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A Concise Review on Calcified Canals - A Review

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Abstract: A calcified canal is a root canal system complication due to hard tissue deposition which makes the canal narrower. Calcification is uncontrolled due to enzyme failure that could result in reduced blood supply to the tissue. Canal calcification is usually termed as an obliteration of the pulp canal. Pulp canal obliteration (PCO) or calcific metamorphosis as sequelae of dental trauma may also occur as sequelae of aging, dental caries, tooth loss or critical pulp therapy, orthodontic care. Extreme physiologic PCO in geriatric patients can arise from secondary or tertiary dentine apposition. Despite the application of high-magnification and cone-beam computed tomographic (CBCT) imaging, access cavity preparation for such cases is prone to procedural errors that may result in substantial loss of dentin structure, thus reducing the long-term prognosis. With the aid of advanced technology, early detection of canal obliteration will save a lot of frustrations. Early intervention as a prophylactic measure may not be reasonable, due to the low incidence of such teeth developing periapical pathosis. Hence, it is important to explain prophylactic action, if intended. Upon failure of other treatment modalities surgical intervention may be a possibility. Given the difficulty in its management, it is recommended that teeth showing signs of obliteration be referred to an Endodontist who can handle such cases with minimal errors in conjunction with specialist training, magnification, proper equipment, and detailed knowledge of dental anatomy, thereby providing a better prognosis. This analysis assists in information about the calcified canals about their etiology, possible modes of growth, diagnosis, and management, thereby helping to provide better treatment quality.

Keywords: calcified canals, negotiation, blood supply, failure of an enzyme, access opening, management.

INTRODUCTION

To all dental practitioners, calcification of the canals is a perplexing problem. Healthy, ill, and even unerupted teeth may suffer from problems with pulpal calcifications. Calcified canal negotiation is a challenge and requires patience; good magnification, illumination, and proper armamentarium (Siddiqui and Mohamed, 2016). Calcification is a process involving the reduction in the size of the intra-dental cavities resulting from the formation of hard tissue by the vital pulp cells. As a result of dentin deposition inside the tooth, it may end in complete calcification. The prevalence of these varies widely. Even if the etiological factors remain unclear (Patterson and Mitchell, 1965).

The causes of calcifications could be trauma, aging, and various systemic diseases such as cardiovascular diseases. There are certain analyses that claim that there is a relation between calcified canals and also linked with systemic diseases (Fonseca and Fonseca, 2015). Furthermore, Long-term discomfort such as deep caries and restorations with close proximity to the pulp were suggested as possible factors involved in the production of pulpal calcifications (Hussainy *et al.*, 2018).

Calcification which is uncontrolled due to pyrophosphatase enzyme failure, capillary permeability reduction, and blood supply induces calcifications. Root canal in teeth where calcific deposits block access to the canals is often hampered by treatment efforts. An attempt to locate the residual canal may extract significant quantities of dentin, and the possibility of root fracture and perforation could be present. Calcific Metamorphosis or pulp canal obliteration may be described as "a pulpal reaction to trauma characterized by rapid deposition of hard tissue within the canal space." This is also known as pulp canal obliteration, dystrophic calcification, diffuse calcification, and calcific degeneration (Fonseca Tavares *et al.*, 2018)**.** Calcified pulp chamber deposits cause darker hue, loss of translucency, and yellowish appearance of the crown of the tooth. It is characterized by the deposition of hard tissue inside the space of the root canal, and clinical crown yellow discoloration (AlDaiji and Alsahaly, 2018).

The exact mechanism of canal obliteration is unclear but it is believed to be linked to damage to the pulp's neurovascular supply during trauma. Such incidents and their clinical treatment that provide the odontologist with considerable challenges; because the sequel can occur several years after the incident, proper medical and dental history, as well as a comprehensive history of the dental trauma, a thorough clinical review can assist the dental practitioner in formulating a correct diagnosis and, consequently, sufficient care (Moradi Majd *et al.*, 2014).

It is generally accepted that the frequency of obliteration from the pulp canal depends on the extent of the luxation injury and the root formation stage. Canal calcification can be basically classified as Partial Obliteration – the chamber of the pulp is not visible, and the canal is clearly narrowed but visible. Total Obliteration – the chamber and channel of pulp is hardly visible or not visible (Ngeow, Ngeow and Thong, 1998).

There are two distinct types of calcification that occur in the pulp, according to Kronfeld and Boyle: calcification that is more frequent in the radicular pulp is generally referred to as diffuse or linear calcifications, whereas pulp stones (denticles) are more commonly found in the coronal region (de Toubes *et al.*, 2017).

They can be categorized into embedded, interstitial, adherent, and free denticles. according to their position. Furthermore, the degree of pulp obliteration may be categorized as absolute obliteration, in which the pulp chamber and root canal are hardly or fully unseen, and partial obliteration, in which the pulp chamber is not discernible and the root canal is distinctly narrowed but clearly visible (Huang and Zhu, 2004).

There's yet another pulp obliteration classification — localized and generalized. The etiologic agent is most commonly trauma in the localized form and this condition has been described relatively frequently following the crown and root fractures, tooth luxation, jaw fractures, tooth replantation, and endodontic procedures. The generalized form is part of the aging process and is usually seen in older people. In most teeth, the pulp chamber may be totally obliterated or hairline thin which is often accompanied by attrition (Geethapriya *et al.*, 2019).

Treating a calcified canal can be challenging because the pulp chamber and pulp canal are narrowed. The narrowing of the pulp chamber will lead to the difficulty in locating the canal's access and will also cause considerable difficulties during cleaning and shaping. It can lead to the breakage of the instrument during cleaning and shaping, due to the calcification of canals. Enlargement of the orifice of the channels is important for easy access to the canal. Obturation quality lies in proper cleaning and shaping (Teja and Ramesh, 2019).

If the calcified tooth is asymptomatic then it is of little concern but endodontic treatment must be performed in a tooth with periapical pathosis. There are many ways the canals can exhibit calcification such as pulp stones or calcific metamorphosis. These conditions will also cause the coronal part of the teeth to become discolored. Calcification is usually associated with tooth trauma that will stop blood supply and diminish the vascularity over time leading to calcification. Because of the canal calcification, this can often lead to a root canal treatment failure due to the difficulty in locating the canal and gaining access channel (Stewart, 1995).

Calcification may be due to a variety of physical factors such as aging, idiopathic factors, fluoride supplementation, hypervitaminosis D, or genetic predisposition, such as imperfect dentinogenesis and dentinal dysplasia, which may even occur in unerupted teeth (McCabe and Dummer, 2012). Our team has rich experience in research and we have collaborated with numerous authors over various topics in the past decade (Deogade, Gupta and Ariga, 2018; Ezhilarasan, 2018; Ezhilarasan, Sokal and Najimi, 2018; Jeevanandan and Govindaraju, 2018; J *et al.*, 2018; Menon *et al.*, 2018; Prabakar *et al.*, 2018; Rajeshkumar *et al.*, 2018, 2019; Vishnu Prasad *et al.*, 2018; Wahab *et al.*, 2018; Dua *et al.*, 2019; Duraisamy *et al.*, 2019; Ezhilarasan, Apoorva and Ashok Vardhan, 2019; Gheena and Ezhilarasan, 2019; Malli Sureshbabu *et al.*, 2019; Mehta *et al.*, 2019; Panchal, Jeevanandan and Subramanian, 2019; Rajendran *et al.*, 2019; Ramakrishnan, Dhanalakshmi and Subramanian, 2019; Sharma *et al.*, 2019; Varghese, Ramesh and Veeraiyan, 2019; Gomathi *et al.*, 2020; Samuel, Acharya and Rao, 2020)

The main purpose of this study is to explore calcified canals in order to better understand them for improved treatment.

MATERIALS AND METHODS

The review was done by collecting 49 articles using search engines such as PubMed, Google Scholar, Scopus, Cochrane, etc. The level of relevant information was analyzed, which was included in this review. Reports on the concept of calcified canals, etiology, pathogenesis, diagnosis, and management.

Quality research was performed on the basis of health evidence – a quality assurance method for gathering review papers (Table 1) (*Health Evidence - Quality Assessment Tool*, 2016). The findings of this study are based on previous studies conducted by respected scholars.

Table 1: Representation of Quality analysis for the articles collected.

Serial Number	Author	Year	Level	Quality of Research
1	Siddiqui SH et al	2016	Level 1	Weak
2	Patterson SS et al	1965	Level 1	Weak
3	Fonseca JM et al	2015	Level 2	Moderate
4	Hussainy SN et al	2018	Level 1	Moderate
5	Fonseca T et al	2018	Level 1	Moderate
6	AlDaiji MT et al	2018	Level 3	Strong
7	Moradi Majd N et al	2014	Level 3	Moderate
8	NGeow et al	1998	Level 2	Strong
9	De Touves KMS et al	2017	Level 1	Weak
10	Huang Y-F et al	2004	Level 2	Strong
11	Geethapriya N et al	2019	Level 1	Moderate
12	Teja KV et al	2019	Level 1	Weak
13	Stewart JJ et al	1995	Level 2	Strong
14	McCabe PS et al	2012	Level 2	Strong
15	Dabuleanu et al	2020	Level 2	Moderate
16	Schafer KG et al	1996	Level 1	Weak
17	Siskos GJ et al	1990	Level 3	Strong
18	Mahajan P et al	2016	Level 3	Moderate
19	Malhotra N et al	2013	Level 3	Strong
20	Kumar D et al	2018	Level 1	Weak
21	Zhao JJ et al	2016	Level 1	Weak
22	Jose J et al	2020	Level 2	Moderate
23	Bauss O et al	2008	Level 1	Weak
24	Delivanis HP et al	1982	Level 1	Weak
25	Rajendran R et al	2019	Level 3	Weak
26	Kulsum u et al	2011	Level 3	Moderate
27	Manohar MP et al	2018	Level 2	Moderate

28	Teja KV et al	2018	Level 1	Strong
29	Kiefner P et al	2017	Level 2	Weak
30	Ramamoorthi S et al	2015	Level 2	Strong
31	Kansu O et al	2009	Level 2	Strong
32	Ravinthar K et al	2018	Level 3	Moderate
33	Garg N et al	2014	Level 3	Strong
34	Rajakeerthi RR et al	2019	Level 1	Weak
35	Janani K et al	2020	Level 3	Weak
36	Amir FA et al	2001	Level 1	Moderate
37	Gopikrishna V et al	2004	Level 2	Strong
38	Nandakumar M et al	2018	Level 2	Weak
39	Johnson PL et al	1956	Level 1	Moderate
40	Noor SSE et al	2016	Level 3	Strong
41	Queiroz AF et al	2019	Level 3	Strong
42	Verutti E et al	2009	Level 3	Moderate
43	Siddique R et al	2019	Level 3	Strong
44	Moiseiwitsch JRD et al	1998	Level 1	Strong
45	Ramanathan S et al	2015	Level 2	Strong
46	Yang YM et al	2016	Level 1	Weak
47	Jain SD et al	2020	Level 1	Strong
48	Rivera ME et al	2019	Level 3	Weak
49	Floratos S et al	2017	Level 3	Strong

Calcification of Pulp

The calcified structure can be classified according to the Kronfield structure which is most commonly used. True denticles (composed of tubular dentine), False denticles composed of concentrated layers, not dentin-like calcified material), Diffuse calcifications (Small calcified deposits scattered throughout the pulp tissue).

Though these structures resemble the same but differ in their mode of development (i.e., true denticles develop as a result of epithelio-mesenchymal interactions, whereas false denticles form on a calcified Nidus). No such strict relationship exists, as shown below (*Cleaning and Shaping Calcified Canals | jcda*, no date). Second, most pulpal calcifications are conglomerates of different tissues: orthodentine, normal, and irregular calcified material, so that a distinction is almost impossible (Schafer, 1996).

Orthodentin, tubular dentin may present in pulp stone and denticles

Denticles

Formed as a result of epithelio-mesenchymal interactions are made up of tubular dentin at the earliest stage of their development, but as the calcified bodies increase, most or all of the odontoblasts decrease in height and disappear.

Pulp stones

These are initially developed as an amorphous calcified nidus. It was suggested that all dental papilla cells undergo initial induction by odontogenic epithelium and by differentiation into odontoblasts and dentin production. But this may not happen when there is a presence of pulp stone that can lead to canal calcification (Siskos and Georgopoulou, 1990).

Regular calcified material found in the peripheral region:

Pulp stones increase in size through the gradual deposition on the surface of the irregularly calcified nidus core of layers of regular calcified material. The most striking feature of the calcified body resulting is that it appears to be microscopically laminated light. A laminated pulp stone consists of layers of concentrated collagen fibers, an interfibrillar material into which mineral hydroxyapatite has been deposited (Mahajan *et al.*, 2016).

Irregular calcified material

These can be found in the core of most pulp stones, but also sometimes on the surface of a laminated pulp stone or even on a denticular surface. This type of material consists of diffuse calcifications. Irregular calcified deposits consist of an irregular matrix of collagen fibers and interfibrillar, electron-dense material into which crystallites of hydroxyapatite have been placed. The collagen fibers apparently form part of the pulp tissue 's natural intercellular matrix. These calcified bodies have an irregular periphery, and they are larger in size. They grow to lie matrix fibers by adding minerals (Malhotra and Mala, 2013).

Etiology of Calcified Canals

The etiological factors which result in the obliteration of the pulp canal are prolonged trauma, the natural aging process, gender, various systemic diseases, non-vital tooth without endodontic treatment, long-term irritation such as dental restorations and crowns which exert a constant force on the tooth (Kumar and Delphine Priscilla Antony, 2018).

Changes in age result in reduced size of the pulp due to secondary dentin deposition, occurring during life contributing to a decrease in canal length and width. Blood supply also decreases with age. The pulp horns and the pulp chamber floor and roof in molars can be reduced to a flat disk in the elderly due to attrition from a large rectangular cavern in the young (Zhao *et al.*, 2016).

Deposition at roots is always concentrated toward the center of the dentine mass. Reactionary and reparative dentine, which is used to minimize the porosity of dentinal tubules exposed to caries, trauma, or dental treatment or to heal pulpal exposures, further decreases the pulp volume (Jose, P. and Subbaiyan, 2020). Generalized pulp obliteration was also observed but in some diseases such as Marfan syndrome and renal osteodystrophy and atherosclerosis, it was not experimentally developed. It is also stated that orthodontic treatment may cause blood vessel compression, which can cause calcification of the canal (Bauss, Neter and Rahman, 2008).

Pulp canal obliteration has been found in all luxation categories and it has been observed that blood vessels are constricted in teeth with closed apices that lead to pulpal necrosis, whereas if the apices are open, the tooth will react with increased sclerotic dentine deposition. Restorative materials may also have an effect on the underlying pulp leading to odontoblastic injury resulting in pulp calcification (Delivanis and Sauer, 1982).

Possible Modes of Development

Due to uncontrollable mineralization due to the failure of the normal functioning of the self-limiting pyrophosphatase enzyme, can develop canal calcification. A loss of parasympathetic inhibition may lead to a reduction in the supply of pulpal blood which could lead to cellular respiratory depression, leading to pathological mineralization of the pulp, some studies hypothesized that the deposition of hard tissue is a consequence of stimulation of pre-existing odontoblast. This also makes the tooth unable for remineralization in which calcium phosphate and fluoride ions are deposited in the demineralized part of the teeth (Rajendran *et al.*, 2019). It has been reported that in humans the average rate of reparative dentin formation is 2.8 microns for deciduous teeth and 1.5 microns for permanent teeth. But in the case of calcified canals, this varies (Kulsum and Farzana, 2011). Two different modes of pulpal calcification production were generally proposed: calcification of tissue components and epithelial-mesenchymal interaction

Calcification of Tissue Components
The initial calcification of a component of pulp tissue (ground substance, necrotic cell residues, collagen fibril), which is served as a nidus on which calcified material is eventually deposited, is present in various calcification promoters and inhibitors, either in concentrated lamellar or in a radial fashion, in any connective tissue. These nidus or bacterial colonies can be avoided by giving intracanal medicament (Ledermix) in early-stage to avoid initiation of calcification (Manohar and Sharma, 2018). In a normally non-calcifying tissue, such as the pulp, calcification may occur when the balance between the two is disturbed; for example, the local breakdown of inhibitors (e.g., proteoglycan complexes) (Teja, Ramesh and Priya, 2018). Local metabolic dysfunction "is the precipitating factor for nidus development. A close spatial relationship exists between calcified structures and the pulp's blood vessels and/or nerves (Kiefner *et al.*, 2017).
Occasionally these nidi (or foci) occur in neurovascular bundles, mostly during shedding in the pulps of the deciduous teeth. While in the latter the calcifications likely associated with the degeneration of the nerves themselves, the observed relationship between calcifications and neurovascular bundles may be coincidental due to the richness of the pulp's neurovascular supply, making the calcified structure almost impossible (Ramamoorthi, Nivedhitha and Divyanand, 2015)
Some researchers suggested that pulpal calcifications may be associated with certain systemic conditions such as arteriosclerosis. While incidence in normal individuals was 46 percent, in patients with arteriosclerosis (53 percent), osteitis deformans (55.7 percent), and acromegaly (57.1 percent), this was somewhat but not significantly higher (Kansu *et al.*, 2009)**.**

Epithelio-Mesenchymal Interactions
During the development of a tooth, the epithelial strands are separated from the enamel tissue. Subsequently, these strands become isolated in the dental papilla where they interact with the mesenchyme papilla, resulting in normal differentiation of odontoblasts around the strands (Ravinthar and Jayalakshmi, 2018)**.**
The undifferentiated ectomesenchymal cells of dental papilla are to differentiate into two daughter cells during the development of a tooth. Under the epithelial effect, the first daughter cell differentiates into odontoblasts and lays down dentin whereas the 2nd daughter cell that is not subjected to epithelial effect survives as a sub odontoblast cell that differentiates into odontoblast as cells and deposits dentine as hard tissue under other influences. These are found in multi-rooted teeth furcation zones, where epithelial extensions subdivide the enamel organ cervical opening (Garg and Garg, 2014).

Diagnosis of Calcified Canals
Clinical findings
Color
Pulpal obliteration of the tooth revealed yellow discoloration. These pulp obliteration teeth are darker in hue than the neighboring teeth and have a dark yellow color due to a reduction in translucency due to a higher dentin thickness under the enamel. More than two-thirds of teeth with pulpal obliteration have also been found to be asymptomatic (R, Rajakeerthi and Ms, 2019).

Pulp sensibility testing
Teeth with partial pulpal obliteration were also reported to be more responsive to electric pulp testing than compared to those that were totally obliterated. The pulse oximeter is a non-invasive oxygen saturation monitoring device that is commonly used in clinical practice to measure blood oxygen saturation levels during intravenous anesthesia administration (Janani, Palanivelu and Sandhya, 2020). It is generally accepted that the absence of a positive response to the electric pulp test does not automatically imply that there is pulp necrosis (Amir, Gutmann and Witherspoon, 2001).

Radiographic findings
The calcified canal radiograph appears either as partial or total obliteration of the pulp canal space per apical pathosis, with or without associated. Total radiographic obliteration of the pulp space does not mean the absence of the pulp canal space; a pulp space with pulp tissue is present in the majority of these cases, but the sensitivity of traditional radiographs is too low to enable the capture of their images (Gopikrishna, Parameswaran and Kandaswamy, 2004).

Histopathology
The pulp status of pulpal canal obliterated teeth has failed to show any symptoms of pathological process inflammation(Nandakumar and Nasim, 2018). Previous studies described pulpal obliteration as a highly irregular, tertiary dentine reaction to trauma in pattern and calcification. In traumatized primary teeth it was

found that dentine-like, bone-like, or fibrotic tissues occluding the pulpal lumen were in nature (Johnson and Bevelander, 1956).

Differential Diagnosis

Canal calcifications are not usually of pathological origin; they may be the result of natural pulp aging. Moderate to extreme periodontal diseases show diffuse calcification (Noor, S Syed Shihaab and Pradeep, 2016). Certain factors, such as alkaline pH of calcium hydroxide bases, unset composite monomers, hand or mechanical condensation pressure, thermal conductivity, and micro-leakage may also stimulate localized reparative dentin deposition leading to the eventual obliteration of the pulp canals. In chronic pulpitis, the pulp tends to become obliterated by the root canal processing of reparative dentin (Queiroz *et al.*, 2019).

Management of Calcified Canals

Krasner and Rankow have laid down other laws that are especially useful in finding calcified orifices for canals. The DG-16 explorer (SybronEndo) is the most important orifice positioning instrument. Number 6 K- file is used for channel negotiation but is very good and lacks rigidity. Channel pathfinder such as canal Pathfinder or instrument with higher shaft resistance, such as pathfinder CS (Kerr), can be used as an alternative (Berutti *et al.*, 2009).

Many practitioners likewise prefer the use of magnification in the form of enhanced glasses or a microscope. Examining highly magnified color changes on the floor will help to locate the orifice of the canal. Chelating agents can be useful in channel irrigation with 2.5 percent-5.25 percent sodium hypochlorite, which increases organic debris dissolution (Siddique *et al.*, 2019).

The penetration of calcified canals can be made easier by using chelating pastes or solutions. Ultrasonic instruments aids to loosen debris in the canal orifices located in the pulp chamber. For the calcified canals, the flaring is one in crown-down fashion to avoid complications. Endodontic microsurgery is an option in the treatment of calcified canals because it provides a direct approach to the root apex (Moiseiwitsch and Trope, 1998).

Cone-beam computed tomography (CBCT) generates three-dimensional dentition scans, the maxillofacial skeleton, and anatomical structural relationships. CBCT's endodontic applications include diagnosing periapical bone defects, assessing internal and external root resorption, detecting vertical root fractures, visualizing and locating perforations, identifying root canals, and treatment planning for surgical and complex cases such as invaginated teeth (Ramanathan and Solete, 2015).

CBCT analysis plays a vital role in detecting the calcification depth by means of gutta-percha points. The benefits of CBCT areas are as follows: Accurate reproduction and measurement in 2D and 3D, Image accuracy, Rapid scans, and Limited Area Sensitive Scanning CT scanners are simpler, less complicated, and less expensive (Yang *et al.*, 2016).

3- Dimensional navigation technology also helps to locate apertures which require a minimally invasive procedure. New dynamic navigation technology with high-speed drills has the ability to achieve minimally intrusive access cavities by finding extremely complex calcified canals. New improvements to dynamic navigation technology promote clinical viability in non-operative drilling to reduce iatrogenic errors (Jain, Carrico and Bermanis, 2020).

Limitations

Locating the orifices with ultrasonic tips can cause teeth damage sometimes (Rivera-Peña *et al.*, 2019). Calcified canal diagnosis still does not have a universal method to follow (Floratos and Miltiadous, 2017).

Future Scope

This analysis will lead researchers to find innovative ways to access calcified canals. Additionally, any advance will lead to the early detection of calcified canals. This review provided a concise understanding of calcified canals that could serve better treatment and management.Our institution is passionate about high quality evidence based research and has excelled in various fields ((Pc, Marimuthu and Devadoss, 2018; Ramesh *et al.*, 2018; Vijayashree Priyadharsini, Smiline Girija and Paramasivam, 2018; Ezhilarasan, Apoorva and Ashok Vardhan, 2019; Ramadurai *et al.*, 2019; Sridharan *et al.*, 2019; Vijayashree Priyadharsini, 2019; Chandrasekar *et al.*, 2020; Mathew *et al.*, 2020; R *et al.*, 2020; Samuel, 2021)

CONCLUSION

The calcification of root canals is a challenge for the dentist and causes a lot of difficulty in instrumentation even though it can be challenging to negotiate and manage calcified canals, they can be managed if a proper protocol is followed. The skill, patience, and proper armamentarium of the operator are necessary to overcome the difficulties of delivering a successful treatment. However, these difficulties can be managed through the use of different instruments to negotiate the canal. By understanding all aspects of the calcified canal, appropriate treatment can be provided by acquiring adequate knowledge about calcified canals, thus leading to successful treatment.

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