Radiographic appearance of apical closure in apexification: follow-up after 7-13 years

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ABSTRACT. Aim This was the radiographic evaluation of 15 maxillary incisors apexification treatment carried out on 7-9 years old patients with periapical pathology due to pulpal necrosis after dental trauma. Materials and Methods The treatment consisted of two phases. The aim of first phase was the formation of a calcified apical barrier through calcium hydroxide medications repeated twice with a three months interval. The aim of the second phase was the obturation of the root canal system once achieved a radiographic evidence of the formation of an apical barrier. The treated teeth were radiographed at six months and then periodically once a year for a period of 7 and 13 years. Results The radiographic analysis allowed to underline three different kinds of apical formation: a physiological development of the apical portion with a final root length equal to the controlateral tooth; the formation of a cap tissue and an apical development with the final root length slightly shorter than the controlateral tooth; or the formation of different layers of mineralised tissue that aggregate together trough the years. Conclusion Apexification isn’t a static phenomenon and the apexified area undergoes through the years to a conspicuous readjustment involving bone, apical root tissues and root filling material. KEYWORDS: Apexification-Apex closure-Calcium hydroxide.

Introduction

Apexification is an endodontic treatment of non-vital permanent teeth with open apex to induce the formation of a calcified tissue and the closure of an apex that hasn’t completed its physiological maturation process [Frank, 1966].

The treatment is mostly performed on anterior permanent teeth with open apex and pulp necrosis, following a traumatic lesion, sometimes associated to periapical abscess and vestibular sinus tract. Pulp necrosis prevents the tooth to complete the development of its radicular portion and to achieve the physiological maturation of the apex. The apical obliteration, final goal of the apexification treatment, is the indispensable condition in order to obtain a correct obturation of the root canal system and the healing of the periapical infection. The application of calcium hydroxide paste inserted with a lentulo spiral in the root canal system induces the formation of an apical diaphragm of mineralised tissues by the apical odontoblasts and cementoblasts. The calcium hydroxide medication induces the formation of a reparative fibrous tissue that progressively mineralises and that has been defined through histological evaluations [Ham et al, 1972; Steiner et al, 1971, Gallusi, 1987] as cementoid or osteoid tissue, in some cases described as bone, dentin, osteodentin or cement. The variability in composition of the apical diaphragm is explained by the presence of residues of apical pulp tissue and of a still active epithelial sheath [Frank, 1966; Feiglin, 1985].

Materials and methods

The apexification treatment was performed on 15 superior central incisors, in 7-9 years old patients, affected by periapical pathology due to pulp necrosis following dental trauma. The treatment has been performed in two phases at a 6 months interval. The aim of the first procedure was the achievement of an efficient apical barrier. The procedures of the first
phase included: isolation of the tooth with dental dam, access to the endodontic spaces, shaping of the canal at a working length 2 mm shorter than the actual canal length and sodium hypochlorite alternated irrigation, drying with sterile paper points, canal filling with calcium hydroxide paste applied with a lentulo spiral at the working length, obturation of the root canal with ZOE paste.

The bacteria elimination from the canal system and its filling with a highly antiseptic material help: the immediate healing of the sinus tract, when present (realised in 5-7 days), the progressive formation of a reparative “scar” tissue (achieved in 5-6 months) and the filling of the periapical bone gap, which is completed over an average time of one year.

Control visits were scheduled once a month to evaluate radiographically the treatment evolution.

The calcium hydroxide medication was repeated at a 3 months interval. It has been observed the progressive formation of a radiopaque tissue occupying the periapical area and, in some cases, frankly infiltrating the apical space. Once the radiographs gave evidence of the complete formation of a barrier at the calcium-hydroxide/reparative tissue interface, the treatment proceeded with the second phase according to the following steps: isolation of the tooth with dental dam, access to the endodontic spaces, removal of calcium hydroxide, irrigation with sodium hypochlorite, drying with sterile paper points, control of the presence and consistence of the apical barrier with manual instrument or paper coins, complete filling with gutta-percha of the root canal system, final crown restoration.

The treated teeth were radiographed at six months and then periodically once a year for a period of 7 and 13 years.

**Results**

1) In 6 cases the obtained healing determined the formation of an apical barrier followed through the years by a progressive development of the apical portion with a final root length equal to the contralateral tooth. The apical portion developed physiologically (Fig. 1-5).

2) In 7 cases the apical closure was determined by the formation of a cap tissue partially invaginated, and apically by the development of a further apical portion with a final root length slightly shorter than the contralateral tooth and completely mineralised at the following radiographic controls (Fig. 6-9).

3) In 2 cases the healing shows the formation of different layers of mineralised tissue that through the years will aggregate in one mineralised tissue of high thickness (Fig. 10-14).

Of the 15 teeth treated have been shown three cases, one for each healing pattern, to exemplify the different kinds of apical closure.

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**Fig. 1** - Coronal fracture of necrotic tooth 1.1 in 7 years old patient. **Fig. 2** - The 2.5 years follow-up. Following apexification the root length increased (when comparing the tooth 1.1 with the contralateral tooth) and a barrier formed apically to the root filling material. Beyond this area it is possible to observe a radiolucent area and more apically another portion of root tissue. **Fig. 3** - At the years follow-up the radiolucent area apical to the root filling material and the a apical root tissue are more evident.
Discussion
The treatment of immature permanent teeth with calcium hydroxide is fully described in literature [Chawla, 1986; Walia et al., 2000; Saad, 1988; Caliskan, 1997] and with high success rates [Chawla, 1986; Walia et al. 2000]. Recently [Shabahang et al., 1999; Hachmeister et al., 2002; Ham et al., 2005; Steinig et al., 2003; Ham et al., 2005] the application of mineral trioxide aggregate has been introduced to obtain the immediate apical closure.

Fig. 4 - 7 years follow-up. The root length of 1.1 appears similar to 2.1 while the radiolucent area apical to the root filling material is still visible. Fig. 5 - 13 years follow up. The radiographic evidences of the previous follow-ups are confirmed even after many years and the apical root area has completed its physiological maturation. Fig. 6 - Coronal fracture of necrotic tooth 1.1 in a 7 years old patient. The tooth appears less developed than the contralateral tooth.

Fig. 7 - 2 years follow-up: due to the apexification, the root length has increased and apically to the root filling material a barrier is invaginating in the root. Fig. 8 - 4 years follow-up: apically to the root filling material (which seems modified in its apical portion) a radiolucent area and more apically a further portion of root tissue are evident. Fig. 9 - 9 years follow-up: the alteration of the apical portion of the root filling material is evident; apically to this area there is a further root portion completely mineralised; 1.1 root length is slightly shorter than 2.1.
of the apex and rapidly proceed with the restoration. This treatment, though it still does not have a long follow-up as the calcium hydroxide [Chawla, 1991; Theter, 1988].

The complete healing after apexification is achieved in about 1±7 months [Kleier, 1991], depending on the presence of radiolucency and periapical infection [Kleier, 1991; Walia, 2000], the size of the apex

**Fig. 10** - Coronal fracture of necrotic tooth 21 in a 7.5 years old patient. **Fig. 11** - 6 months follow-up. Calcium hydroxide was placed with a lentulo spiral into the canal, which was 3-4 mm shorter than root length owing to a technical problem during treatment. There are two radiopaque areas at the coronal and apical levels. **Fig. 12** - 1.5 years follow-up. The two radiopaque bridges are more evident. Two radiolucent areas are one adjacent to the root filling material and the other one between the radiopaque bridges. Root length is similar to that of the contralateral tooth.

**Fig. 13** - 3 years follow-up. A higher mineralization of the apical root portion is evident, with consequent reduction of the radiolucent area between the two radiopaque bridges. No changes are visible on the radiolucent area adjacent to the root filling material that is slightly modified when compared to the previous follow-up. **Fig. 14** - 10 year follow-up. The apical root portion has completed its mineralization. It is still present, though reduced, the radiolucent area adjacent to the root filling material that shows further modification. Root length is slightly shorter than that of the contralateral tooth.

The radiographic aspect of the apical closure obtained after apexification treatment has been classified [Frank, 1966; Feiglin, 1985] in 4 clinical types according to the presence or absence of the Hertwig epithelial sheath and its relationship with the apical residues of the pulp tissue. If the sheath is still present and the apical odontoblasts are still vital, the root will develop normally with a physiological process of apexogenesis (Type 1). If the Hertwig sheath is still vital but are missing vital odontoblasts, the root will lengthen without a physiological maturation of the apex (Type 2). When the Hertwig sheath and the odontoblasts are both non-vital, the healing can only take place with the formation of a cap of mineralised tissue produced by osteoblasts and cementoblasts activity either at the apex level (Type 3) or coronal to the apex (Type 4).

The calcified bridge formed following apexification is a porous structure [Walia et al., 2000]. Follow-up after 6-12 years shows that this structure remains the same, consolidates or decreases [Chawla, 1991].

In our experience, the type of apical closure seems related to the following factors:

a) the kind of contact between calcium hydroxide and apical tissue;

b) vitality and potentiality of the epithelial sheath.

The healing patterns obtained allow some considerations.

In all cases there was a chronic periradicular pathology often associated with abscess and vestibular sinus tract. The final root length of the treated teeth, though initially highly reduced, was slightly shorter than that of the contralateral tooth and in some cases about the same. This healing pattern does not seem related to the proximity of calcium hydroxide to the apical area. In no case a physiological maturation process has been observed as time went on, nor in radiographic anatomy. These findings show that, though was still present a guide (Hertwig sheath) to the root development, the specialised cells (odontoblasts) were not available, and thus not able to immediately perform the instructions. These were completed over a longer period of time by mesodermic cells differentiated under the influence of the epithelial sheath. The final result was a root development that never appeared absolutely physiological, though it determined the lengthening of the apical portion.

The site of the formation of the first apical cap seems directly related to the level of insertion of calcium hydroxide and to its contact with the apical tissue. It is also necessary to underline that the aspect and the quality of the apical obliteration is highlighted in its form when radiopaque root filling material has contact with the cap. The filling material works as contrast medium highlighting its interface with the apical barrier. Radiographs often show a small radiolucent area between the root filling material and the apical cap, that remains visible over the years. The meaning of this area cannot be referred to a gap in the obturation, on the contrary it is due to the presence of a reparative tissue that can be made radiopaque with difficulty because of the colonisation of cementoblasts and osteoblasts; since their pattern of mineralization goes from the periphery to the centre of the canal and the already mineralised tissues obstructs the cell activity and slows down the progression of the mineralization process.

When comparing radiographs, the apexification does not appear a static phenomenon and it is characterised by a continuous modification of the apexified area over the years. In fact it is evident a readjustment of the bone structure and the apical tissues that continue their development according to the instructions given by the epithelial sheath; even the filling material undergoes a certain amount of modifications.

Conclusions
Apexification is not a static phenomenon. The apexified area undergoes a conspicuous readjustment through the years, involving bone and apical root tissues until the epithelial sheath instructions are completed. Further readjustments involve the root filling material.

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