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Challenges and Treatment Strategies of Tooth with Open Apices. A Narrative Review

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Abstract
Routine root canal treatment protocols to clean and obturate teeth with open apex cannot be adequately performed because of immature roots. The absence of apical seal predisposes the apical extrusion of irrigants and filling materials. Biomechanical instrumentation in such teeth with wide apical anatomy and thin dentinal walls may further compromise the strength of the root. Also the forces generated during obturation, especially by lateral condensation technique may also fracture the root. The treatment of teeth with blunderbuss anatomy presents unique endodontic and restorative challenges and requires careful assessment and treatment planning. Various treatment modalities are recommended for the management of such cases which include long term apexification with calcium hydroxide, retrograde root end filling using various restorative materials, formation of apical plug using tricalcium phosphate, mineral trioxide aggregate and more recently the pulp revascularisation.

Keywords*-Open apex, vital pulp therapy, apexification, pulpotomy, pulp revascularization.*

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I. Introduction

The conservation of natural dentition has long been the main objective in root canal treatment. Conventional root canal filling techniques rely on the presence of a constriction at the apical level of the canal; therefore, the absence of the apical constriction presents a management challenge. According to the glossary of endodontic terminology given by American Association of Endodontists (AAE), the blunderbuss canal is defined as an incompletely formed root in which the apical diameter of the canal is greater than the coronal diameter [1].Cvek's classification describes the five stages of root development: **I** = < 1/2 root length, **II** = 1/2 root length**, III** = 2/3 root length, **IV** = wide open apical foramen and nearly complete root length and, V = closed apical foramen and completed root development. Cvek's stage **V** describes mature, fully formed teeth, the remaining four stages describe teeth with open apices and a lack of apical constriction development but significant morphological differences [2].

Pathophysiology of open apex

The development of the roots begins after enamel and dentin formation has reached the future cementoenamel junction (CEJ) and continues up to 3 to 4 years after eruption of the tooth [3]. There may be cessation of root end development if trauma or carious exposure occur during this stage as there is damage of Hertwig's epithelial root sheath and necrosis of the pulp that leads to a necrotic immature tooth with blunderbuss canal anatomy [4]. Open apex develops in completely formed roots due to certain pathology like external inflammatory root resorption, iatrogenic over-instrumentation or root resection [5-7]. Open apex is associated with young permanent teeth that have been subjected to a dental trauma that has terminated root development prematurely [8].

Challenges faced clinically
Working Length Determination

It is quite challenging to determine working length in open apex. Failure to establish correct working length may result in accidental extrusion of root canal irrigant, dressing or filling and persistent periapical inflammation and postoperative pain [9,10]. Combining the use of electronic apex locator (EAL) with radiographs was recommended in a subsequent paper to avoid over-instrumentation [11]. The paper point technique described by Rosenberg to supplement initial EAL readings could be considered for the working length determination of open apices in relatively straight canals. The technique is described as follows: given that the canal is dry, an initial paper point is placed 0.5 mm short of the EAL indicated length. If the point comes out dry, it is advanced apically in the canal in small increments (0.25 mm) under magnification until some fluid is picked up. Another paper point is used just short of this point, and the working length is then the maximum length that a point can be placed into the canal and remains dry. The paper point should only remain in brief contact before any capillary action has taken place [12].

Cleaning & Shaping

The infected root canal space cannot be disinfected with the standard root canal protocol with the aggressive use of endodontic files hence there exists much reliance on root canal irrigants and intracanal medicaments although it predisposes the apical extrusion of irrigants and filling materials. These teeth show thin radicular walls with increased susceptibility to fracture thus conventional root canal cleaning and shaping is difficult to perform [13].

Obturation

The 'blunderbuss' anatomy of the canal often poses difficulties to achieve adequate obturation for successful endodontic therapy. Obturation of the root canal is critical because incomplete obliteration of the root-canal system accounts for 60% of endodontic failures [14]. Studies have shown that the endodontically treated immature tooth is more prone to fracture than its fully developed root filled counterpart [2]. Standard Gutta percha points cannot fit snugly in wide apices. Gutta percha cones can be modified into a large rod shaped cone by using various chemicals and heat [15]. In the rolled cone technique, a number of heated, coarse gutta percha points are positioned butt to tip on a sterile glass slab, and the points are then rolled with a spatula into a single rod shaped mass by repeated rolling and heating. There should be no voids in the bulk of rolled gutta percha, and it should be cooled with ethyl chloride spray or ice water before trial fitting. Heat flash or immersing the customized gutta percha point in a solvent can also soften the outer surface [16]. Tailor-made a heat polymerized polymethyl methacrylate resin as an endodontic obturator, has also been reported in literature [17]. In cases of blunderbuss root canal teeth, back filling of the canal with injectable thermoplasticized gutta percha over the artificial apical plug, can predictably avoid fracture of the root with thin dentinal walls.

II. Management -

Treatment options for vital immature permanent teeth

Apexogenesis

Apexogenesis is defined as "a vital pulp therapy procedure to encourage continued physiological development and formation of the root end" [18]. Apexogenesis will allow continued root development along the entire root length thereby maintaining the pulp vitality. Depending on the extent of inflammation, pulp capping, partial pulpotomy, or conventional pulpotomy may be indicated. Cvek et al demonstrated that in teeth with complex crown fractures, the exposed pulp maintained its vitality for up to 7 days. In these teeth, only the most superficial 2 mm of the pulp is inflamed and requires removal [19].

Direct Pulp Capping

Direct pulp capping is defined as "treatment of exposed vital pulp by sealing the pulpal wound with material such as mineral trioxide aggregate or calcium hydroxide to facilitate the formation of reparative dentine and maintain pulp vitality" [18]. In 1756, Pfaff described the first method of capping exposed pulps, using gold foils. In 1920, Datwyler conducted the first scientific clinical study to compare different capping materials [20]. Calcium hydroxide was introduced to the dental profession in 1920 and has been considered the gold standard of direct pulp capping materials for several decades [21]. Calcium hydroxide has excellent antibacterial properties which is dependent on the release of hydroxyl ions in an aqueous environment [22].

Pulpotomy

Pulpotomy is most commonly used in primary or immature teeth with carious exposure of pulp without any symptoms [23]. The coronal pulp is amputated, with aim to preserve the vitality of the remaining radicular pulp tissue surface. Its indication as a treatment in permanent mature teeth is relatively a new concept [24]. Full pulpotomy is defined as "The removal of entire coronal pulp to the level of the root canal orifice or as much as 2-3 mm apical to the orifices" [18]. Complete pulpotomy stops dentin deposition in immature permanent teeth and can result in root canal obliteration. [25,26]. Thus, it should be followed by complete endodontic therapy once root development is completed [27,28]. Partial Pulpotomy is defined as "The surgical removal of coronal portion of vital as a means of preserving the vitality of the remaining coronal and radicular pulp tissues" [18]. The key variables of successful vital pulp therapy are the factors such as amount of exposure, its origins (traumatic, mechanical, or carious), and microbiological contamination of the site [29].

Treatment options for nonvital immature permanent teeth
Apexification

Apexification is described as the process of creating a calcific barrier in the apical zone of an open apical root or the continuous apical development of an incompletely formed root in teeth with necrotic pulp [30]. The hard tissue apexification barrier might take the form of a cap [31], bridge, or ingrown wedge made of cementum, dentin, bone, or osteodentin [32]. Calcium disinfects the site, but it also creates an environment conductive to calcification and closure of the broad apex when combined with the high pH. Apexification using calcium hydroxide can only create a hard tissue barrier at the apex, not root growth [33]. The principal problems for calcium hydroxide, which can be remedied by MTA, are the Swiss cheese appearance of the barrier, which can induce over extrusion of the obturating materials [34]. The apexification barrier of osteodentin is often incomplete and results in the formation of the so-called tunnel defects. Such defects may allow bacterial re-infection [35]. Long term intracanal calcium hydroxide dressing can make the tooth brittle due to its hygroscopic [36] and proteolytic [37] properties that acts on the organic matrix of dentin. Mineral trioxide aggregate(MTA), a biocompatible material, can be used to create a physical barrier. Mineral trioxide aggregate has gained widespread popularity for the apexification procedure. It induces substantially more consistent apical hard tissue development than calcium hydroxide [38]. It also helps in the formation of hard tissue and cementum around its interface [39].

One-visit apexification

One-visit apexification is defined by Morse et al. as the non-surgical condensation of a biocompatible substance into the apical end of the root canal [40]. The rationale is to create an apical stop that allows the root canal to be filled quickly, with no attempt at root end closure. Instead, an artificial apical stop is formed. A variety of materials, including tricalcium phosphate [41,42], calcium hydroxide [43], freeze-dried bone [44], and freeze-dried dentin [45], have been proposed for this purpose. Endo Sequence root repair material (ERRM), Bio Aggregate, and iRoot BP Plus [46] are among the new bioceramic materials being investigated for this purpose. The prevention of overfill and under fill is one of the technical difficulties associated with the placement of MTA as apical barrier. Lemon proposed internal matrix theory for the treatment of root perforations. He suggested for the insertion of hydroxyapatite through the perforation to create an external barrier and matrix against which amalgam can be condensed. [47]. Bargholz proposed the modified internal matrix concept, he suggested using collagen as a completely resorbable barrier material against which MTA can be placed as a perforation repair material [48] . This concept is also utilized for the placement of MTA apical barrier in immature teeth. The combination of PRF as a matrix and MTA as an apical barrier can be considered as a good option for one-step apexification procedure [49].

Regenerative endodontics
Pulp revascularization

The ability of residual pulp, apical, and periodontal stem cells to differentiate is crucial for pulp revascularization [50]. These stem cells have the ability to produce a living tissue that is highly vascularized. They eventually differentiate into newly produced odontoblasts, which cause apposition of hard tissue [51]. Regenerative endodontic therapies in permanent immature traumatized teeth have been proposed by Gracia-Godoy F and Murray PE. They stated that in the case of traumatic teeth with an immature apex, revascularization/regeneration should be used only if the tooth is not a good candidate for conventional root canal therapy and treatments such as apexogenesis, apexification, or partial pulpotomy are thought to have a poor prognosis and have already been tried [52]. Generally, pulp revascularization occurs over two clinical sessions. The first treatment session involves disinfection of the root canal wall with sodium hypochlorite. Minimal instrumentation should be performed to avoid further weakening of thin dentinal walls. Trope recommended the use of a triple antibiotic paste (mixture of equal amounts of ciprofloxacin, metronidazole and minocycline in a propylene glycol carrier) for at least 4 weeks to ensure proper disinfection [53]. The periapical tissues are then lacerated with a #15 hand file inserted 2-3 millimeters beyond the apex, causing bleeding in the cleaned root canal. In the coronal aspect of the canal, a thin layer of MTA with a moist cotton pellet might be applied. The cotton can be removed after one day and the cavity sealed with resin modified glass ionomer cement [52].

Surgical intervention

According to current recommendations, all inflammatory periapical lesions should be treated first with conservative nonsurgical approaches [54], with surgical intervention being advised only when nonsurgical techniques have failed [55]. This notion also applies to teeth with periapical disease and a blunderbuss canal. Surgical is the last resort when all other therapeutic options have failed. If such teeth are linked with a substantial or long-standing periapical lesion, surgery can be performed [56].

III. Conclusion-

The treatment of teeth with blunderbuss anatomy presents unique endodontic and restorative challenges and requires careful assessment and treatment planning Various treatment modalities have been advocated in such teeth. Regenerative endodontics is a paradigm shift in treating endodontically involved immature permanent teeth that allow tissue regeneration and repair to achieve maturogenesis.

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