failure (+ RPD, bridge, etc) -Cement failure and post loosening -Post fracture (rare)

    - Ferrule can be gained by crown lengthening or orthodontic extrusion

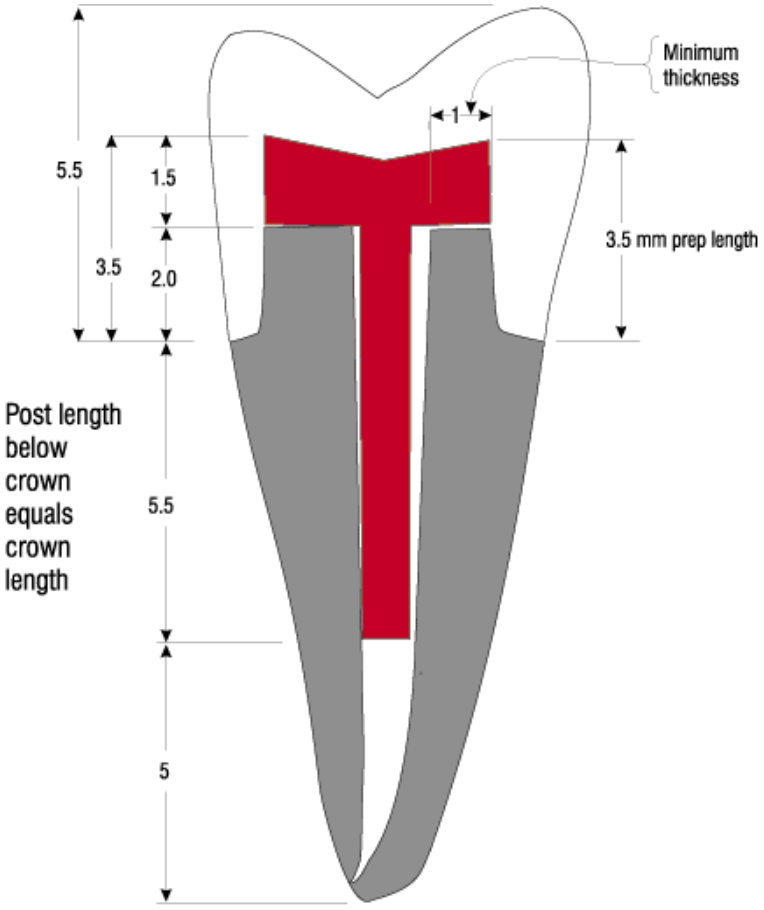
- Considerations in placing posts
    - Used when there is insufficient tooth structure to retain a core. The post only acts as a source of retention for the core. It does not strengthen the tooth in any way
    - Risks
        - Posts weaken teeth and may cause vertical root fracture, especially in pts with parafunctional habits
        - Post placements can disrupt endodontic seal
        - Post-cement interface can leak
        - Poor placement of drill or using the wrong size can lead to perforation
    - Considerations
        - Size of tooth and position in arch
        - Amount of coronal structure remaining
        - Curved canals, thin roots, mesial concavities (premolars)
        - In teeth with multiple canals, select the largest and straightest canal
            - Palatal in max molars, distal in lower molars, palatal of upper premolars
        - Longer posts have better retention, but at the cost of compromising apical seal
    - Post use on anterior/posterior teeth

Anterior	Premolar	Molar
-Composite restoration can be done if there is enough tooth structure -If there is too much tooth structure loss, a crown and post may be indicated	-Premolars are usually single rooted and have small pulp chambers → hard to get core retention -Exposed to lateral forces during mastication -Due to these factors, PM's tend to need posts more often than molars -Beware of thin roots and root concavities	-Molars have large pulp chambers and vertical loading forces -Can extend core material 1~2mm into the pulp chamber for more anchorage of core -Rarely need posts, unless there has been significant loss of tooth structure

    - Post design

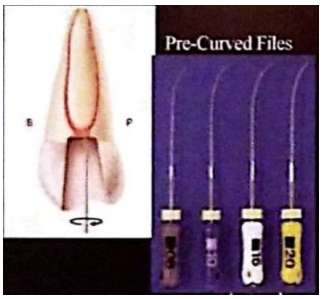
Material	Metal	-Strong and stiff, but concentrates unfavourable forces at the root -Root fractures generally happen at the base of the root -<u>Prefabricated:</u> stainless steel or titanium -Titanium has the same radiopacity as GP, so may be missed when interpreting radiographs -<u>Custom (cast post and core):</u> lab fabricated. Takes 2 appointments, with a temporary post placed in between -Casts P&C preps need to taper so there are no undercuts, but this requires more tooth removal in the coronal portion
	Non metal	-Not as strong as metal, but do distribute forces more evenly -Good for anterior teeth -<u>Materials:</u> zirconium coated carbon fiber, glass fiber, quartz fiber, fiber reinforced composite, ceramic, and zirconia -Carbon fiber posts embedded in epoxy matrix are radiolucent and black
Taper	Tapered	-Less retention and concentrates forces in the root like a wedging effect -Follows natural taper of root canal, so less dentin removal
	Parallel	-Better retention and more even force distribution -May require more tooth structure removal
Retention	Active	-Mechanically engages dentin walls with threads like a screw -More retention, but higher risk of root fracturing during post placement -Avoid whenever possible
	Passive	-Retention from luting cement and adaptation to canal wall -Surface can be smooth or serrated for some additional retention

- Post placement
  - Remove gutta percha to create post space
    - Avoid Gates Glidden burs and parapost drills
    - Only use heated instruments like Touch and Heat to avoid perforation
  - Size
    - Smallest post = least tooth structure removal = best prognosis
    - Increasing post width has no significant effect on retention
    - Always leave >1mm dentin on either side of the post at narrowest portion of canal
  - Apical depth
    - Post should be at least the height of the restored crown
    - Approximately ½ the root length in bone
    - Should leave at least 5mm of GP to ensure apical seal. More GP is better
    - If the tooth is likely going to have apical surgery, add 2-3mm more GP as that is about how much is usually removed at the tooth apex
  - Coronal height
    - Post should be embedded within the core
    - Coronal part of core should not be exposed on the core (possible source of leakage)
  - Cementation
    - Luting cements: resin modified GI (Rely-X), resin, zinc phosphate
    - Spin down cement with lentulospiral then coat post with cement and seat all the way down
    - Coating only the post could lead to voids and worse retention
- Retrieving posts
  - Frequently, even more dentin removal may be necessary to gain access to remove a post
  - Ultrasonic instruments and special burs under microscopes are used to remove posts
  - Some are difficult or impossible to remove (ceramic and zirconia)
  - If too much tooth structure needs to be removed, then a surgical approach may be needed
  - Should only be done by a specialist

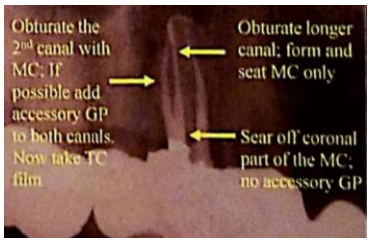


Multi canaled or multi rooted teeth and canals that join

- Identify which canals are largest
  - Mand anterior: facial > lingual
  - Mand premolars: buccal > lingual (frequently in a "h" shape) →
  - Mand molars: DB > DL > MB > ML
  - Max premolars: palatal > buccal (MB and DB)
  - Max molars: P > DB > MB1 > MB2
- Be familiar with laws of pulp chamber floor anatomy
  - Law of symmetries
    - 1: orifices of canals are equidistant from a line drawn M-D through the center of the chamber
    - 2: orifices of canals lie on a line perpendicular to a line drawn in a M-D direction
  - Law of colour change
    - Colour of pulp chamber floor (grey) is always darker than the wall (yellow/white)
  - Law of orifice location
    - 1: orifices of canals are located at the junction of walls and the floors
    - 2: orifices of canals are located at the angles of the floor-wall junction (isn't this the same as #1?)
    - 3: orifices of canals are located at the terminus of the developmental fusion lines (grooves on pulp floor)
- Working length and instrumentation
  - Radiograph: use different size files or different type of files in each canal, so they can be identified on radiograph
  - When instrumenting, do one canal at a time so you don't lose track of WL and which file sizes to use where
- Obturation
  - Obturate each canal separately, up to the trial cone + 1 accessory cone
  - Take the trial cone radiograph after 2 canals done, or if possible, do it after 3 canals are done
  - If there is no room: take the trial cone radiograph of 2 canals, burn them off, then trial cone the remaining canals
  - Need to ensure all canals have a proper trial cone before proceeding with lateral condensation
- Oval orifices
  - Must be explored using pre-curved files, as they have multiple canals underneath
  - Curve buccally when looking for the buccal canal, and palatally when looking for palatal canal

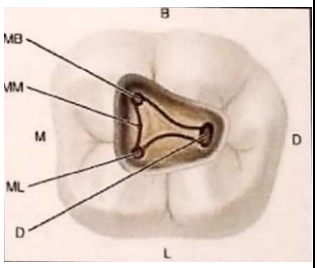
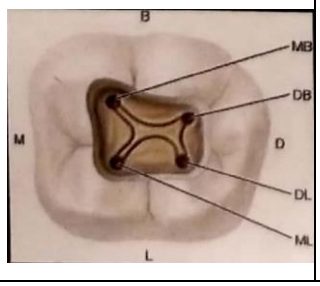
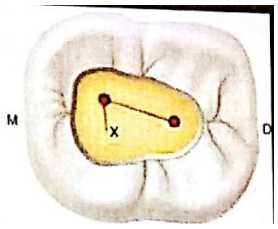
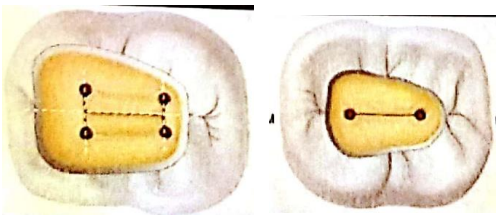


- Canals that join
  - Try to identify joining canals prior to instrumenting, as instrumenting the joined part will create an hourglass prep at the apex
  - Place one file (ideally in the straighter canal) up to WL
  - Place a second file in the other canal
  - If the canals join, the second file shouldn't be reaching WL unless the first file is removed
  - However, size 10 files may both go to WL, so try to use larger files to do this test
- Canals that split (Vertucci 3, 5, 7)
  - May appear as 2 PDL lines radiographically (important for mand anteriors, where 30% have a 2nd canal)
  - Fit one formed master cone into the larger/longer canal first
  - Sear off the coronal GP and push it away from the opening of the second canal
  - Place the second master cone in the second canal
  - If space is available, add accessory cones to one or both canals
  - Take trial cone radiograph
  - Once everything is confirmed, sear off the MC's and proceed with the rest of the obturation



  - If it's not possible to reach the second canal after obturating the first one, modify the orifice opening (often bucco-lingually) by coronally flaring it

Management of mandibular molars

	Mandibular first molar	Mandibular second molar
Canal stats	-4 canals: 60% -3 canals: 39% -5~6 canals: 1~15%	-3 canals: 60% -4 canals: 40% -2 canals: 1~5%
Roots	-2 roots (M and D) -Extra DL root found in 5% (radix entomolaris)	-2 roots (M and D) -May have fused roots -Could have 1 single root
Mesial root	-2 canals (MB, ML), or 3 canals (MB, MM, ML) -Apex usually curves distal or is S shaped **Vertucci type** -Usually 2 and 4 -Sometimes 3, 6, 7, 8	-2 canals (MB, ML) or 1 canal -Usually curves distally
Distal root	-1 canal or 2 canals (DB, DL) -Apex usually curves mesial, sometimes distal, or S shaped -Apex may also curve buccally, which is hard to find on radiograph -If DL root is present, it commonly curved buccally **Vertucci type** -Usually 1, 2, 4 -Sometimes 3, 5, 6, 7	-1 canals, or 2 canals (DB, DL) -Apex may curve distally or mesially -Apex may curve buccally and not always appreciated radiographically
Special considerations	**DL root**  -Tends to curve suddenly to the buccal when near the apex -Very easy to perforate, and may need apical access to treat -Precurve the file to avoid perforation **Always check for proper removal of dentinal triangles**	**C shaped canals**  -8%, but 30% in Asians -Rather than a circular canal, is shaped like a C -Connects some or all of the canals **IAN proximity** -Be careful when instrumenting or filling with CaOH on 2nd molars because if they are extruded out the apex, it could cause nerve damage
Access prep	-Start access assuming 3 canals (MB, ML, D) -Access will look triangular  -Start at MB cusp and go straight to ML, which forms the base of the triangle -Extend apex of triangle along the midline of the tooth, until D canal is reached -If there is a line between MB and ML canals, suspect a MM canal somewhere along that line  -If the D canal is not found on midline, then suspect DB+DL canals to exist -Extend the distal wall towards the buccal and lingual -Will turn the triangular access into a rhomboid/rectangular shape	-Start triangular and extend to rhomboid/rectangular if necessary  

- Mandibular third molars
  - Highest anatomic variation
  - Roots often fused, short, curved, and/or malformed
  - Can be root canal treated, but prognosis depends on periodontal condition, restorability, crown:root ratio, etc
  - Single wide canal can taper to a single apical foramen

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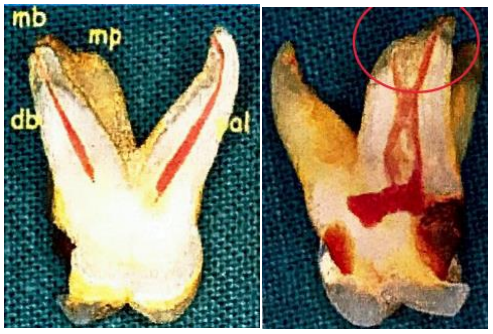
Management of maxillary molars

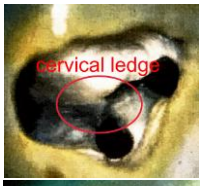
- Anatomy

Maxillary first molar	Maxillary second molar	Maxillary third molar
-3 roots (P, DB, MB) -4 canals: >90% -3 canals: <10% -5+ canals: <1% (3 mesial, 2 palatal)	-More varied anatomy than 1st molars -Occasionally 2 palatal roots -4 canals: 50% -1~4 canals with 1~4 roots -Triangular outline access	-Radicular anatomy unpredictable -1~3 canals with 1~3 roots

- Maxillary first molar roots
  - Palatal
    - Longest and largest diameter
    - Root is round and angled away from the crown
    - Easiest canal to find
    - Typically curves to the buccal near the apex
  - Distal buccal
    - Round, conical, and usually straight
    - Frequently has a distal dilaceration
  - Mesiobuccal
    - Ovoid root shape
    - 2 canal system >90% of the time (MB1, MB2)
    - MB2 is straight palatal to MB1
    - MB2 is generally the smallest canal
    - Retreatment needed most often due to missed MB2
    - Can be quite curved, leading to ledging with improper instrumentation

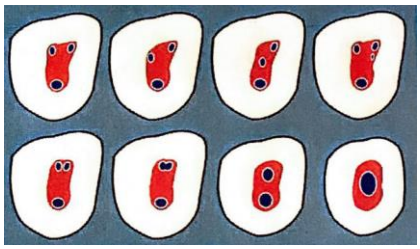


- Access prep
  - Draw a line between MB1 and P canals
  - MB2 is usually located mesial to this line
  - Straight line access is critical to minimizing risk of instrument failure
  - Don't need to see all the canals at the same time, as long as each individual canal has a straight line access
  - Coronal 1/3 of root canals should be flared and all cervical ledges should be removed
  - Furcation areas are "danger zones" with thin dentin, and high risk of perforation



- Locating canals
  - If you find only 3 canals, proceed with instrumentation and coronal flaring, as it will help one orient to the internal anatomy and improves ability in locating additional canals

- Instrumenting
  - It's not possible to instrument all of the canal anatomy
  - Even with the best instrumentation, only ½ of the surfaces are accessible
  - For endodontic success, we rely on chemical disinfection and irrigation



- Working length
  - Use a consistent reference point, like the MB cusp tip
  - Can take 2 films to capture all WL's: P+DB canals, then MB1+MB2
- Obturation
  - Obturate (master cone + 1 accessory) in palatal canal first, then DB canal
  - If there is room, do MB1 or MB2. If no room, then take a trial film
  - Heat and remove the obturated canals so there is more space in the access prep
  - Proceed to obturate the leftover MB canals
  - If adjustments are necessary, GP can be removed using a Hedstrom file (#30-#40) pushed 2~3 twists into the GP
- Reasons for endodontic failure in maxillary molars
  - Missed canal (MB2) or inadequate debridement
  - Leakage through restoration, post space, or recurrent decay (exposed GP has bacteria at apex in 30 days)
  - Extraradicular infection, foreign body reaction

Endodontic diagnosis

- In endodontics, you need to make 2 types of diagnoses: pulpal and periapical

Pulpal diagnoses	Periapical diagnoses
-Normal -Reversible pulpitis -Symptomatic irreversible pulpitis -Asymptomatic irreversible pulpitis (hyperplastic pulpitis) -Pulp necrosis -Previously treated/initiated therapy	-Normal -Symptomatic apical periodontitis -Asymptomatic apical periodontitis -Acute apical abscess -Chronic apical abscess -Condensing osteitis

- Periapical inflammatory disease
  - Lesion present when a radiograph is taken
  - EPT will have no response, as pulp is dead for lesion to start
  - There are several types of periapical inflammatory diseases

Acute	Chronic
-Symptomatic apical periodontitis -Acute apical abscess -Phoenix abscess -Swelling present	-Asymptomatic apical periodontitis -Chronic apical abscess (suppurative apical periodontitis) -Condensing osteitis -Swelling absent
-Dx: see pulp necrosis	-Dx: cold (-), hot (-), percussion (-)

- Cysts vs abscesses
  - **Abscess**: collection of pus due to an infectious process in a local area
  - **Cyst**: closed sac with a membrane lined by local cells which have mutated. Can be filled with air or mass
  - A radiograph cannot differentiate between an abscess or a cyst, so a RCT is done assuming it is an abscess
  - If the lesion still grows or doesn't resolve in a year, then it suggests a cyst which would need surgical treatment
  - Cysts are usually resorbed, but could enlarge as fluid fills the lined sac
  - Endodontists believe that cysts can resorb, whereas oral pathologists believe cysts need to be enucleated
- How to approach a difficult differential diagnosis
  - Consider possibility of misdiagnosis
    - **Misperception**: not enough teeth were tested as a baseline prior to testing tooth in question
    - **Misinterpretation**: not doing the tests properly
    - **Incomplete diagnostic examination**: not doing all the tests
    - Full coverage restorations may also skew sensitivity tests (insulates heat/cold, no EPT, etc)
  - Consider coronal or root fracture
    - Search for clinical signs (like a broken restoration or cracked cavit)
    - Take radiographs to look for fracture, although it doesn't always show
  - Consider non odontogenic entities
    - Could just be an anatomic structure or a non-odontogenic pathology
- Interpreting endodontic tests into a diagnosis

	Cold	Hot	Percussion	EPT	Signs and symptoms	RCT
Reversible pulpitis	+	+	+	+	-Symptoms last as long as stimulus is applied -Possibly due to recent resto, caries, hyper-occlusion, cutting dry -No spontaneous pain	No
Irreversible pulpitis	++ Prolonged, severe	+/-	+	++	-Throbbing pain, not an ache -Spontaneous pain -Canals will bleed 	Yes
Asymptomatic irreversible pulpitis	-	-	-	++	-Chronically inflamed young pulp exposed by caries -Mild pain during mastication -Canals will bleed 	Yes
Pulp necrosis	- Cold relieves pain	+/++	+++	-	-Continuous, throbbing, spontaneous pain -Patient can localize tooth -Canals have pus (5%) or are dry -Check occlusion	Yes

- Initial exam
  - **Subjective findings**: medical history, dental history, chief complaint
  - **Objective findings**: EO, IO, radiographic exam. Check for swelling, asymmetry, lymphadenopathy
  - **Pain questioning**: spontaneous? Awakening at night? Cold/hot/touch sensitive? Linger? Worse on release?
  - **Radiographic findings**: a >25 sized GP point can be inserted into a suspicious lesion or a lesion exuding pus to see if it's a sinus tract to a chronic abscess. Don't anesthetize because you will need to do pulp testing later
- Endodontic tests

<table>
<tr><td rowspan="5">Peri-radicular tests</td><td>Palpation</td><td colspan="2">-Palpate with finger to see if it's tender. Area of interest should feel soft and fluctuant
-Can help determine how far the acute apical abscess has spread
-Helpful in localizing the area to incise and drain, if needed
-Easier to determine in maxilla due to thin buccal bone and possible fenestrations</td></tr>
<tr><td>Percussion</td><td rowspan="2">-Determines presence of inflammation in the PDL, not any information on pulpal health
-Sensitivity could be due to periapical lesion (inflammation or necrosis), trauma, parafunctional habits, occlusal issues, or periodontal disease
-Only in periapical lesion or trauma would you consider RCT</td><td>-Start with light digital pressure and start on non-suspected teeth as a control
-Then, use the blunt end of an instrument (like a mirror) and tap on the tooth on its long axis</td></tr>
<tr><td>Bite pressure</td><td>-Can bite on a Q tip, cotton roll, or tooth sloth
-Normal bite + lateral movements
-Check each tooth and each cusp on tooth
-If there's more pain on release, suspect a crack</td></tr>
<tr><td>Periodontal probing</td><td colspan="2">-Probe the entire circumference of the tooth by "walking it," not just the 6 surfaces
-Multiple deep pockets and generalized bone loss is likely to be periodontal disease
-Narrow probing defect may be due to a draining sinus tract, vertical root fracture, or perforation</td></tr>
<tr><td>Mobility</td><td colspan="2">-Gives no information on health of pulp
-Mobility in the absence of trauma is usually due to periodontal disease
-In acute apical abscess/inflammation, patient will complain that the tooth feels elevated</td></tr>
<tr><td rowspan="3">Pulp vitality tests</td><td>Heat test</td><td colspan="2">-Have an air-water syringe ready to cool the tooth immediately if it's sensitive to heat
-Pain will be triggered when the pulp-dentin junction reaches 47 degrees
Gutta percha stopping instrument
-Applicator shaped instrument with hardened GP on the tip
-Apply Vaseline on tooth prior to placing heated GP stopping on the tooth
-Use heated GP with caution because if it drips, it will burn the tissues and irritate the patient
Touch n heat
-Coat tip with Vaseline, place touch n heat tip on tooth
Frictional heat
-Prophy cup applied on tooth and activated</td></tr>
<tr><td>Cold test</td><td colspan="2">-Apply a cold object on patient's tooth <u>for 8~10 seconds</u> and tell patient to raise hand when they feel pain
-Pain will be triggered when the pulp-dentin junction reaches 29 degrees
-Explain to patient about pain before doing it, otherwise you lose rapport
-Test <u>3~5 other teeth</u> as a baseline before testing tooth in question (contralateral tooth OK)
-Sudden cold will cause an outward flow of fluids and trigger A delta fibers which send pain signals
Endo ice
-Hold cotton pellet (#2) with pliers → spray endo ice on pellet until it starts dripping → apply on tooth
-Avoid Q tips or #4 pellets because they don't hold the cold for long enough
Other cold sources
-CO_2, frozen anesthetic cartridges loaded with ice
Limitations
-Calcified canals, large restos, porcelain covered teeth may trigger a false positive
-Applying the cold on the buccal/lingual surface may yield different results
-Refractory period of a few minutes – don't repeat the test on the tooth immediately after first test</td></tr>
<tr><td>Electric pulp test (EPT)</td><td colspan="2">-Set rate of EPT machine to 4.5
-Dry the tooth then apply an electrolyte like toothpaste on the probe (wet = could stimulate gingiva)
-Place EPT probe on tooth (incisal edge if anteriors) and tell patient to hold on to it with fingers
-Tell patient to release when they feel a little pain
-If it reaches the max, it's probably necrotic
-Any other reading (0~79) doesn't indicate how healthy the pulp is
-Must be placed on natural tooth structure, as it's not reliable on restorative materials
-If the adjacent tooth has a metallic resto, separated them so the current doesn't go down that tooth</td></tr>
</table>

Apexification, apexogenesis, regeneration

- In young patients, a permanent tooth may not be fully formed
  - Immature teeth have large pulp chambers with no apical constriction, so traditional RCT is not possible
  - These immature teeth will need to be treated via apexification or apexogenesis + regeneration

<table>
<tr><th></th><th>Apexification</th><th>Apexogenesis</th><th>Revascularization</th></tr>
<tr><td>Definition</td><td>-Inducing apical closure by the formation of osteocementum or a similar hard tissue of an incompletely formed tooth in which the <u>pulp is non vital</u>
-Fill the root canal system in 3 dimensions while keeping the material in the root canal system</td><td>-Therapy that aims at <u>maintaining a vital pulp</u> to allow the tooth to mature and develop</td><td>-Growth of hard tissue into the root canal of a previously necrotic tooth</td></tr>
<tr><td>Diagnosis</td><td>-Necrotic pulp +/- apical periodontitis</td><td>-Vital tissue remains</td><td>-Apical periodontitis</td></tr>
<tr><td>Technique

Notes:
-During access, if there is lots of blood and pus, then the pulp is likely fully non vital
-Always check periapical region for chronic or apical abscess, which would auto-matically contra-indicate apexogensis
-If there is a sinus tract, pulp is dead</td><td>Access
-Straight line access is not difficult due to the large pulp chamber
-Remove all pulp horns and radicular pulp
Instrumentation
-Apex locators will not help, so determine WL using files
-Files can be held in place with cotton pellets stuffed in the access cavity
-Use a file large enough to engage the canal walls, don’t go 3 sizes above the first file to bind at WL (like normal RCT’s)
Drying canal
-Paper point is placed backwards in the canal
Placement of medicament (CaOH) + obturation
<table>
<tr><th>Traditional</th><th>Contemporary</th></tr>
<tr><td>-CaOH placed for months~years to stimulate apical closure before the final filling</td><td>-CaOH placed for 2w to disinfect canal then barrier formed at apex</td></tr>
<tr><td>-CaOH paste: H_2O, glycerin, and $Ca(OH)_2$
-Spin paste into canal using a lentulospiral
-Premeasured paper point can be used to push CaOH to the apical foramen
 
-Then, CaOH is packed up to the CEJ
-1st Image: CaOH applied, but no apexification at 6 months
-Change this dressing every 6w. If it has not washed out at 6w, then double recall time (6w → 3m → 6m)
-New radiograph every 6m to check for hard tissue formation at apex
 
-But, radiographs may be misleading because it can only show M-D closure of the apex. The B-L closure happens after M-D and may not be seen
-2nd Image: apexification successful
-Use #40+ file to check if hard barrier has formed at apex
 
-It’s better to have a bit of CaOH out of the apex than filling short of apex
-Obturate once apical barrier has formed. Thermoplasticized GP + vertical compaction works well
-3rd image: GP placed to new apex</td><td>-CaOH paste is placed into canal to aid in disinfection
-MTA is placed in apex to create a plug/barrier to allow apical repair
 
-MTA should take up the apical third
-After MTA has hardened, remaining space in root canal is obturated with GP
-GP should stop below CEJ
  </td></tr>
</table>
Temporization between appointments
-Cotton pellet in chamber with a hard setting temp material
 
-Don’t use cavit alone – it will wash out
-Ideally: cotton pellet → cavit → GI/composite
Obturation
-Due to how large the canal space can be, use the formed cone technique and GP can even be placed backwards
Final restoration + seal
-Resin composite or GI can be used to fill the remaining space</td><td>Access
-To the level of the vital tissue
-<u>Do not place a file to determine WL</u>
-Can begin and proceed with no LA
-In multi rooted teeth, remove pulp in chamber but leave the pulp in canals
-In single rooted teeth, remove 1~2mm of inflamed pulpal tissue
-To determine how far the pulp is inflamed, insert a paper point into the canal <u>without LA</u> and push until patient feels discomfort. This is where the vital pulp starts.
Control of hemorrhage
-Bleach moistened cotton pellet pressed into pulp for 5 minutes
 
-CaOH powder placed on pulp
Placement of medicament
-CaOH powder: it will wash out, avoid
 
-Dycal: sets hard, can be used
-IRM: can be used
-MTA: can be used, but minimum thickness is 2mm
-Biodentine: can be used
Final restoration + seal
-Usually done all in 1 appointment
-After pulp capping material, GI is placed as a base
-Then, the final sealing material is resin composite
Monitoring
-Recall at 6m, 1y, 2y
-Monitor for pulp vitality and pulpal pathoses
-RCT if necrosis or symptomatic pulpitis occurs</td><td>Steps
-Give patient LA without vasoconstrictor
-Induce bleeding (how?)
-Place collagen matrix (Collacote) to support MTA placement
-Place MTA and a triple antibiotic paste (minocycline)
-Place composite restoration over MTA
 
-Initial lesion – pulp is necrotic and apical abscess seen
 
-1 year recall – increased thickness of RC walls
-Apical abscess has healed
-Pulp testing was positive</td></tr>
</table>

Pathology of pulpal and periapical lesions

- **Pulpal diagnoses**: normal, reversible pulpitis, irreversible pulpitis, acute pulpitis, chronic pulpitis, pulpal necrosis
- **Periapical diagnoses**: normal, acute apical perio, chronic apical perio, periapical cyst, periapical lesion with fistula
- **Others**: internal/external resorption, hyperplastic pulpitis

- Pulpitis
  - Defined as the inflammation of pulpal tissue, does not mean there is always an infection
  - Diagnosed based on indirect assessment (history, clinical exam)
  - Causes
    - **Bacterial infection** via cracks, deep pockets, malformed teeth
    - **Trauma** from fractures, partial avulsion, bruxism, or abrasion
    - **Iatrogenic** from heat generation, deep preps, dehydration of tubules, pulp exposure, filling materials
  - Pathophysiology
    - The pulp chamber only has 2 access openings: the apical foramen and accessory canal openings
    - With age, the chamber gets smaller and the access openings shrink as well
      - Although this offers better protection from insults, it leaves the pulp in a very confined space
    - If the pulp ever gets inflamed, it will try to expand in the confined pulp space → leads to pain, internal pressure, strangulation of blood supply
    - Inflammation of the pulp could lead to necrosis due to strangulation of blood
  - Histopathology
    - Not a direct correlation between clinical and histopathologic disease states, as both are on a spectrum
    - Pulp hyperemia: dilation of capillaries and interstitial edema
    - Acute: dilated capillaries with neutrophils
    - Chronic: lymphocytes and fibroblasts
  - Types of pulpitis

	Pathophysiology	Symptoms	Tx
Reversible	-Pulp is irritated, but still able to fully heal -Mild inflammation -Vasodilation with increased permeability of vessels -Mild acute PMN and lymphocyte infiltration -Increased pressure → ↑ sensitivity of Aδ fibers	-Acute pain when a stimulus is applied, but goes away in a few seconds -Non spontaneous pain	-Remove irritant and repair damage
Irreversible	-Pulp will not heal -PMN infiltration, even to the extent of abscess formation -Can be acute exacerbation of a chronic inflammatory condition -Increased vascularity and congestion may cause local tissue anoxia -Pulp tissue vulnerable to ischemia -Pain is more C fiber mediated	-Pressure is increased to the point where there is spontaneous pain -Pain can be dull, prolonged, and referred to another tooth/structure -May be difficult to localize	-RCT or exo
Necrosis	-Tissue is no longer living -Sequela of acute or chronic pulpitis or trauma induced immediate ischemic necrosis -Nerve degeneration can make the tooth asymptomatic -May be sensitive to percussion as necrosis byproducts induce inflammation	-Asymptomatic -No response on EPT -Sensitive to percussion -Tooth may be discoloured (hemosiderin accumulation)	-RCT or exo
Hyperplastic pulpitis	-Seen in recently erupted molars with extensive caries -Inflammation does not kill the pulp, as the apical foramen is wide and there is ample blood supply -Pulp tissue grows, forming granulation tissue -Eventually becomes hyperplastic, forming a stratified squamous granulation tissue on exposed pulp		-RCT or exo

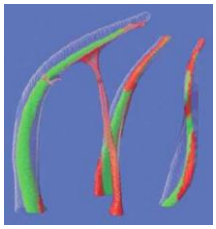
- Periapical lesions

	Pathophysiology	Signs and symptoms
Chronic apical periodontitis (periapical granuloma)	-Exposed dentin or compromised tooth seal allows bacteria to enter pulp and cause necrosis -Spreads to apical region -Chronic inflammatory cell infiltrates and fibroblasts -Deposition of dense collagen (fibrovascular CT)	-Widened PDL -Periapical radiolucency -Discontinuous lamina dura -Minimal pain, possibly asymptomatic -Possible sensitivity to percussion -Long standing lesions may present as hypercementosis (radiopaque bone around apex)
Acute exacerbation of chronic apical periodontitis	-PMN's seen	-Can be suddenly symptomatic
Suppurative apical periodontitis (draining sinus)	-Could be due to an acute flare-up of chronic apical periodontitis -Pus forms and drains via the path of least resistance -Often, a parulis (gum boil) will form, which is where the pus drains out of	-Asymptomatic if pus is draining without obstruction -Pimple-like lesion on the gums (parulis)
Periapical cyst (radicular cyst, apical periodontal cyst)	-Happens when chronic apical periodontitis is untreated for a long time -Rests of Malassez cells enlarge due to bacteria related inflammation or pulp necrosis -These cells proliferate to form a cyst -Non keratinized squamous epithelial lining -Connective tissue wall with inflammatory infiltrates, +/- cholesterol crystals, foreign body giant cells, and hemosiderin	-Cyst on radiograph with a well defined opaque border -Lesion will not heal with only RCT, needs to be enucleated after endo/exo 
Periapical scar	-Dense collagenous connective tissue devoid of inflammatory infiltrates	-Persistent apical radiolucency that does not respond to treatment
Periapical abscess	-Can be de novo or as an acute exacerbation of a chronic state (AKA phoenix abscess) -Debris, enzymes, and toxins exit through the apex and stimulate periodontal tissue and adjacent alveolar bone -Etiology is similar to acute pulpitis -Radiograph: widening of PDL, lamina dura discontinuity -Histology: overwhelming neutrophil exudate	-Painful, even severe -Possibly febrile and malaise -Tooth extrusion from socket due to inflammation of PDL -Sensitive to percussion -Unresponsive to thermal stimulus -Could lead to cellulitis or osteomyelitis **Osteomyelitis** -Inflammation of trabecular bone -<u>Acute</u>: consists of granulation tissue, purulent exudate, and islands of non vital bone. Rapid bone destruction -<u>Chronic</u>: causes bone to form and become more dense. May not have an infectious etiology

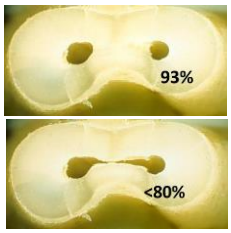
- Periodontitis complex
    - Endo-perio: periapical pathology spreads coronally up to the sulcus, leading to periodontal problems
    - Perio-endo: periodontitis extends apically to the apical tissue
- Mimics of periapical lesions
    - Ameloblastomas and odontogenic keratocysts can resemble periapical lesions or radicular cysts
    - Lateral periodontal cysts can mimic lateral radicular cysts
    - Periapical cemental dysplasia can mimic periapical disease
    - Langerhan's cell histiocytosis
        - Neoplastic proliferation of histiocytic cells can present as a periapical lesion
        - Histologically seen as proliferation of eosinophils

Control and elimination of endodontic infection

- Prevention of spreading
  - **Host defense**: prevents spreading of infection, and can keep the infection symptom free. However, it cannot eliminate the infection in the root canal
  - **Systemic antibiotics**: only used in special indications to help control spread of infection. Can help bring the lesion to an asymptomatic state faster, but can't eliminate infection in the root canal
    - Antibiotics mainly reach the site of infection via the blood supply. In areas of necrosis (like the root canal), there is no blood supply so antibiotics cannot penetrate very well
    - Antibiotics enter these sites by diffusing through inflammatory exudates
    - Antibiotics can kill the bacteria in the tissues (with the exception of PA actinomyces), but not within the root canal or root surface
  - Spreading of infection can be through lateral canals or dentin tubules and affect adjacent teeth or adjacent roots
- Killing of microbes
  - Methods of killing
    - Direct killing: bactericidal chemical is applied in root canal system
    - Ecological killing: void the bacteria of new nutrients by having a well filled and sealed restoration
  - **Instrumentation**



    - Mechanically enlarging and cleaning root canal will take out a lot of the bacteria
    - Breaks the biofilm and compacts bacteria into a new layer called the "smear layer"
    - Creates space for irrigation, disinfection, and root filling
    - Instrumentation to a size of 50 was more effective in debriding infected root canals than instrumentation to an apical size of 35
      - Small size preparation leads to poor disinfection
    - However, factors like curved canals and complicated anatomy means that not all root canal surfaces are debrided properly. A study found up 50% of molar RC surfaces can be untouched. To have a successful root canal, we also need to rely on adequate irrigation and good apical seal
      - Image: green is debrided, red it untouched after instrumentation
  - **Irrigation (see next lecture)**

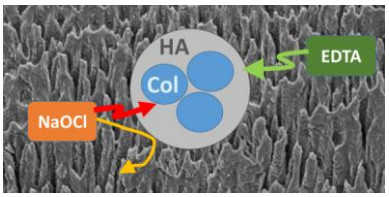


    - Removes the "smear layer" left by instrumentation
    - Should be applied using a small syringe. A 30G safety tip side vented needle is best
    - If there are no connection of canals, 93% of canals are bacteria free after chemomechanical preparation
    - If canals are connected, it drops to <80%
  - **Local medicaments**
    - Some studies showed that placing a CaOH dressing for long term (7d~4w) after instrumentation + irrigation provided a bacteria-free canal. This supports 2 appointment RCT
    - However, other papers have demonstrated success just leaving the canal empty
    - General consensus is to place CaOH as an intracanal medicament to get predictable success
- Prevention of re-infection
  - **Root filling and sealer**
    - Placing sterile water or gutta percha into a canal did not inhibit growth of new bacteria
    - Placing sealer showed active killing of bacteria and inhibition of new bacteria
    - Not only is sealer crucial in preventing reinfection, it is also important in killing leftover microorganisms
  - **Coronal restoration**
    - Root fillings without a coronal seal will leak. Must be protected by a high quality coronal restoration
- When is endodontic surgery needed?
  - If bacteria colonize the root surface, it may not be possible to eradicate with just a RCT
  - Will appear as a lesion that does not heal for 1~2 years after RCT
  - Endodontic surgeon will cut the root tip and do a retrograde filling for these cases
  - Surgery doesn't mean original treatment has failed, as sometimes the case is beyond conservative endo
  - Accounts for 0~10% of all endos. If it happens to >20% of cases, then there is need for self inspection
  - Indications of endo surgery: root surface biofilm, actinomycosis, anatomical obstacles, complications (eg file fracture), long posts in root canal

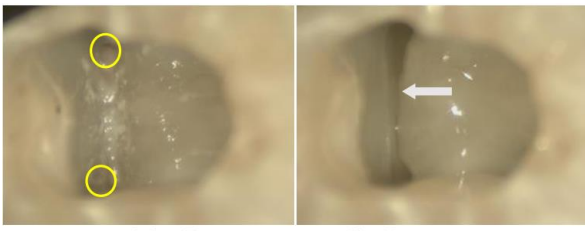
Irrigation

- Challenges in irrigation
    - Biofilms
        - Contains extracellular polymeric substances which bind to canal walls and root surfaces
        - Acts as a barrier so that bleach, CaOH, or antibiotics cannot penetrate and kill bacteria
        - Renders irrigation less effective
        - Instrumentation removes/disrupts this biofilm, and leaves a smear layer instead. The smear layer can then be dealt with via irrigation
    - Fluid mechanics in a root canal
        - Using a syringe to irrigate the canal doesn't guarantee fluid will reach the apex
        - At the apex, you are left with stagnant infected liquid
        - "Water closest to the shoreline (tooth apex) moves slowest"
    - Vertical root fracture
        - Irrigation can remove dentin structure and weaken the tooth
        - Leaves the tooth prone to vertical root fractures
    - Bleach accident
        - Good irrigation is critical to a successful treatment
        - However, forcing hypochlorite too vigorously can force some out the apex and cause a bleach accident
        - May require hospitalization
    - Overall, there are still issues with cleaning, disinfection, and possible negative effects on the patient
- Goals of irrigation
    - Mechanical washing
    - Reduce friction
    - Balance temperature
    - Dissolve tissue and kill microbes located in areas not reachable by instrumentation (fins, isthmus, lateral canals, dentin canals)
- Rate of killing
    - Not linear. 6% NaOCl will kill 50% of bacteria in 3 minutes. However, only 75% is dead at 6 minutes
    - The rate of bacterial killing slows down due to the sensitive bacteria being knocked out first. The resistant ones linger and are not killed by the irrigant
    - Emphasizes the importance of good instrumentation and good root filling to entomb these resistant bacteria from causing re-infection
- Is it viable to mix irrigants?
    - No, mixing irrigants will cause issues. They have to be used separately
    - NaOCl + EDTA → NaOCl inactivated
    - NaOCl + CHX → brown p-chloroaniline
    - ETA + CHX → white precipitate
- Irrigation at the apex
    - Traditional irrigation does not adequately reach the apical part of the canal
    - It's okay to leave some biofilm at the apical foramen. There is a balance between removing all biofilm (and destroying the apical seat) and leaving some biofilm (and allowing the apical seat to have a good seal)
    - There are flexible syringes that help irrigate closer to the apex
    - Forcing the syringe closer to the apex or around a curved canal is dangerous as it could build up pressure and cause irrigant to leak out the apex. Always leave some clearance room
    - Side venting needles may be safer and better at circulating irrigant to the apex
    - Some endo irrigating tools: EndoActivator, EndoUltra, PiezoFlow, EndoVac
    - Negative pressure irrigation (EndoVac)
        - Suction needle is forced to the apex, then irrigant is applied into the canal
        - Irrigant is forced to the apex due to the negative pressure from the suction
        - Rather than having a stagnant 3uL of irrigant the whole tx, you can circulate >1000 uL within a minute
        - No risk of extrusion because all irrigant reaching the apex is suctioned away
    - Ultrasonic irrigation (EndoUltra)
        - Makes NaOCl much more effective, especially in isthmus areas

- Safe and efficient irrigation protocol
  - Irrigant of choice
    - Classic protocol: NaOCl during RCT → EDTA to finish (or citric acid)
    - Classic protocol 2: NaOCl during RCT → EDTA (or citric acid) → CHX
    - Modern: NaOCl → Qmix (modified EDTA which kills bacteria like NaOCl but does not erode dentin)
  - Duration and concentration
    - NaOCl 5% for 1 minute → cleans the canals adequately
    - NaOCl 2.5% for 5 minutes → worse than above. Some organic matter left
    - NaOCl 1.3% for 10 minutes → necrotic tissue, predentin, biofilms not removed adequately
    - NaOCl 6% for 20 minutes → dissolved too much tooth structure, compromising the root
  - Sequence of irrigants



    - NaOCl is used during endo to remove all the <u>organic</u> matter
    - EDTA is used last to remove the remaining <u>inorganic</u> matter
    - After EDTA is used, you should never go back to NaOCl because it can cause dentin erosion
    - When NaOCl is used, the organic matter is removed while the organic collagen fibers embedded in dentin are protected by hydroxyapatite crystals
    - When EDTA is used, it dissolves the hydroxyapatite crystals and exposes collagen fibers
    - If you go back to NaOCl, then it now has access to these collagen fibers and will cause dentin erosion
  - Active vs passive irrigation
    - Passively leaving the irrigant did not clear the debris as well as actively flushing the irrigant
    - The difference between active and passive is more prominent in lower concentrations
    - In high concentrations of irrigants, there is less of a difference
- GentleWave
  - Endodontic cleaning and disinfecting system
  - Dissolves pulp tissue and cleans canals using degassed solutions and cavitation
  - System is under negative pressure, so less risk of leaking out of apex
  - Only system that can completely remove all calcium hydroxide
  - Can clean the isthmus between 2 canals, accessory canals, and divergent canals
  - Irrigating tip is placed only into the pulp chamber, and all the canals get cleaned out



- Overall Irrigation Strategy
  - Touch the surface
  - Irrigate, agitate, and energize canal walls
  - Dissolve and clean bacteria
  - Kill as much as possible
  - Fill and seal to entomb any remaining bacteria

Endodontic treatment outcome: retreatment vs microsurgery

- Methods of evaluating outcome of a RCT

Clinical criteria	Radiographic criteria	Histologic criteria
-Absence of pain or tenderness to percussion/palpation -Functional tooth -Normal soft tissue -Normal periodontal probing -Resolving of pre-existing sinus tract	-Normal PDL space and lamina dura -Reduction/elimination of previous rarefaction -Resorption arrested -Root filling radiodense, no voids, proper length	-Absence of bacteria and inflammatory cells -Regeneration of PDL -Regeneration of bone -Gold standard of assessing outcome but not practical
-However, normal function and absence of symptoms do not always mean the absence of infection	-Patient can be symptomatic even with normal radiographic findings and proper root filling -Conversely, patient can be asymptomatic with normal PDL space but the root filling is inadequate	-Apical tissues may be repaired with scar tissue but if there are no bacteria and inflammatory cells, it is successful

- Contemporary classification of RCT outcome

Healed	Healing	Non healing
-Clinical presentation normal -Radiographic presentation normal	-Clinical presentation normal -Reduced radiolucency -Evaluation at 6mo, 1y, 2y, 3y, 4y	-No change in radiolucency -Symptomatic or clinical signs present

- Factors affecting outcome

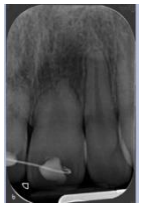
Pre-operative	Intra-operative	Post-operative
Incorrect diagnosis **Poor case selection** -Case difficulty assessment -You own the case once you start it **Pre-existing conditions** -Pulp status -Size of PA lesion -Traumatic injuries -Endo-perio or perio-endo -Resorption	**Failure to achieve biologic objectives** -Inadequate debridement -Inadequate obturation/apical seal **Failure to achieve mechanical objectives** -Not preserving tooth structure **Other operator errors** -Ledges, broken canals -Perforation -Broken instrument	**Inadequate final restoration** -Posterior teeth need cuspal protection -Inadequate coronal seal → exposure to saliva and recontamination of the root canal system

- Outcome statistics
  - If endos are done properly and restored properly, success rate is >92%. >98% if true cystic lesions are excluded
  - Root canal treatment + apical microsurgery has 99% success rate
  - Compare this to the survival rate of implants, which is 95%
    - "Survival" rate criteria is a lot more lenient than "success" rate
    - Survival rate of 1.4 million endo treated teeth is 97% after 8 years
- Clinical decision making: retreat or surgery?

	Retreatment	Apical microsurgery
Risks	-Ceramic fracture or damage to existing crown -Crown dislodgement -Root fracture during post removal -Perforation -Unable to obtain WL due to previous ledges, blockages, or transpositions -Non resolved lesion (aberrant apical anatomy, extraradicular infection, true cyst)	-Damage to anatomical structure -Surgical complication -Shortened root -Gingival recession -Unable to clean bacteria remaining in the root canal system
Benefits	-Less invasive -Best treatment for missed canal or inadequately cleaned system -Minimize bacteria in unclean or recontaminated root canal system -Indirect assessment of microleakage	-One visit -Tissue sample for biopsy -Visualize root fracture -Removes apical aberrations, extraradicular infections, cysts, and addresses non resolved lesions

- Non healing RCT → perform retreatment first, unless it is not feasible (like due to restorative reasons)
  - Posts can almost always be removed
- Coronal leakage or recurrent decay → retreatment and new restoration
- Poor RCT with a new restoration needed → retreatment and new restoration
- Poor RCT with a good restoration → observe

Root resorption (Thank Michael Wong) – Told by a 4th year we should know this?

	Clinical Symptoms	Vitality	Radiographic	Treatment
External Surface Resorption	-Sub-clinical -No inflammation -No destruction of bone		-Cavitation in cementum/dentin -Altered root contour	-Self-limiting -No tx necessary
External Inflammatory Resorption (sterile) 	-Associated with pressure from orthodontics -Ectopic teeth, bony pathology -Impacted teeth	-Yes -No if in response to trauma	-Shortening roots -Roots appear blunted	-Removal of stimulus (impacted tooth, bony pathology)
External Inflammatory Resorption (infective) 	-Associated with trauma and/or pulpal necrosis -Associated with apex or lateral canal	-Non-vital	-Canal visible -Bowl shaped resorption of root and corresponding radiolucency in bone	-**If avulsed**: replant → splint 2w -**Open apex**: 50% will re-vascularize if replanted in 60min -**Closed apex**: do RCT in 7-10d -Abx – tetracycline – Ledermix paste in root canal space
External Cervical Resorption 	-Can have no symptoms -Discomfort from gingival inflammation -Cervical enamel/ cementum appear pink -BOP -Sharp edges of cavity -Cavity is hard -Purulent exudate	-Vital (unless extremely extensive)	-Difficult to distinguish from internal resorption -Asymmetric irregular radiolucency in cervical region -Loss of alveolar bone -Irregularity in periphery of lesion	-Need to seal cervical aspect to prevent bleach from leaking -Seal GP and floor of cavity with GIC, cavit, IRM -Other methods: ortho extrusion, access from internal aspect, or deliberate replantation -Do RCT if pulp is involved
External Replacement Resorption 	-No symptoms -Symptoms when 10-20% of root affected -**High pitched metallic sound** to percussion -Lack of mobility -Possible infra-occlusion		-Later stages: loss of lamina dura -Root dentin appears irregular or completely "moth-eaten" as bone replaces dentin	-No effective treatment – progression will result in complete resorption of root -Tx options: restore, autotransplant, surgical reposition, exo, decoronation for implant later
Internal Inflammatory Resorption  	-History of trauma (crown prep) -Appears as "pink spot"	-Partially vital -Symptoms of pulpitis	-Thin dentin + granulation tissue under enamel -Symmetrical oval lacunae in canal -Sharp, smooth margin	-RCT
Internal Replacement Resorption	-Pink area at crown of tooth	-Vital unless crown/root perforation	-Asymmetric and irregular enlargement of pulp canal -Distortion of canal -Canal/pulp appears to be obliterated or replaced with mixed radio-opaque area	-Curette -Apply 90% trichloracetic acid

Endodontic clinical protocols at UBC

- Prior to seeing endodontic consult
  - Review: CC, med Hx, relevant dental history
  - Complete intra/extraoral exam
  - Review radiographic findings (2 PA's: straight and off angled)
  - Have a tentative endodontic diagnosis ready
  - Assess restorability and formulate restorative treatment plan with ICC/prosthodontic consultant
- During consultation
  - Present CC, med Hx, dental Hx, clinical findings
  - Present radiographic findings (entire tooth captured)
  - Discuss and confirm pre-treatment diagnosis for pulp and periapical status
  - Discuss restorative treatment plan
  - Restorability of tooth must be ascertained prior to endodontic treatment
  - Present endodontic findings in a table like seen here →

Tooth #	Percussion	Palpation	Cold	Bite	EPT	Probing	Mobility
12	-	-	+	-	25	WNL	0
13	-	-	-	-	80	WNL	0
14	+	-	-	+	80	WNL	Fremitus
16	-	-	+	-	53	WNL	0
17	-	-	+	-	68	WNL	0

- Endodontic treatment approval – needs 3 requirements
  - Endodontic case classification (developed by Canadian Academy of Endodontics to assess difficulty of endos)
  - Consent for endodontic treatment (different than normal consent form)
  - Endodontic treatment plan entered and approved in Axium
  - All of these requirements must be signed off by the endodontic consult prior to the start of treatment
- Endodontic case classification (see next page for form)
  - Assesses difficulty of the RCT by looking at patient, tooth, and other considerations
  - Score of 1 is assigned for <u>average risk</u>, score of 2 for <u>high risk</u>, score of 5 for <u>very high risk</u>
  - All factors are assigned points then added up for a total score
    - Score <17 = class 1 ← this is the only class suitable for DMD students
    - Score 18~25 = class 2
    - Score >25 = class 3
    - On average, 70% of primary treatment cases will be class 1 or 2
- Endodontic patient assignment and booking
  - Endo patients come from ICC screening, urgent care, oral surgery, grad endo, or the faculty clinic
  - Regardless of where the patient is from, all Tx plans must be swiped by the endo consultant
  - The patient will be assigned to the student upon approval from the clinic advisor
  - Endo sign up list: 6 spaces with 2 on wait list
  - Dental operating microscope should be set up prior to the appointment by a technician, in the following ops:
    - EN ops 1, 2, 3, Bay ops 1.1-1.3, 1.5-1.7, 2.1, 2.7, 3.1, 3.7, 4.1, 4.7, 5.1, 5.7, 6.1, 6.7
- Expectations before and during treatment
  - Case classification form signed and endo consent form signed
  - Pre-treatment radiographs displayed and proper number of radiographs requested
  - Know clinical findings, diagnosis, treatment plan, and what was accomplished last appointment
  - Know goals for the day
- Expectations after treatment
  - Critique clinic session
  - Proper documentation in Romexis and Axium
  - Paper Endodontic Grading form should be completed and signed off at the end of each step by the endo instructor
- Grading form
  - Examination, diagnosis, patient management, asepsis technique
  - Radiograph quality, access prep, WL, instrumentation, obturation
  - Professionalism
  - Case classification form + this grading form + consent form should be submitted within 2 weeks to the patient allocation coordinator
  - ½ credit is given for completion of endodontic examination and diagnosis when the patient needs to be referred to Grad endo for treatment

CASE CLASSIFICATION ACCORDING TO THE DEGREES OF DIFFICULTY AND RISK

Criteria and Subcriteria	Average Risk (1 unit/ item)	High Risk (2 units / item)	Very High Risk (5 units / item)
A. PATIENT CONSIDERATIONS			
1. Medical history / anesthesia / patient management	☐ No medical problem (ASA Class I)	☐ Special attention: pacemaker / antibiotic allergy (ASA Class II) ☐ Vasoconstrictor intolerance ☐ Lack of cooperation / fear	☐ Complex medical history / serious illness / disability (ASA Classes III and IV*) ☐ Intolerance to anesthetic ☐ Resistance to anesthetic
2. Diagnosis	☐ Signs and symptoms straight forward : clear diagnosis	☐ Differential diagnosis of usual signs and symptoms	☐ Confusing and complex signs and symptoms : difficult diagnosis ☐ Indeterminable diagnosis
3. Mouth aperture and physical limitation	☐ Normal mouth aperture (35mm+)	☐ Reduced aperture (25-35mm) ☐ Difficulty holding film	☐ Non-functional aperture (-25mm) ☐ Limited reclination
4. Radiographic difficulties	☐ Average conditions	☐ Gagging ☐ High floor (lower premolars and canines) ☐ Narrow or low palatal vault	☐ Hard to solve superimposed anatomical structures
B. TOOTH CONSIDERATIONS			
5. Position in the arch and inclination	☐ Anterior or premolar ☐ Small inclination (-10°) ☐ Small rotation (-10°)	☐ 1st or 2ind molar ☐ Moderate inclination (10-30°) ☐ Moderate rotation (10-30°)	☐ 3rd molar ☐ Extreme inclination (+30°) ☐ Extreme rotation(+30°)
6. Tooth isolation and access / morphologic aberrations of the crown	☐ Normal original crown morphology or adequate restoration ☐ No pretreatment required for isolation ☐ Stable clamp	☐ Taurodontism / microdens ☐ Simple pretreatment required for isolation ☐ Unstable clamp (no retention)	☐ Fusion / dens in dente* ☐ Extensive pretreatment required for isolation ☐ Impaired access (post / core / broken instrument / amalgam…) ☐ Porcelain / gold occlusal restoration or crown / splint ☐ Clamp almost impossible to place
7. Canal and root shapes	☐ Canal curvature into *I* form ☐ Small or no curvature(-10°) ☐ Single canal anterior or premolar ☐ Closed apex	☐ Canal curvature into *J* form ☐ Moderate curvature (10-30°) ☐ Molar with 3 canals or less ☐ Premolar or anterior with 2 canals ☐ Previously initiated endodontic treatment ☐ Crown axis different from root axis	☐ Canal curvature into *C* or *S* form ☐ Extreme curvature (+30°) ☐ Molar with 4 canals or more ☐ Premolar with 3 canals ☐ Canal subdivision in the apical or middle thirds ☐ C-shape canal system ☐ Very long tooth (+30mm) ☐ Open apex
8. Canal calcifications	☐ Wide and clear canal	☐ Canal and chamber are visible but quite reduced ☐ Pulp stones	☐ Almost indistinct canal path in part or throughout ☐ Canal no longer visible*
9 Resorptions		☐ Internal resorption (without perforation) ☐ Apical resorption	☐ Internal resorption with perforation* ☐ External resorption with* / or without perforation
10. Mechanical perforation		☐ Supra-osseus root perforation	☐ Sub-osseous root perforation*
C. ADDITIONAL FACTORS			
11. Trauma History	☐ Uncomplicated crown fracture of mature or immature teeth ☐ Radicular fracture in apical third ☐ History of concussion	☐ Complicated crown fracture of mature teeth ☐ Radicular fracture in middle third ☐ History of subluxation / alveolar fracture	☐ Complicated crown fracture of immature teeth ☐ Radicular fracture in cervical third ☐ Other luxations / avulsion
12. Retreatment			☐ Retreatment
13. Periodontal–endodontic condition			☐ Mobility/ pocket / fenestration / dehiscence ☐ Furcation involvement ☐ Root resection / hemi-section (expected or done)
***ASA Class IV, fusion / dens in dente, invisible canal, sub-osseous / resorptive perforation belong to Class 3 automatically.**			

RESULTS : Total — 15 to 17 units : Class 1; 18 to 25 units : Class 2; More than 25 units : Class 3

DISPOSITION : ☐ Accepted or ☐ Referred

Aikenhead PBL

- Dentin characteristics
    - Dentin is a permeable structure full of tubules connecting the oral cavity to the pulp chamber
    - Dentin permeability: pulp horn dentin > axial dentin > occlusal dentin > secondary dentin > tertiary dentin
    - There is a constant outward flow of fluid from the pulp chamber to the dentin surface
        - This protects the tooth against bacterial ingress
    - Rapid fluid movement within these tubules can trigger nerves and cause sensitivity
    - Normally, these tubules are occluded by plaque, smear layer, and other things like precipitin ($CaPO_4$-protein complex found in saliva). However, these tubules can become patent when cleaned, cut, or etched
    - Dentin tubules can also be occluded internally by forming tertiary dentin, via 2 mechanisms
        - **Reactionary dentinogenesis:** growth factor cause existing odontoblasts to deposit dentin
        - **Reparative dentinogenesis:** odontoblasts are made by migrating + differentiating mesenchymal cells to the damaged area, where dentin is then deposited. This kind of dentin can have no tubules
        - Tertiary dentin tends to be less tubular, more irregular, more poorly mineralized, and with larger lamina
- Hydrodynamic theory of dentin sensitivity
    - Stimuli such as heat, cold, air, or the tip of an explorer can displace the fluid in these tubules and stimulate the nerve inside the pulp chamber
    - It is likely that the pain is from mechanoreceptors, and not thermoreceptors. This is because the rapid pain response is not possible with how slow thermal changes take place
    - Fluid movement is converted to electrical pain signals via mechanotransduction on A fibers
    - Delayed pain (if heat/cold is applied for long enough) will be carried by C fibers
    - **Cold:** fluid contracts, pulling fluid away from the pulp. Generates a stronger nerve response than hot
    - **Hot:** fluid expands, pushing fluid into the pulp
    - **Air:** fluid on the surface desiccates, pulling fluid away from the pulp
    - **Sugar (or any hyperosmotic substance):** draws fluid out of tubules due to osmosis, pulling fluid away from pulp
    - **The rate of flow (of fluid) positively correlates to the rate of discharge from the pulp nerves**
    - Pain lasts 1~2 seconds and has a rapid onset once cold is applied
- Other triggers to tooth sensitivity/pain
    - Mechanical forces (percussion/palpation)
    - Chemicals (like dietary acids) diffusing directly into the pulp and irritating it
    - Electrical currents going to the pulp via transdentinal condution to excite pulpal nerves
- Which of these mechanisms may cause sensitivity when tooth brushing?
    - Mechanical, if the patient is brushing too hard
    - Chemical and osmotic from toothpaste
    - Thermal (hot/cold), depending on the water temperature used while brushing
- Some patients experience a delayed response to cold. What could be the reasons?
    - Calcification of the canal
    - Pulp is necrotic or inflamed
    - Composite or any base/cements under amalgams
    - Porcelain crown or any base/cements under a metal crown
    - Delayed hypersensitivity to cold is typically due to reversible pulpitis
    - Managed with fluoride, debridement, oral hygiene instructions, and a desensitizing toothpaste
- What steps should you take if LA is not working?
    - Check if you've used the proper block for the region
    - Check that the anesthetic is not expired
    - Try an alternative block that will anesthetize that region
    - Source of pain could be referred from another site or tooth
        - Referred pain does not cross the mid line, but can cross upper/lower arches
        - Pain from mandibular premolars can be referred to maxillary molars
        - Pain from mandibular molars can be referred to the ear/angle of the mandible
        - Perform a clinical exam of the possible referred region to see if there is any pathology there
    - Try a PDL injection

L.T. Balty PBL

- How could you get pain in a previously endo treated tooth?
  - Periodontal, periosteal, or osseous tissues get acutely inflamed
  - Sensitization of afferent nerves by inflammatory mediators: histamine, serotonin, kinins, PG's, LT's
  - Heat, redness, and swelling are due to vasodilation and increased vascular permeability
  - Exudated fluid causes pressure on sensory nerve endings
- Management of a patient presenting with acute swelling
  - Remove the cause of infection/inflammation via chemomechanical debridement of root canal
  - Open and drain the abscess if it is associated with just the periapical space
  - Incise and drain the abscess if there is vestibular swelling. Trephination may also be necessary
    - Drain placement is a Penrose tube or rubber dam piece that's sutured to the incision
    - Leave the drain for 2~3 days
  - Adjunctive antibiotic therapy may be necessary if infection is spreading
- Antibiotics to manage endodontic infection
  - When to prescribe
    - Signs of systemic involvement: fever, malaise, lymphadenopathy, trismus
    - Signs of progressing infection: swelling, facial space infection, cellulitis, osteomyelitis
    - General principle is to use the narrowest spectrum antibiotic but cover all the types of bacteria. Also, don't mix bactericidal and bacteriostatic drugs in the same therapy
  - Types of bacteria seen
    - **Non-endo treated tooth**: pocket flora, facultative anaerobes, predominantly anaerobes (esp G- rods)
    - **Endo treated tooth**: E. faecalis (G+ cocci, facultative anaerobe) predominates
  - Which antibiotics to use
    - **Mild infection**: Pen VK 300~600mg q6h x 7 days
      - Bactericidal, covers narrow spectrum G+ cocci, and some anaerobes
      - Amoxicillin is less ideal (wider spectrum), but has better oral absorption and used for prophylaxis
    - **Moderate infection**: add Metronidazole 250~500mg q6h
      - Bactericidal, effective against anaerobes
    - Clindamycin 150~600mg q8h 7~10days
      - Bacteriostatic at low dose, bactericidal at high dose, reaches high concentrations in bone
      - Used for infections that are non responsive to pen VK or if patients are allergic to penicillins
  - Limitations
    - Know that antibiotics will only manage and limit the spread of infection, but will not cure it
    - The source of infection (necrotic pulp) has no blood supply, so no antibiotic will reach there
    - Must be dealt with at the source
- Treatment options for a failed endo
  - Root canal retreatment
  - Endodontic apical microsurgery
  - Root amputation
  - Hemisection
  - Intentional replantation
  - Extraction
- Single appointment vs multiple appointment treatment
  - Tendency towards 2 visit appointments, with CaOH placed as an intracanal medication in the meantime
  - CaOH kills bacteria, reduces inflammation, and neutralizes toxins
  - Ideally, wait a minimum of 2 weeks between appointments
  - Unlike NaOCl, CaOH exerts its effect slowly
- Steps in apical microsurgery
  - Surgical flap incision and flap reflection
  - Periradicular curettage and biopsy
  - Root end resection → retrograde filling
  - Flap reposition and suturing

- Healing after apical microsurgery
    - Blood coagulates in surgical site
    - Wound edges of bone become devitalized
    - Reparative cells (fibroblasts) migrate to the periphery of the coagulum
    - Angiogenesis and granulation tissue formation
    - Growth of woven bone from wound edges
    - Bone maturation and remodelling
- Know how to differentiate the following conditions on a radiograph
    - Unilocular periradicular radiolucency
        - Periapical fibrous scar
        - Nasopalatine duct cyst (incisive canal cyst)
        - Traumatic bone cyst
        - Benign fibro-osseous lesion (early stage): central ossifying fibroma, cemento-osseous dysplasia
        - Langerhan cell histiocytosis (eosinophilic granuloma)
        - Benign nerve sheath tumors (neurofibroma, schwannoma)
    - Uni/multilocular periradicular radiolucency
        - Keratocystic odontogenic tumor
        - Ameloblastoma
        - Lateral periodontal cyst
        - Other odontogenic tumor cysts
        - Benign fibro-osseous lesion (early stage): periapical cemental dysplasia
        - Malignant neoplasia
            - Primary (carcinomas, lymphoma, sarcomas)
            - Metastatic (lung, breast, kidney, prostate, thyroid)
    - Periradicular radiopacity
        - Idiopathic osteosclerosis (dense bone island)
        - Cementblastoma, osteoblastoma
        - Benign fibro-osseous lesions (late stage)
        - Odontogenic tumors and cysts
        - Malignant neoplasms

Problem solving in endodontics

- 12 year old patient presents with crown fracture involving the pulp (pinpoint exposure)
    - Look for the fractured piece
        - Patient may have swallowed, or it may be embedded in soft tissue
        - Could reattach fragment to tooth
    - Check for pulp vitality
        - If responsive to cold test, you know the pulp is vital. In this case, tooth did respond to cold
    - Check for periodontal damage
        - PDL and alveolar bone may have expanded or broken
        - In this case, mobility increased slightly which is suggestive of subluxation
        - Immediate treatment is required, especially when there is damage to the PDL
    - Treatment options
        - Since patient is 12, the apex is open and you want it to close
        - Luckily, the pulp is still vital so we can try our best to keep it vital (apexogenesis)
        - Amputate pulp to a vital level (patient feels pain, and bleeding has stopped)
    - Sequelae of trauma
        - Resorption (external inflammatory, replacement, cervical, apical, surface resorption)
        - Pulp necrosis
        - Discoloration
        - Pulp canal obliteration (but still vital), usually 3~6 months after trauma

- 16 year old patient with toothache and swelling on maxillary anterior tooth
    - Relevant findings: pulp test revealed non-vitality, was tender to palpation
    - Since tooth was non vital, a root canal was indicated
    - Upon accessing the tooth, a lot of pus was exudated through the access
    - At 16 years old, the apex is mostly done forming, so a normal RCT can be done
    - Pulpal diagnosis: irreversible pulpitis transitioning to pulpal necrosis
- Other cases were straight forward, look in slides

Management of traumatic injuries to permanent dentition

- Goals of emergency treatment
    - Identify hidden or underlying medical conditions
    - Timely referral for appropriate care
    - Reduction and stabilization of displaced hard tissues
    - Management (I.e. suturing) of soft tissues
    - Assess and manage injuries to the pulp and periradicular tissues
    - Pain relief
- Key concepts
    - Preserving pulp vitality is needed for growth of an immature permanent tooth
    - Maintaining tooth is required for proper growth and development of the dento-alveolar complex
    - Tooth with an open apex is more likely to maintain pulp vitality after trauma
    - Limiting the damage to the periodontium is important for the prevention of root resorption and preservation of the supporting apparatus
- Things to consider when treating trauma
    - Determine the pulp status of the tooth
        - Vitality testing is less reliable in immature teeth (EPT less reliable than cold test)
        - May take months after trauma for pulpal response to come back
        - First response to return is likely EPT before cold
        - Important to establish baseline results to monitor for pulp healing and vitality
        - **Signs of necrosis**: gingival swelling, sinus tract, change in tooth colour, increased periapical radiolucency, all with negative pulp vitality tests
    - Determine if we are dealing with a mature root
        - Age of patient
        - Radiographs
    - Radiographic examination
        - To visualize apices, root/alveolar fractures, luxation injuries, stage of root development, root resorption, or teeth fragments embedded in soft tissue
        - Multiple radiographs with different angles may be required
- Types of injuries
    - **Fracture**: enamel infraction, enamel fracture, enamel-dentin fracture, enamel-dentin-pulp fracture, crown-root fracture (no pulp), crown-root fracture (with pulp), root fracture, alveolar fracture
    - **Luxation**: concussion, subluxation, extrusion, lateral luxation, intrusion, avulsion

- PARL = periapical radiolucency
- CR = composite resin

- Fracture injuries

	Description	Pulp test	Treatment
Enamel infraction	-Surface enamel fracture -No loss of tooth structure -Can be seen better with transillumination	**Vitality** -Usually (+) -If (-), likely temporary and may ↑ chances of necrosis in the future **Percussion sensitivity** -Usually (-) -(+) may indicate underlying luxation injury	-No treatment needed -Reassess as needed
Enamel fracture	-Fracture confined within enamel		-Reattach if fragment available -Polish enamel or restore with CR -Reassess @ 8w and 1y
Enamel-dentin fracture (uncomplicated)	-Fracture to dentin, but not to pulp -May see transient apical breakdown (widening of PDL, PARL at apex) which needs to be monitored		-Reattach if fragment available -Restore with CR -Key is to seal dentin tubules -Reassess @ 8w and 1y -If there is a PARL that is not healing, RCT -If open apex, try to revascularize
Enamel dentin fracture (complicated)	-Fracture extending to dentin and involving pulp		**Open apex** -Vital pulp therapy (direct pulp cap, pulpotomy) -Use MTA or CaOH and restore with GI or CR -Reassess @ 8w and 1y **Closed apex** -RCT is usually needed, especially if associated with luxation injury
Crown root fracture (uncomplicated)	-Fracture involving enamel, dentin, and cementum, but not the pulp	**Apical segment** -(+) pulp vitality and percussion **Coronal segment** -Missing or mobile	-Depends on location of fracture -Remove coronal segment, treat apical -Restore apical segment with GI and CR -Sometimes fractured segment can be bonded -Gingival recontouring/crown lengthening -Orthodontic/surgical eruption -Reassess at 8w/1y **Submergence of the root** -Done on unrestorable apical segments, to avoid exo -Very important in children with growing alveolus -Decoronate the tooth, RCT it, and submerge it under the gingiva to maintain alveolar bone level
Crown root fracture (complicated	-Fracture involving enamel, dentin, cementum, and pulp	**Apical segment** -(+) or (-) pulp vitality -(+) to percussion **Coronal segment** -Missing or mobile	-Depends on location of fracture -Remove coronal segment, treat apical -Subgingival fractures may need gingivectomy, crown lengthening, or ortho/surgical eruption **Open apex** -Vital pulp therapy (direct pulp cap, pulpotomy) -Use MTA or CaOH and restore with GI or CR -Reassess @ 8w and 1y **Closed apex** -RCT is usually needed, especially if associated with luxation injury **Submergence of root** -See above
Root fracture	-Fracture confined to the root -Crown may be discoloured and mobile	**Vitality** -Usually (-) **Percussion** -May be (+)	-Treatment dependent on mobility and the pulpal/periradicular status -Fracture apical to middle 1/3: flexible splint for 4w -Fracture in coronal 1/3: flexible splint for 4m -Soft diet 1w -Reassess at 4w, 8w, 6m, then 1x/yr for 5 years -If pulpal necrosis, RCT only the coronal segment
Alveolar fracture	-Fracture of alveolar bone -Mobility of one tooth translates to other teeth	**Vitality** -Usually (-) **Percussion** -(+)	-Reposition, check occlusion, rigid splint for 4w -Soft diet for 1w -Reassess at 4w, 8w, 6m, then 1x/yr for 5 years -No immediate RCT

- Luxation injuries

	Description	Pulp test	Treatment
Concussion	-Injury to supporting structures without abnormal mobility or displacement	**Vitality** -Usually (+) -If (-), does not indicate necrosis **Percussion sensitivity** -(+), usually the only sign	-No treatment needed -Reassess at 4w, 8w, 1y
Subluxation	-Injury to supporting structures with abnormal mobility but without displacement	**Vitality** -May be (-) -If (-), does not indicate necrosis	-Occlusal adjustment if in premature contact -Flexible splint for 2w, then soft diet for 1w -Reassess at 4w, 8w, 1y
Extrusive luxation	-Tooth displaced axially with alveolus intact -Tooth appears elongated and displaced palatally -Tooth is highly mobile -Apical part of socket appears empty on radiograph	**Vitality** -May be (-) initially, indicating transient or irrev. pulpal damage	-Reposition tooth and flexible splint 2-3w -Soft diet for 1 week **Open apex** -No immediate RCT, monitor for healing or necrosis -Reassess at 2w, 4w, 8w, 6m, 1y **Closed apex** -Revascularization unlikely -Can wait up to 3m to see if PVT will become (+), if there are no signs of resorption -Start RCT prior to splint removal -Reassess at 2w, 4w, 8w, 6m, 1y
Lateral luxation	-Tooth displaced eccentrically and complicated by comminution (fracture) of the alveolus -Usually displaced palatally → root tip displaces buccally, breaks the buccal alveolus, and gets wedged → immobile -Apical part on radiograph looks empty	**Vitality** -Usually (+) **Percussion** -Produces a high pitch metallic tone	-Reposition tooth and flexible splint 4w -Soft diet for 1 week **Open apex** -No immediate RCT, monitor for healing or necrosis -Reassess at 2w, 4w, 8w, 6m, then 1x/yr for 5 years **Closed apex** -Revascularization unlikely -Can wait up to 3m to see if PVT will become (+), if there are no signs of resorption -Start RCT prior to splint removal -Reassess at 2w, 4w, 8w, 6m, then 1x/yr for 5 years
Intrusive luxation	-Tooth displaced into bone and complicated by fracture of alveolus -Tooth displaced axially and is immobile as it is trapped in bone	**Vitality** -Usually (-) **Percussion** -Produces a high pitch metallic tone	**Open apex** -<7mm → wait for spontaneous eruption. If no movement in a few weeks, then do orthodontic extrusion ->7mm → use surgical or orthodontic extrusion -No immediate RCT as complete healing can occur -Reassess at 4w, 8w, 6m, then 1x/yr for 5 years **Closed apex** -Needs ortho/surgical extrusion -Pulp necrosis likely, so RCT after extrusion -Reassess at 4w, 8w, 6m, then 1x/yr for 5 years
Avulsion	-Complete displacement of the tooth out of its socket -Socket is empty or filled with coagulum	-60 min is the maximum extra-oral time for PDL cells to maintain vitality. This time is the <u>single most important</u> prognosticating factor of PDL healing -Tooth should be rinsed in water/saline for 10 seconds and replanted immediately -Then, bite on gauze to hold tooth in place -If patient is unable to, then tooth should be placed in Hank's balanced salt solution (best), milk, or placed on cheek to bathe in saliva. <u>Do not use water or let tooth dry</u> -See next page for full treatment options on an avulsed tooth	

- Treatment options for an avulsed tooth

	Closed apex	Open apex
<60 minutes, in storage media	-Avoid touching root surface and rinse in saline -Flexible splint for 2w	-Avoid touching root surface and rinse in saline -Soak tooth in doxycycline 1m/20mL saline x5min -Flexible splint for 2w
>60 minutes	-Remove debris and necrotic PDL on root surface using gauze -Immerse tooth in 2% NaF for 20 min (to prevent osteoclasts from resorbing root dentin) -Flexible splint for 4w	-Remove debris and necrotic PDL on root surface using gauze -Immerse tooth in 2% NaF for 20 min (to prevent osteoclasts from resorbing root dentin) -Flexible splint for 4w
Applies to both <60min and >60 min	-Remove coagulum from socket -Replant tooth with finger pressure -Verify position radiographically -Suture gingival laceration -Rx: doxycycline BID x 7d or penicillin QID x 7d -Refer to physician for tetanus booster PRN -Soft diet 2w, soft brush after meals, rinse with 0.12% CHX BID -RCT initiated 7~10 days after replantation -CaOH or ABX + corticosteroid intracanal medicament for up to 1 month -Should be able to trace intact lamina dura around entire root surface -Reassess at 4w, 3m, 6m, 1y, then 1x/yr	-Remove coagulum from socket -Replant tooth with finger pressure -Verify position radiographically -Suture gingival laceration -Rx: doxycycline BID x 7d or penicillin QID x 7d -Refer to physician for tetanus booster PRN -Soft diet 2w, soft brush after meals, rinse with 0.12% CHX BID -No RCT, unless signs/symptoms confirm necrosis -Complete healing with pulp revascularization can occur -Reassess at 4w, 3m, 6m, 1y, then 1x/yr

- Post-traumatic sequelae

Condition		About	Management
Discoloration from pulp necrosis			-RCT -Internal bleaching
Pulp canal obliteration (calcific metamorphosis)		-Indication of pulp vitality -May give negative vitality test due to increased dentin thickness	-No RCT, but monitor as pulp may become necrotic in the future
Internal root resorption		-Inflammation inside the pulp chamber is causing resorption	-RCT -Remove all cells in pulp (RCT) = no cells to resorb = no issue
External root resorption	Surface	-Only seen microscopically, not clinically	-No tx, self limiting
	Inflammatory (pulp necrotic)	-Pulp infection → leaks out dentin tubules to cementum → once cementum is infected, it gets resorbed	-Early RCT can prevent this, but may continue after RCT
	Replacement (ankylosis)	-Damaged cementum exposes bare dentin → dentin gets resorbed and bone grows into it	-No tx available, progresses independent of pulp status
	Cervical	-Happens in the gingival sulcus area -Penetrates into the pulp, but never perforates pulp as it is protected by the predentin layer	-Repair only if diagnosed early -Move gingiva down -Repair and RCT if resorption close to pulp, extraction if damage is extensive and tooth unrestorable