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Study of calcium hydroxide apexification in 26 young permanent incisors

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Abstract – This study was carried out in order to observe the effectiveness of apexification in young permanent incisors. The sample comprised 26 young permanent incisors with necrotic pulp and open apices. The time taken to obtain apical closure, its form and size were analysed in order to find out if closure was influenced by existing pathology or size of apex. The treated teeth were compared with their corresponding contralateral teeth. The test of McNemar and ANOVA was used and a result of $P = 0.05$ was considered significant. Teeth with pretreatment apical shapes that were convergent or parallel all resulted in physiological apical shapes after treatment. Eight teeth had divergent apical shapes before treatment. Of these, one had a physiological shape, five ended with rounded apices and two teeth had straight apices post-treatment. Apical closure was obtained in 100% of the cases studied, of these 88.4% needed three to four sessions of calcium hydroxide treatment (an average of 3.23 sessions) in order to obtain apical closure, the average time employed was 12.19 months. Clinical symptoms resolved in all teeth that presented with symptoms. Preoperative symptoms did not affect outcome. Pathology of the tooth before treatment does not influence the time needed to obtain apical closure.

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After traumatic injuries the pulps of young permanent teeth often necrose. This occurs most commonly in the permanent maxillary incisors leaving the teeth with incomplete radicular development and open apices. In these cases treatment is aimed at promoting complete apical closure. At a later date a complete filling of the root canal is carried out in order to prevent inflammatory stimulators affecting the periapex.

Several different treatments have been described in order to achieve apical closure (1). One is apexification, which is defined as the induction of apical closure in a tooth with non-vital pulp. This induction is promoted by stimulating the formation of mineralized tissue (osteocement) at the end of the root (2), either with or without radicular growth.

Since its first presentation by Kaiser and Frank in 1964, apexification has been used with great success by many researchers (3–9). It is a treatment that complies with the aforementioned objectives: it allows apical closure and promotes radicular lengthening if the Hertwig's epithelial root sheath has not been irreversibly damaged (3). The drawback of this technique is that the time needed for treatment is prolonged. For this reason some authors prefer to carry out apexification in just one session (10) or obturation of the radicular canal with a gutta-percha followed by apicectomy with retrograde filling.

Many kinds of materials have been used to induce apexification in teeth with immature apices: antiseptic pastes, antibiotic pastes (11), ceramic tricalcium phosphate, the osteogenic protein-1, mineral

trioxide aggregate (MTA) (12–14), calcium hydroxide mixed with different substances in solution (3–9), etc.; however, treatment with 'pure' calcium hydroxide has become the standard.

This study was carried out for several reasons: in order to verify the effectiveness of this technique of apexification using calcium hydroxide; to observe the length of time required for apical closure; to analyse the shape and size of the apex formed compared with the contralateral tooth, and finally to find out if the shape of the apex has any bearing on the time taken to achieve apical closure.

Material and methods

This study involved 19 patients, 14 boys and five girls, between the ages of 6 and 9 years old. They attended our teaching unit of Integrated Paediatric Dentistry at the Dental School between 1995 and 1998. All children who presented with pulp necrosis in their incisors were included in this study. They were all treated by students from the final year of Dental studies, supervised by a professor. A clinical record was taken and an examination carried out (inspection, palpation, percussion and mobility). There was also a radiological examination (periapical X-rays with positioner) and direct observation of the pulp space. Although vitality tests were also carried out, they have not been included in this study due to their subjectivity. Out of the 19 patients included in our study one girl stopped attending our unit because she moved to another city. Therefore, this study was completed with 18 patients (14 boys and four girls), and 26 teeth were treated (22 central incisors and four lateral incisors).

These incisors were compared with their healthy contralateral incisor (seven patients/13 teeth).

All teeth were treated with the technique of apicoformation after local anaesthetic and use of a rubber dam. The chamber ceiling was perforated with a tungsten 330 high-speed refrigerated 330 burr. The remaining coronal pulp was removed with a tungsten low-speed round burr and with the help of broaches. This was followed by irrigation with 5% sodium hypochlorate until the entrance to the canals was thoroughly visualized. In order to avoid surpassing the apical constriction the length of the root canal was determined with high-calibre K-files (numbers 25–30) (conductectomy). When the working length had been ascertained the instrumentation of the canals with K-files was commenced. The first used had the same measurement as that used for the measurement of the canals; larger calibre files were used progressively in order to widen the canal. After each step the canals were flushed with 0.5% sodium hypochlorate, then filled with pure, pro-analysis calcium hydroxide powder [$Ca(OH)_2$] dissolved in distilled water.

In order to facilitate treatment in further sessions a cotton pellet was placed on the chamber floor, IRM or ionometer was added, and finally the tooth was restored with a permanent material in order to avoid the possibility of leakage.

Patients underwent a clinical and radiological check-up every 3 months, unless they missed their appointment or were on holiday. At each check-up apical size and shape were measured, and clinical symptoms observed. The material used for filling was replaced and the technique of apexification formerly described was repeated until the existence of a barrier or apical stop was found. When this occurred root filling with gutta-percha and sealer was performed.

The shape of the open apices was classified before treatment in the following way: convergent walls (CAW), parallel apical walls (PAW), or blunderbuss (DAW); after treatment as closed form, physiological closure (PC) or similar, round apical closure (RC) and straight bridge (SBC). The apical diameters of the treated teeth were compared, whenever possible, with their matching contralateral teeth if these were healthy. They were measured with a milimetrical ruler. The statistical tests used were ANOVA and MacNemar.

Results

In this study all cases of pulp necrosis were due to traumatic injuries, with a higher percentage of boys (73.4%) than girls (26.3%). The patients were treated until apical closure was achieved. One patient (5.26%) was excluded from the study due to missed appointments. Twenty-six incisors were studied and apical closure was 100% successful. At the first examination eight of these teeth presented no clinical signs or symptoms (30.8%) and 18 presented symptoms (69.2%). These signs and symptoms were: spontaneous pain 57.7%, provoked pain 11%, fistula 3.8%, slight periodontal widening 19.2%, apical radiolucency 11.5%. All clinical symptoms disappeared after treatment (100%, 26 teeth) ($P < 0.0005$) (Table 1). There was no relationship found between time needed for apical closure and the clinical symptoms prior to treatment.

The shape of the apex after apexification was similar to the physiological shape (73.1%), rounded (19.2%) and straight (7.7%) (Table 2).

After taking into account the shape of the apex before treatment and the shape obtained after treatment the results showed that 100% of teeth with open apices and CAW (seven teeth) obtained apical closure which was very similar to phys-

Table 1. Symptoms observed in incisors before and after apexification

Symptoms	Before treatment (%)	After treatment (%)
Without symptoms	8 (30.8)*	26 (100)*
With symptoms	18 (69.2)	–
Provoked pain	3 (11.5)	–
Spontaneous pain	15 (57.7)	–
Fistula	1 (3.8)	–
Abscess	–	–
Mobility	–	–
Apical image	3 (11.5)	–
Widening of periodontal ligament	5 (19.2)	–

*$P < 0.0005$.

Table 2. Apical shapes before and after treatment

Apical shape before apexification	
Convergent apical walls (CAW)	7 (26.9)
Parallel apical walls (PAW)	11 (42.3)
Divergent apical walls (DAW)	8 (30.8)
Apical shape after apexification	
Apical closure similar to physiological closure (PC)	19 (73.1)
Rounded apical closure (RC)	5 (19.2)
Straight apical closure (SBC)	2 (7.7)

Values in parentheses are in percentage.

iological closure. Teeth (100%) with parallel apical walls (11 teeth) obtained apical closure, which was very similar to physiological closure; eight teeth had open apices with divergent walls before apicoformation, of which one tooth obtained an apex similar to the physiological shape, five teeth round apices and two teeth straight apices. On comparing the apical form of the affected teeth with their matching contralateral teeth it was observed that any healthy apical form gave rise to physiological closure. This is not true of teeth with apicoformation as the wider the apices the greater the different forms of apical closure ($P = 0.000108$).

The apical diameter of teeth with apicoformation progressively decreased in size during treatment ($P = 0.001049$); the same occurred with their healthy contralateral teeth ($P = 0.019295$) (Table 3).

Teeth (88.4%) studied obtained apical closure after three to four sessions of treatment with calcium hydroxide (average 3.25 sessions). The average time needed for apical closure was 12.19 months (Table 4).

The following results were observed after taking into account the apical shape before treatment and the time needed to obtain apical closure: one tooth with divergent walls needed five sessions of calcium hydroxide; eight teeth needed four sessions, of which three had divergent walls and five parallel walls; 15 teeth obtained closure with three sessions, four of these teeth had divergent walls, six parallel walls and five convergent walls. There were two teeth that needed only one session of treatment and both had convergent walls. It can be observed that more sessions of treatment with calcium hydroxide are needed for teeth with divergent apical walls ($P = 0.003686$).

Table 3. Apical diameters before and after apexification. Comparison with contralateral tooth

Apical size (mm)	Tooth with apexification		Contralateral tooth	
	BT	AT	BT	AT
0.6–1	1 (3.8)	4 (15.4)	2 (15.4)	4 (30.8)
1.1–2	9 (34.6)	14 (53.8)	5 (38.46)	9 (69.23)
2.1–3	10 (38.43)	5 (19.2)	6 (46.15)	–
3.1–4	5 (19.2)	3 (11.5)	–	–
4.1–5	1 (3.8)	–	–	–
Average	2.69	2.17	2.15	1.62
SD	0.91	0.81	0.75	0.46

Values in parentheses are in percentage. BT, before treatment or during the period of time taken to complete treatment; AT, after treatment or after period of time taken to complete treatment; SD, standard deviation.

Table 4. (a) Sessions of calcium hydroxide treatment. (b) Time taken to obtain apical closure

Teeth	Sessions
(a)	
2 (7.7)	1
15 (57.82)	3
8 (30.8)	4
1 (3.8)	5
Average 3.23	
	Time (months)
(b)	
3 (11.5)	3
2 (7.7)	10
12 (46.2)	12
4 (15.4)	15
4 (15.4)	16
1 (3.8)	20
Average 12.19	

Values in parentheses are in percentage.

Discussion

In this study apical closure was obtained in 100% of teeth treated and is therefore in accordance with results obtained by other authors (between 74 and 100%) (4–9). Some authors consider that the existence of radiolucent apical images larger than 5 mm delays the formation of apical barriers or provokes the formation of irregular apical barriers (7, 15). In this study, there were three cases of radiolucent apical images but none resulted in delayed or irregular closure. These radiolucencies disappeared in 100% of cases. This is a higher percentage than that found by Heithersay (3), 1975 (95.24%) or by Morfis and Siskos (8), 1991 (89.66%). In the present study, it is considered that

apical lesions were closed through the use of a precise technique.

Ghose states that in 78% of cases apical closure is obtained 5 or 6 months after completing treatment and two sessions of calcium hydroxide treatment are usually required (4). Mackie et al. obtain closure in an average time of 10.3 months (16); Yates in 9 months (17); Cvek in 18.2 months (15). Many authors consider that the size of the apical opening before treatment influences apical closure (16, 17). The results of this study confirm their findings. No evidence has been found to prove that symptoms such as severe pain or severe infections affect the time required to obtain apical closure (7, 15), possibly because no such symptoms were present in this study. According to Torneck and Smith (18) the reopening of the canal at each session delays apical formation. However, Morfis and Siskos (8) and Ghose et al. (4) consider apicoformation to be totally independent to the number of sessions of treatment, or age or sex of the patient. Cvek (15) states that calcium hydroxide treatment should be repeated after 3–4 months because after this time calcium hydroxide appears to lose its antibacterial properties its ability to form an apical barrier. A recent study carried out on monkeys (19) seems to indicate that there is no advantage in carrying out a greater number of sessions of apexification before 6 months have passed (20).

The apical shape most frequently observed in this study was similar to the physiological shape (73.11%), followed by a rounded form (19.2%) and a straight form, or bridge (7.7%). These results differ from those of Morfis, which indicate that the straight bridge is the most frequent (66.7%), and from Ghose (65% rounded closures and 24% straight bridges). For some authors the shape of the apical barrier is completely independent to the apical diameter before treatment (4, 8). In this study, the teeth that presented convergent or parallel walls before treatment obtained a closure similar to the physiological shape. However, when the walls were divergent there was no relationship found between the shape of the walls and apical closure as rounded, straight or physiological shapes were all found. The physiological shape was due to the fact that the HERS had not been irreversibly damaged. For this reason 100% of healthy contralateral teeth had a physiological development that showed pointed apices with a small diameter.

The apical diameter of teeth with apexification decreases during treatment. This is also true of healthy antagonist teeth as the root develops, due to the HERS or to odontogenesis of the apex. In most cases the apical diameter of a treated tooth is larger than its healthy contralateral tooth.

Although the success of apexification with calcium hydroxide treatment is widely accepted, nowadays the use of other materials such as MTA (12–14) or pastes containing tetracycline (11) is being studied.

Conclusions

Apexification using calcium hydroxide as a temporary material for filling is an effective means of inducing apical closure. This has been achieved with an average of 3.23 sessions of treatment over an average period of 12.19 months. There was no evidence to indicate that signs or symptoms prior to treatment had any influence on the time take to achieve apical closure. The most frequent shape after closure was physiological (73.1%), followed by rounded (19.2%) and straight bridge (7.7%). The apical diameter of teeth treated with apicoformation progressively decreased after treatment. This factor indicates that treatment is instrumental in achieving apical closure. The more divergent the apical walls the longer it takes to obtain apical closure.

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