 Apexification With Calcium Hydroxide - When Should The Dressing Be Changed? The Case For Regular Dressing Changes

Introduction

The use of long-term calcium hydroxide dressings in root canals with an "open apex" has been an accepted endodontic procedure for many years. The calcium hydroxide is placed in the root canal in order to stimulate apexification - that is, the formation of a hard (osteoid or cementoid) tissue barrier across the open apical foramen prior to the placement of a root canal filling (Figs. 1-5). Other materials have also been used for apexification but calcium hydroxide has been shown to be the most reliable and, internationally, it is the most widely used medicament for this procedure (1).

The main purpose of the hard tissue barrier is to prevent over-extension of the root filling materials into the perapical tissues (2) (Fig. 5). The barrier provides a "matrix" against which the root filling material can be packed in an attempt to provide a more adequate apical seal to the root filling. The barrier also reduces the surface area of the root filling which is in contact with the perapical tissues. This reduces the exposure of the sealer (cement) to the tissue fluids and thereby reduces the rate at which the sealer can be dissolved. If the sealer dissolves, leakage of tissue fluid occurs which will provide nutrients to any bacteria present within the root canal system.

Apexification with calcium hydroxide is a relatively simple and predictable technique with reported success rates of up to 100% (range: 74% (3) to 100% (4-6) with most above 95% (2, 7, 8)). Essentially the technique involves placing a calcium hydroxide paste within the root canal system and waiting until an apical hard tissue barrier has formed before placing the root canal filling. Some debate exists amongst dental practitioners about whether the calcium hydroxide dressing needs to be replaced at regular intervals (and how regular these should be) or whether it suffices to place the paste only once and wait for radiographic evidence of a barrier having formed before placing the root canal filling. Proponents of the latter technique usually claim that the calcium hydroxide is only required to initiate the healing reaction (that is, to act as a catalyst) and therefore further or continual applications are not warranted (4). Practitioners using this approach only replace the calcium hydroxide dressing when symptoms develop or when the calcium hydroxide has washed out of the apical two-thirds of the canal (8, 9, 10). Those that use several regular dressings claim that regular application of fresh calcium hydroxide promotes a faster healing response (2, 6).

The comparative speed of barrier formation with the different methods has not been reported. It is very difficult to carry out such research because there are too many uncontrollable variables that exist between every tooth, every patient and each treatment situation. However, several studies from the United Kingdom have shown that regular dressings (initially after 1 month and then after every 3 months) can produce hard tissue barriers within average times that are as short as 5.1 ± 4.5 months (using an average of 2.4 ± 1.5 visits) (6), 7.8 months (with a mode of 3 calcium hydroxide dressings) (2), and 9 months (11). In these studies, the

Figure 1: Tooth 1.1 had a pulpless and infected root canal system with chronic apical periodontitis as a result of trauma. The root was incompletely developed at the time of pulp necrosis so the apical foramen was "open". Endodontic treatment and apexification with calcium hydroxide was indicated for this tooth. Note that the 2.1 also required endodontic treatment due to a pulpless and infected root canal system and external inflammatory root resorption.
Calcium hydroxide was placed in the canals of both the 1.1 and 2.1. After three months, a radiograph was taken to assess the healing responses and it is clear that the calcium hydroxide has been washing out of the canals. In the 1.1 the calcium hydroxide has washed out of the apical end of the canal, whereas in the 2.1 the paste has washed out of the canal adjacent to the area of root resorption. At this stage, only the dressing in the 2.1 was changed.

Initial canal infections were first treated with a polyantibiotic paste which increased the overall treatment time slightly. For example, in one study (2) the polyantibiotic paste was used over an average of 2.1 visits and 2.3 months which extended the total treatment time to an average of 10.3 months and required a total of six visits. This study also reported that the time for apical closure was significantly related to the size of the original opening (average 6.2 months for less than 2mm opening; and average 11.0 months for greater than 2mm opening). The treatment was also delayed considerably if patients failed to attend appointments or if the canals became infected between appointments. This latter observation was similar to that observed in another study where apexification was delayed by an extra 5 months if inter-appointment symptoms developed (5). An interesting observation from two studies (5, 11) is that apical closure can occur before the periapical radiolucency has completely healed - this occurred in 38% of cases in one study (11) which was in contrast to Cvek’s observations that periapical radiolucencies healed in an average time of 15 months but apical closure took an average time of 18.2 months (8). However, Cvek used a single application of calcium hydroxide and only radiographic assessment to determine whether the apical barrier had formed.

Text-book descriptions of the single application technique suggest that the apical barriers should form within one year (12) or within 6-24 months (10) but neither of these books refer to any studies that support these suggestions. Cvek’s study (8) showed an average time of 18.2 months but case reports indicate that the barriers could take much longer than this (for example, up to five years) (9) when the presence of an apical barrier is assessed solely by the use of regular periapical radiographs.

Calcium hydroxide - Mechanism Of Action

The exact mechanism of action of calcium hydroxide is not clearly understood but it is generally accepted that it works by causing necrosis of the tissue surface (because it is a toxic substance) and this necrotic layer then calcifies passively (7, 13). There has been no research reported in the literature to show whether a single application or repeated exposure to calcium hydroxide is necessary but the clinical experience reported by proponents of both methods suggests that apexitification can be achieved in many ways.

Calcium hydroxide - Properties

Calcium hydroxide has several other uses in endodontics and these must also be considered in the debate about how often the dressing should be changed. Firstly, calcium hydroxide is an anti-bacterial agent that has a good spectrum of activity against commonly-reported endodontic micro-organisms and it has been shown to be the most effective anti-bacterial root canal medicament in several studies (14, 15). The anti-bacterial action of calcium hydroxide is largely achieved through its high pH (most calcium hydroxide pastes have a pH of about 12.2) which creates an environment within the tooth root that is unsuitable for the survival of bacteria. Calcium hydroxide pastes release hydroxyl (OH⁻) ions which diffuse through the dentinal tubules to achieve a “high pH” environment (16). Because bacterial invasion of the root canal has led to the need for endodontic treatment in the first place, and as healing of the periapical tissues and the formation of a hard tissue barrier will not occur in the presence of bacteria, it is essential...
that all bacteria within the tooth are destroyed as part of the apexification procedure. In addition, it is essential that the tooth root remains free of any bacteria throughout the active treatment process otherwise healing will be delayed or arrested (2, 5).

Secondly, tissue repair is considered to be encouraged by a high pH environment (7). The release of OH$^-$ ions from a root canal medicament allows them to diffuse through the apical foramen and reach the periapical tissues. Although there will be a rapid dilution once the OH$^-$ ions reach the periapical tissues, it is believed that they will still have some effect in increasing the pH and thereby promoting healing.

Thirdly, calcium hydroxide is used in endodontics for its tissue dissolving capabilities (17, 18). Calcium hydroxide can dissolve pulp tissue directly (17) and it also makes pulp tissue more readily dissolved by sodium hypochlorite (NaOCl) solution (17, 18). In very wide canals (as well as canals with unusual anatomy or internal resorption), some pulp tissue debris may remain after the initial instrumentation procedures have been carried out. The application of calcium hydroxide followed by subsequent irrigation with NaOCl at a later appointment may help to ensure that all debris has been removed.

Finally, as outlined above, in order for calcium hydroxide to be effective, it must be able to release the OH$^-$ ions which implies that the material should be soluble - the degree of solubility will depend on the carrier-medium used. Hard-setting cements containing calcium hydroxide are available and have been shown to be soluble in tissue fluid (19). It might appear that a hard-setting calcium hydroxide cement could suit proponents of the one application technique for apexification as they could do an immediate root canal filling with such a cement - however, it is impossible to control the root filling and contain it within the root canal when the apical foramen is open. The use of such a procedure is very likely to complicate the healing process, may result in foreign body reactions to the extruded material, may complicate endodontic re-treatment, and periapical surgery may become necessary - all of these are the very reasons why apexification should be carried out prior to placing a root canal filling. Diffusion of the OH$^-$ ions from a hard-setting cement would be expected to be slow which could delay the healing process. Therefore, a hard-setting cement would be unsuitable and either a liquid or paste form should be utilised. Diffusion from liquids will always be very rapid as no dissolution is required - therefore the useful life of liquid medicaments would be very short (probably only a few days at the most) which renders them unsuitable for apexification procedures.

Pastes will remain active for a longer time than liquids but the actual time will depend on the paste base - that is, the more liquid the consistency, the less active time. Several commercial calcium hydroxide pastes are made with saline solutions (e.g. EndoCal,* Calasept,* DT1) while others have a "creamier" base formed with methyl cellulose (e.g. Pulpdent,§ TempCalafi). Pulpdent paste is preferred by the author since the methyl cellulose base makes it less soluble and therefore it will remain within the canal for longer periods of time. This consideration of paste solubility is particularly important in the early stages of apexification when the apical foramen is wide open - the wider the opening then the more area available for dissolution or washing out of the paste from the canal. This is amplified when the periapical tissues are inflamed (from the original disease and from the initial treatment) as the tissue fluid will dilute the paste rapidly (Figs. 2, 3) - hence the recommendation of several authors to change the first calcium hydroxide dressing after one month (2, 6, 11). Yates (11) has also noted that the rate of dissolution of the paste from the canal decreases as healing progresses and the barrier forms (Fig. 4).

**Clinical Considerations**

Regular changes of the calcium hydroxide dressing are recommended for the following reasons:

1) to maintain a high pH within the canal and the tooth root in order to ensure an anti-bacterial environment is maintained;

2) to allow regular and sustained delivery of OH$^-$ ions to the periapical region which helps to promote hard tissue repair;

3) to renew the temporary restoration since all temporary filling materials have a limited time of "usefulness" (if the temporary breaks down and loses its marginal seal then bacterial invasion can occur and lead to delayed healing and even failure of the endodontic treatment. The regular replacement of the calcium hydroxide also allows regular replacement of the temporary filling which helps to maintain the sterility of the canal system);

4) to allow the operator to test or "feel" for the presence of the apical hard tissue barrier (the progress of barrier formation can be assessed from within the canal at each dressing change appointment by using paper points - the apical region should be tapped gently with the paper point to physically feel for the barrier. If there is any blood or exudate on the paper point or if there is any sensitivity to the paper point probing reported by the patient then the barrier is

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previous openings during the root filling procedures, paper point test and by fitting the presence of a customised gutta-percha point using the 'heat-softened impression technique.' Hard tissue barriers can be seen radiographically to have formed across the apical foramen of the 1.1 and in the resorption region of the 2.1. Further confirmation is provided by the lack of radiographic evidence of any sealer having flowed through the previous openings during the root filling procedures.

incomplete and the dressing should be replaced. The presence of a complete barrier can be further tested by fitting a customised gutta-percha point using the heat-softened impression technique. Hard tissue barriers can be seen radiographically to have formed across the apical foramen of the 1.1 and in the resorption region of the 2.1. Further confirmation is provided by the lack of radiographic evidence of any sealer having flowed through the previous openings during the root filling procedures.

5) to replace the calcium hydroxide paste which washes out of the canal readily, especially in the early stages of apexification (11) - this can be seen radiographically and indicates that the barrier is incomplete (Figs. 2, 3);

6) to reduce exposure to unnecessary radiation since fewer radiographs are required;

7) radiographs cannot be relied upon to demonstrate whether the barrier is complete because:
  - radiographs are only a two dimensional view of the object;
  - the barrier forms from the periphery towards the centre so it is impossible to tell whether the barrier has completely formed on a penapical radiograph;
  - radiographs only show gross changes so a considerable amount of hard tissue must be formed before it is visible on a radiograph and therefore a sufficient apical barrier may form before being radiographically evident (8);
  - if radiographs are the only criteria used to assess the barrier then a much longer treatment time may be used than is really necessary (8, 9);

- radiographs are only useful if standard views are taken to allow an assessment of change - film holders are required to achieve standardisation and if they are not used, then an accurate assessment is impossible and renders the radiograph useless (which implies that the patient has been exposed to unnecessary radiation);
- the time required to change the dressing in an efficient practice environment is only slightly longer than that required to take and develop a penapical radiograph - considerably more useful information can be obtained by changing the dressing than that gained from a radiograph so the benefit:risks ratio and the time factors are far more favourable;
- calcium hydroxide pastes have a similar degree of radiopacity to dentine (8) and the apical hard tissue barrier (Fig. 4). It can be impossible to distinguish between them so a radiograph can only be used to assess the presence of a barrier if there is no calcium hydroxide within the canal (this implies that the dressing must be removed prior to the radiograph being taken and then it must be replaced if the barrier is incomplete. In this case, it is simpler and involves less radiation for the patient to have the dressing changed anyway and to use the paper point test as outlined above to assess the barrier);

8) to keep patients "in the system" - regular reviewing and treatment is more likely to keep the patient aware of the temporary situation within the tooth and the need for further treatment. If the patient actually receives some form of treatment every 2-3 months then they are less likely to forget and lose interest than a patient who is only reviewed with a radiograph every six months. It is well known that it is very difficult to recall patients after endodontic treatment with the usual maximum rate of recall attendance being in the 44-50% range (20). If this applied to apexification cases then a high rate of failure may result due to the treatment being incomplete. A "tracking" protocol would be required for dental practices using a single application of calcium hydroxide for apexification procedures to ensure these patients do return for the completion of treatment;

9) to ensure complete contact between the calcium hydroxide and the apical tissues since it is unlikely that the calcium hydroxide will make full contact with the apical tissues with just one application, particularly if any necrotic pulp tissue is left within the canal. Repeated applications are more likely to be effective in contacting the tissue across the entire open apex and therefore the treatment will be more likely to proceed within a shorter time period.

Suggested Technique

A suggested treatment regimen is outlined below for a patient that presents with signs and symptoms indicating a pulpless and infected root canal system with chronic apical periodontitis and an open apex (note - all treatment must be carried out under rubber dam isolation):

**1st appointment:** Establish working length; irrigate and prepare the root canal. Place Ledermix paste** or a 50:50 mix of Ledermix and Pulpdent pastes within the canal to control the infection and arrest any apical inflammatory resorption that may be present as a result of the infection. Place an adequate temporary restoration such as a "double seal" of Cavit and IRM.

**2nd appointment:** Between 4-6 weeks later - replace the dressing with Pulpdent paste. Replace the temporary restoration.

**3rd appointment:** Two months later - again replace the dressing with Pulpdent paste. Replace the temporary restoration.

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4th appointment: Two to three months later (depending on the width of apical opening) - again replace the dressing with Pulpdent paste. Replace the temporary restoration.

5th appointment: Three months later - replace with another dressing of Pulpdent paste. Replace the temporary restoration. Repeat at three-monthly intervals until a complete barrier can be felt with the paper point test.

Final appointment: Three months after the barrier has been deemed to be complete - place a root canal filling using the gutta-percha "heat-softened impression technique" as a final test of barrier formation and to ensure good adaptation of the apical root filling to the canal. Finally, restore the access cavity.

Further Useful Notes

When using the above approach of replacing the dressings regularly, interim radiographs are not normally required unless the treatment has extended over a long period of time. In this case, a radiograph should be taken after 12 months of calcium hydroxide dressings to determine whether perapical bone healing is occurring. This radiograph should not be relied upon to give evidence of the "completeness" of a hard tissue barrier for the reasons outlined above. This "check radiograph" is used to reassure the operator and the patient that there have been no setbacks and that treatment is progressing normally.

Proponents of the "one application" technique state that the dressing should only be changed if symptoms occur or if the paste has washed out of the apical two-thirds of the canal (8, 10, 12). However, if symptoms do occur then the healing process will be delayed (2, 5, 6, 11) because of the presence of infection. The lack of contact of the calcium hydroxide with the apical tissues after it washes out may also delay healing (11). Prevention of these problems appears to be a better approach and this can be easily achieved by regularly renewing the dressing as outlined above and as proposed by many authors (2, 3, 5, 6, 11, 22).

At the initial appointment, paper points used in the root canal will usually show haemorrhage from the apical tissues or absorption of tissue fluid or exudate. At subsequent appointments, local anaesthesia should not be used and any sensitivity felt by the patient indicates the apex is still open. At the second and possibly the third appointments some sensitivity, bleeding, exudate and tissue fluid are to be expected. The presence of these shall diminish with subsequent appointments - usually the sensitivity and exudate disappear first, followed later by the bleeding and lastly by the tissue fluid. The appointments at which these changes are noticed will vary in each case, according to the nature of the original pathology, the size of the opening, the presence of infection, and the time intervals utilised.

There is no need to re-file the canal walls at the dressing change appointments. The previous dressing can be rapidly washed out of the canal by thorough irrigation which could be supplemented by ultrasonic activation (if available) of a root canal file to "break up" the paste material into finer particles for easier flushing from the canal. At the first and second appointments, sodium hypochlorite solution could be used to dissolve any remaining tissue debris within the canal but at all other appointments the only irrigant required is EDTAC solution - to avoid the formation of smear layer on the canal walls.

Calcium hydroxide paste can be placed in root canals by various methods, such as: with a file or reamer, with a paper point, with a spiral filler, with an ultrasonically activated file, by injection, or by a combination of these techniques. Studies using sealer cements have shown that files, reamers and paper points are ineffective as they tend to remove the paste from the canal as they are withdrawn. Paper points should not be left in the canal as they break down and can cause foreign body reactions which will prevent healing (21). Ultrasonics may help sealers to flow through the canal but calcium hydroxide pastes are too thick to flow well with this method. Injection directly from the carrier syringe is potentially dangerous as there is no control over the placement of the material and over-extension can easily occur into the periapical tissues (22) which may delay healing. Infection control is a further consideration with injection techniques - the syringe should not be used on more than one patient in order to avoid the chance of contamination and cross infection. The safest and most effective method is to use a spiral filler (22, 23) in the following manner - place some paste on the spiral filler and insert it into the canal so it is 3mm short of the "working length", start the handpiece engine spinning in a forward direction, jiggle the spiral filler vertically a few times and then remove it from the canal. This procedure should be repeated at least 2-3 times to ensure the canal is completely filled with the calcium hydroxide paste. It is important to keep the spiral spinning until it is completely removed from the canal so the space created by the spiral is filled as the spiral is removed.

The final "working length" to which the canal can be filled will often be shorter than the length initially determined - due to the thickness of the apical barrier. Practitioners should avoid trying to "recapture" their original length as this is not required and it may destroy the newly-formed apical barrier.

The anatomy of the canal within the apical few millimetres may be quite complex and will certainly be different to that found after root canal preparation of teeth with closed apices. Therefore, a root filling technique that utilises softened gutta-percha is usually required - the simplest way to do this is to use heat to soften the tip of the gutta-percha point and then to take an impression of the apical canal with this softened point (1). Lateral condensation or other root canal filling techniques can then be used to fill the canal. Care should be taken not to apply too much force in a vertical direction as this could dislodge the apical barrier from the tooth root (9) resulting in over-extension of the root filling material into the periapical tissues. The use of this "heat-softened impression technique" allows the operator to confirm the presence of a complete barrier across the apical foramen as the point can be inspected on removal from the canal. If it shows any sign of over-extension through an opening in the barrier, then the canal should be medicated again with further calcium hydroxide. In very immature teeth, the shape of the apical third of the canal may resemble a "blunderbuss". In these situations, the "heat-softened impression technique" can still be used but the customised point can not be withdrawn for inspection because of the presence of undercuts in the canal. Therefore, the customising of the point musts be done as part of the actual root filling procedure with the sealer cement already placed in the canal.

Once the apical barrier appears to have completely formed, it is advisable to medicate the canal again with calcium hydroxide for another three months to allow further hard tissue repair and to ensure that the barrier is as completely formed as possible. Hence, the above recommendation to wait a further three months before placing the root filling. However, if there are time constraints then this extra period of medication is not essential if the paper point test and the custom fitted gutta-percha point indicate good apical closure.

Practitioners should not be in any hurry to complete the root canal filling. It is preferable to defer placing the root canal filling until all of the aims of apexification have been satisfied because endodontic re-treatment of teeth with over-extended root canal
fillings is very difficult and such teeth will have a significantly reduced prognosis. They may also require surgical intervention which may reduce the prognosis even further.

**Conclusion**

In summary, although a single application of calcium hydroxide may produce the same end result - that is, an apical hard tissue barrier - regularly replacing the dressing has many advantages and may lead to shorter treatment times with less complications. The ideal time to replace a dressing depends on the stage of treatment and the size of the foramen opening and this must be assessed for each individual tooth at each stage of treatment.

**References**