THE INFLUENCE OF OBTURATION TIMING AND THICKNESS OF MINERAL TRIOXIDE AGGREGATE ON SEALING ABILITY OF CANAL WITH OPEN APEX

Kyung-In Kwak, Dong-Sung Park, Hyeon-Mee Yoo, Tae-Seok Oh*

Sungkyunkwan University School of Medicine, Department of Conservative Dentistry

The Institute of Oral Health Science, Samsung Medical Center.

ABSTRACT

근관충전 시기와 MINERAL TRIOXIDE AGGREGATE의 APICAL MATRIX두께에 따른 치근단 밀폐도의 평가

곽경인 · 박동성 · 유현미 · 오태석*

성균관대학교 의과대학, 삼성의료원 치과진료부 보존과

임상에서 점차 Mineral Trioxide Aggregate (MTA) 에 대한 우수성이 소개되면서, apical matrix로의 사용은 주목할 만하다 할 수 있다. 본 연구의 목적은 개방형근관에서 MTA가 apical matrix로 사용될 때의 치근단 밀폐효과를 알아보고, 근관충전의 시기와 matrix의 두께가 치근단 밀폐에 미치는 영향을 치근단 미세누출의 측면과 matrix탈락빈도의 측면에서 관찰하고자 하는 것이다.

개방형 근관을 재현하고자 45개의 발거된 단근치에 #90크기로 근단공을 형성하였고, 투명레진등을 이용하여 치근단 병소를 갖는 치조골을 재현한 후, 4개의 실험 군과 1개의 대조 군으로 분류하였다. A군: 2mm두께의 MTA matrix 형성후, 열연화된 Gutta-percha와 AH26 sealer 를 이용하여 즉시 근관충전. B군: 2mm 두께의 MTA matrix 형성후, A군과 같은 방법으로 24시간 후 근관충전. C군: 4mm 두께의 MTA matrix 형성후, A군과 같은 방법으로 즉시 근관충전. D군: 4mm 두께의 MTA matrix 형성후, A군과 같은 방법으로 24시간 후 근관충전. 대조군: matrix를 사용하지 않고 열연화된 Gutta-percha와 AH26 sealer를 이용하여 근관충전하였다. Matrix의 탈락이 있는 경우 기록하고 완전수세 후 다시 시행하였다. 색소침투정도의 평가를 위해 methylene blue 에 치아를 48시간 침수시킨 후 협설로 양분하였다. 각 시편들을 고배율 현미경 관찰 후 비디오촬영 하였고, digitalized image analysing program 을 이용하여 두 명의 관찰자가 누출의 정도를 평가한 후, One-way ANOVA로 통계적 유의성을 검증하여 다음과 같은 결과를 얻었다.

1. Matrix를 사용한 실험 군이 matrix를 사용하지 않은 대조 군에 비해 유의성 있게 낮은 누출을 보였다($p<0.05$). 그러나 근관충전시기와 matrix의 두께를 달리한 실험군 내에서는 누출에 유의성 있는 차이가 나타나지 않았다.
2. 모든 실험군에서 gutta-percha를 이용한 근관충전의 시기에 matrix탈락 및 gutta-percha 의 압출은 발생하지 않았다.

주요어 : Mineral Trioxide Aggregate, Apical matrix, 치근단 밀폐, 미세누출, 근관충전

I. INTRODUCTION

Complete obturation of the root canal is one of the objectives of endodontic treatment. To fulfill this objective, it is advantageous to make an apical stop during the root canal shaping. But, when the apex is opened, the dentist has difficulties in restricting the obturaion material in the root canal during obturation.

Several methods have been introduced for controlling the open apex. These are customized gutta-percha cones, short filling, periapical surgery, apexifica-

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* 책임저자

tion (apical closure induction), and one-visit apexification[1].

The most recent development in the treatment of open apex is to condense orthogradely a biocompatible material into the apical end of the root canal. The rationale is to establish an apical stop that would then enable the root canal to be obturated immediately. This has been proposed as an alternative to the multi-visit apexification procedure. The advantage of this procedure over the conventional apexification is achieving of endodontic treatment in a single visit. Dentin chips, tricalcium phosphate, calcium hydroxide, and Mineral trioxide aggregate (MTA) have been proposed as matrix materials[1-6].

Recently, a material called mineral trioxide aggregate, MTA (ProRoot, Dentsply, USA) has been introduced and applied in various clinical situation[7,12]. MTA has a good sealing ability[13-16], biocompatiblity[8,9] and promotes the regeneration of the original tissues when placed in contact with the dental pulp or periapical tissues[9-11]. These characteristics are good when used as an apical matrix. Shabahang *et al*[11] compared the efficacy of OP-1, calcium hydroxide, and MTA for root-end induction in the immature roots of dogs and demonstrated that MTA produced an apical hard tissue formation with a significantly greater consistency. They concluded that the placement of an apical matrix using MTA is an alternative to the conventional long-term calcium hydroxide therapy[10,11].

Although MTA had many advantages, it had some disadvantages in the areas of clinical usage. This included prolonged setting time ()2h 45min), moderate compressive strength lower than super-EBA and IRM at the initial setting period of 24h, and need for moisture to set[18]. These characteristics required the placement of a moist cotton pellet in the root canal and prolonged waiting before gutta-percha obturation when MTA was used as an apical matrix[7].

Although many researches have presented good sealing ability of MTA when used as a root-end filling and perforation repair, no research had been performed for the sealing ability of MTA matrix. Because the dislodgment of matrix into the periapical tissue was vastly related to the loss of sealing ability, adequate thickness and strength of matrix, it could be a prerequisite to the one-visit apexification procedure.

The purpose of this in vitro study was to determine the influence of gutta-percha obturation timing and thickness of MTA on the sealing ability when MTA was used as an apical matrix in open apex. Sealing ability was investigated through the evaluation of apical leakage and frequency of MTA dislodgment into the simulated periapical lesion.

Ⅱ. Materials and method

Forty-five extracted anterior single-rooted human teeth were used in the study. Calculus and tissue debris were removed from the root surface by ultrasonic scaler and the teeth were soaked in a 5% sodium hypochlorite solution for 24 hours. The crown of each tooth was removed at the cementoenamel junction with a #557 bur to permit adequate access to the root canal. Each root was then placed in a numbered vial containing normal saline solution and refrigerated to inhibit bacterial growth.

The root canals of all teeth were prepared to simulate an open apex[4,6]. After verification of apical patency with a #10 file, the root canals of all 45 roots were prepared by serial filing using K-flex file and H file until a #80 file extended 5mm beyond the apex. After this, coronal flaring was done by step back serial preparation with no 4, 5, 6 Gate-Glidden drill. After each filing, the canals were irrigated with copious amounts of 5% NaOCl.

All roots were then coated with 2 layers of nail varnish except apical 2mm. After the nail varnish was allowed to dry for 24hours, wax was attached to the root apex to make room for periapical lesion. All roots were then placed into an acrylic block to simulate the alveolus. After setting of block, a window was made at the base of the acrylic block and the wax was removed by a wax carver and steam sprayed throughly. Saline moistened cotton was loosely filled in that room to simulate periapical granulation tissue (Fig. 1).

Forty-five specimens were randomly distributed into three experimental groups consisting of 10 teeth each and a control group of 5 teeth (Table 1).

MTA was mixed as described by Torabinejad[7]. The mixture was carried with a small amalgan carrier to the canal and condensed into the apical end of the root with an endodontic plugger (Hu-Friedy Co.,

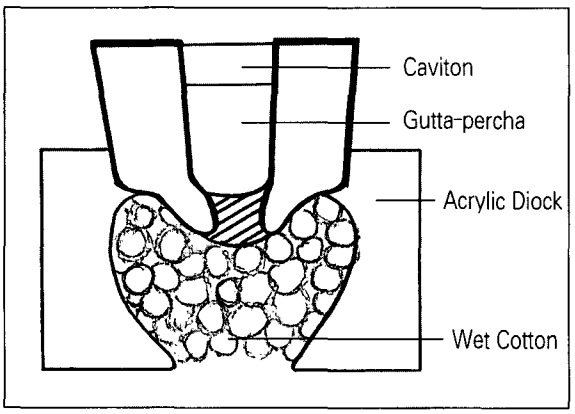

Fig. 1. Schematic drawing of model which simulates the open apex with apical pathosis condition.

Table 1. Group classification

Group	Number of specimens	Matrix Thickness and Obturaion Timing
Group A	10	2mm MTA matrix/obturated immediately
Group B	10	2mm MTA matrix/obturated 24hours later
Group C	10	4mm MTA matrix/obturated immediately
Group D	10	4mm MTA matrix/obturated 24hours later
Control	5	No matrix/obturated

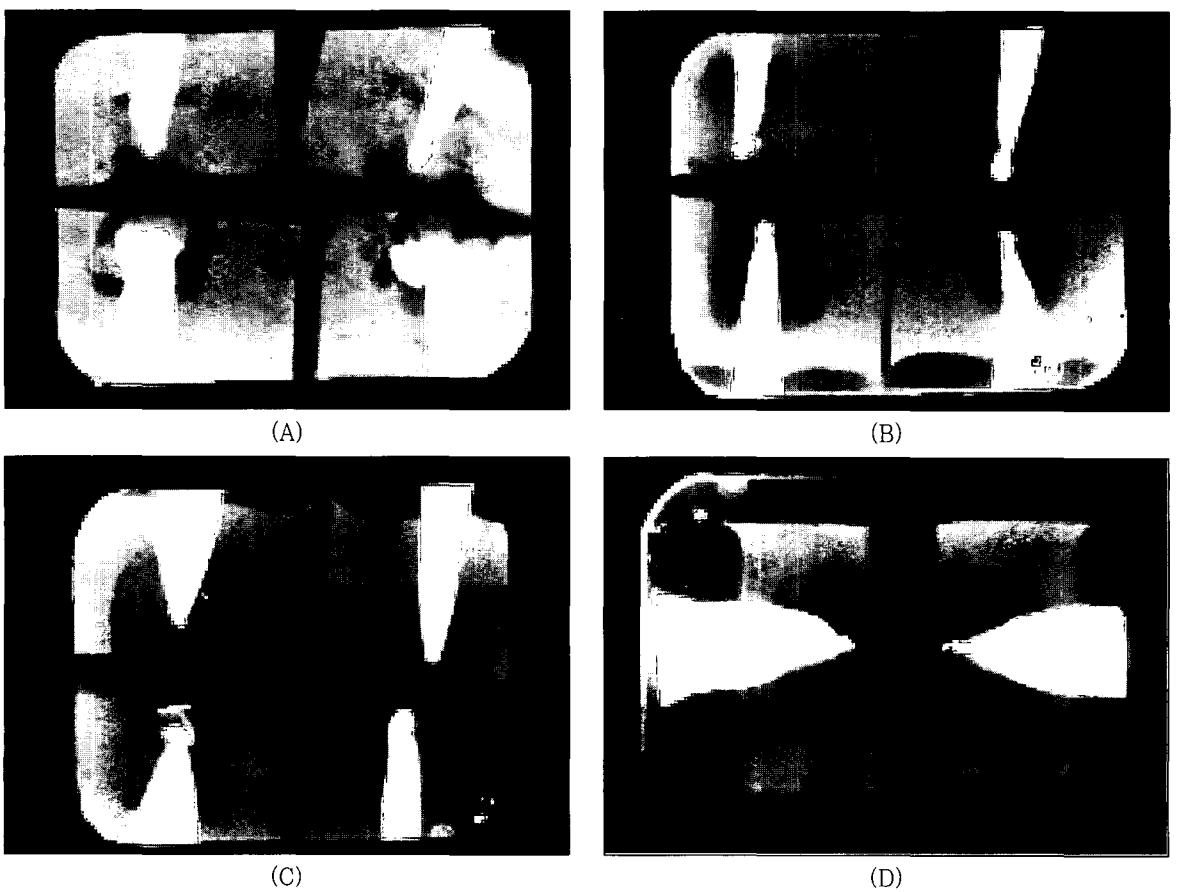

Fig. 2. Radiographic confirmation was done in every step. 2mm thickness (A), and 4mm thickness (B) of MTA matrix was packed. (C) MTA matrix and gutta-percha obturation was done. (D) Gutta-percha (Obtura II) was obturated without matrix.

Chicago, USA) and paper point. The pluggers were pre-fitted with a rubber stop set 2mm and 4mm short of the open apex. In Groups A and B, 2mm thick MTA matrix was formed with these pluggers prefitted with a rubber stop set 2mm. In Groups C and D, 4mm thick MTA matrix was made with the

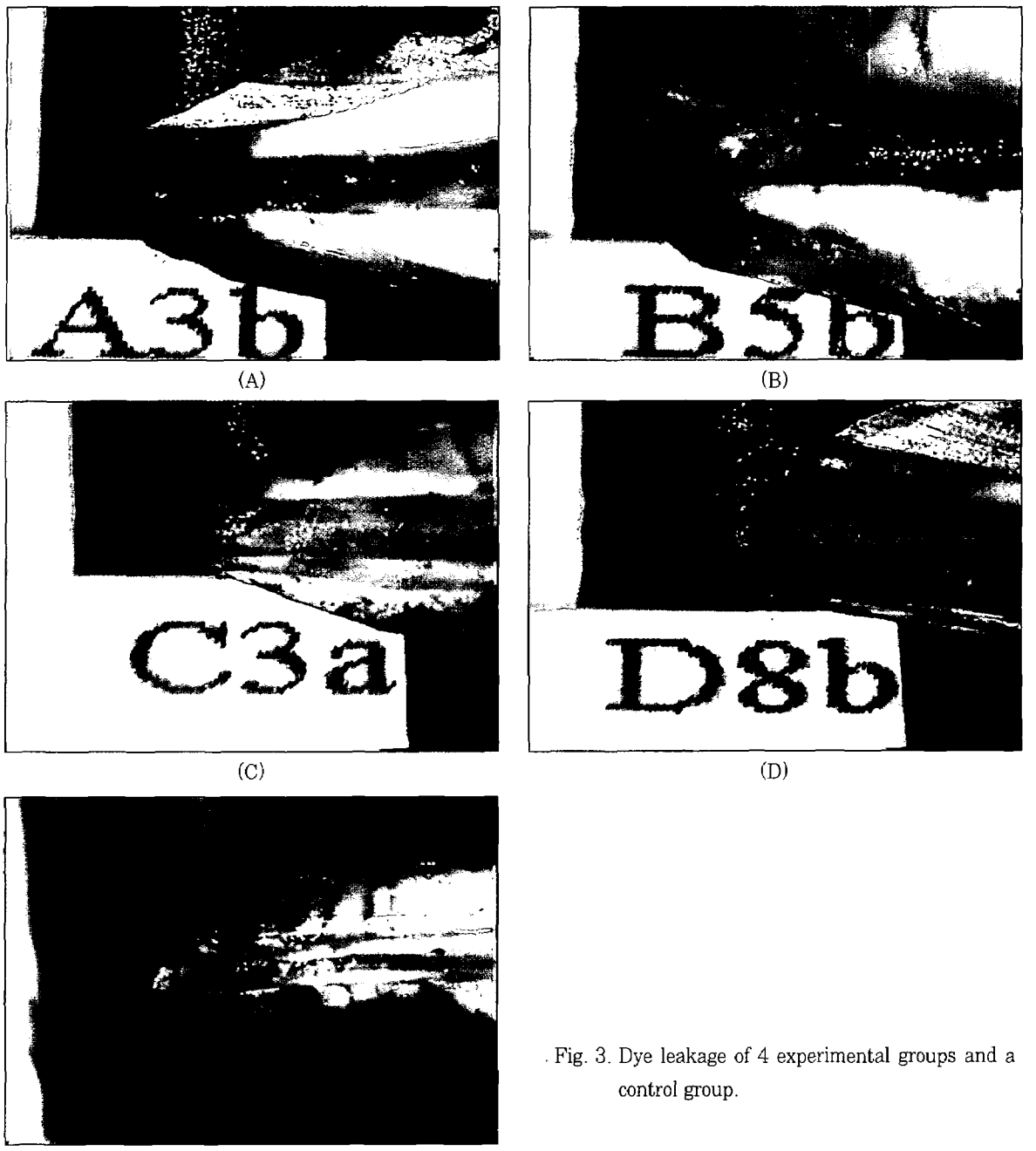

Fig. 3. Dye leakage of 4 experimental groups and a control group.

pluggers prefitted with a rubber stop set 4mm. With larger files, excess MTA was removed when necessary and it was radiographically confirmed. If creation of a consistent matrix failed or dislodgment of matrix occurred, MTA was throughly rinsed out with a water spray and the procedure repeated again.

Immediately after making the apical matrix, the canals were dried with paper point. AH26(De Trey, Germany) sealer was placed into the canal with #80 file rotated in a counterclockwise direction. The rest of the root canals were vertically condensed with the thermoplasticized gutta-percha using Obtura II system (Texceed Corp., CA, USA) in Groups A and C. In Groups B and D, a moist cotton pellet was placed in the pulp chamber and the access cavity closed with a Caviton (GC corp., Japan). The canals were dried with paper point 24 hours later. The rest of the root canals were obturated in the same way as

Table 2. Mean dye penetration (mm) and standard deviation

Group	Mean	S.D.
A	0.69	0.26
B	0.78	0.40
C	0.46	0.27
D	0.54	0.17
Control	1.50	0.22

Table 4. Number and period of matrix dislodgment

Group	Matrix dislodgment	
	During matrix adjustment	During G.P. obturation
A	4	0
B	4	0
C	0	0
D	0	0

Groups A and C. Radiographs were taken both in the faciolingual and mesiodistal direction to ensure that all canals are well obturated and to check the dislodgment of MTA matrix (Fig. 2). After obturation, all coronal canal entrances were sealed with Caviton. Specimens were placed into 100% humidity at 37℃ for 48 hours.

All specimens were immersed in methylene blue dye for 48 hours. They were rinsed, dried and split longitudinally using thin diamond disc, chisel and mallet. Gutta-perch and MTA were removed from the canal. Both halves of each specimens were observed under stereomicroscope(×15) (Storz, Global surgical corporation, USA) and the images were recorded in a computer(Fig. 3). Using the Sigma scan/image, version 1.20 (Jandel scientific Corp., CA, USA), two observers measured the maximum linear distance of the dye penetration from the apical end. The mean of the two values obtained for each measurement was calculated for each specimen. The real lengths were calculated by recording the ruler under the same magnification. Statistical anaysis was performed using an one-way ANOVA with the Bonferroni multiple comparison test at a significant level of $p<0.05$.

Table 3. Statistic analysis of dye penetration value of each group

	Group A	Group B	Group C	Group D
Group A				
Group B	NS			
Group C	NS	NS		
Group D	NS	NS	NS	
Control	SS	SS	SS	SS

NS : not statistically significant , SS : statistically significant ($p<0.05$)

Ⅲ. Results

Results are summarized in Table 2, 3 and 4.

All of the experimental groups showed significantly lower dye penetrations than the control group ($p<0.05$). However, the difference in the dye penetration was not statistically significant among four experimental groups.

Matrix dislodgment occurred in Groups A and B. All of the dislodgment occurred during the process of MTA packing and adjustment of the matrix thickness to 2mm.

Ⅳ. Discussion

Weisenseel *et al*[4] and Goodell *et al*[6] demonstrated that teeth with apical matrix of $Ca(OH)_2$ and calcium phosphate had significantly less apical leakage than those without apical matrix and the average dye penetration was 1.5±3.0mm in $Ca(OH)_2$, 2.88± 1.11mm in calcium phosphate respectively. In our experiments, the use of MTA matrix in open apex showed a significant decrease of apical leakage, and the average dye penetration was 0.62±0.30mm. MTA matrix showed better sealing ability than the data of previous $Ca(OH)_2$ or calcium phosphate. Lee *et al*[16] repaired the lateral perforation with MTA in extracted molar, which extruded 5mm beyond the root surface and that was same to this experiment. Average dye penetration was 0.28mm with a range of 0 to 0.8mm. Many of the research[13-17,20-25] demonstrated superior sealing ability of MTA compared to amalgam, super-EBA and IRM.

This present experiment showed that the obtura-

tion timing of thermoplasticized gutta-percha and the thickness of MTA matrix did not affect the sealing ability significantly. There was no significant dye penetration between the experimental groups and no matrix dislodgment during obturaion. Torabinejad[7] recommended the following clinical procedure: create a 3 to 4mm MTA matrix and place a moist cotton pellet in the canal for at least 3 to 4 hours to allow the MTA to set and then obturate the rest of the canal space with gutta-percha or a composite resin. Adequate bulk and setting of the materials was important for the apical matrix to prevent extrusion of obturation material into the periapical tissue. However, during the experiment, all the experimental groups had adequate matrix resistance to dislodgment. Clinically, Matrix resistance was tested with an apical pressure using vertical plugger. Regardless of the setting, packed MTA showed considerable hardness and resistance and was difficult to handle. Keeping the packed MTA matrix at 2mm needed much effort. During this step, matrix dislodgment happened repeatedly.

However, there were some limitations that cannot accept this result clinically. First, we cannot simulate the various root apex anatomies and apical size of open apex. Our experimental model was only limited to #90 file size and root canal converging toward the apex. Second, humidity and pH was a variable for the setting of the MTA. In this experiment, moisture was only supplied from the wet cotton. However, in vivo, granulation tissue will supply enough moisture to set the MTA. In a high degree of inflammation, that is low pH, the setting of MTA will be delayed. Immediate gutta-percha obturation made it impossible to detect the setting of MTA. These several variables were supposed to change the clinical results. Further researches are necessary.

Although most of the radiographs taken to confirm the good filling in every step showed that MTA was extruded beyond the root apex, the biocompatibility of MTA was well established[8,9]. Pitt Ford *et al*[19] demonstrated histologically that when the MTA had been extruded into the bony defect, the cementum had formed around the extruded MTA. Shabahang *et al*[11] showed a well-defined band of hard tissue around the entire extruded segment of MTA in open apex.

Various leakage tests could be used, which includes dye leakage test, bacterial leakage test and fluid filtration tests. Recently the relevance of leakage tests in endodontics has been debated and some shortcomings of dye leakage test was claimed[26-28]. Dye studies, however, are the simplest method to evaluate the leakage. Chong *et al*[29] compared the sealing ability with the bacterial leakage, dye leakage and confocal microscopy and they concluded that there was no difference between the three methods.

MTA requires several hours to set into a hard mass. Most internal repairs or orthograde fillings with MTA requires multiple visits to complete the root canal therapy or restoration. From the results of the present experiment, Gurra-percha could be condensed immediately if the proper resistance form was presented and moisture was available from the outside of the tooth. However, the clinical application is still questioned. Further studies are needed to determine the precise characteristics of MTA and standardized open apex model in evaluating the sealing abilites of apical matrix materials is needed.

Ⅴ. Conclusion

The purpose of this in vitro study was to determine the sealing ability of MTA and to determine the influence of gutta-percha obturation timing and thickness of MTA on apical seal when MTA was used as an apical matrix in simulated open apex. Apical seal was investigated by evaluating the apical leakage and frequency of MTA dislodgment to the simulated periapical lesion.

Open apex with large periapical pathosis was simulated in the 45 extracted single-rooted teeth. All the roots were divided into 4 experimental groups and a control group as follows: Group A: 2mm thick MTA matrix was formed in the apical root end and obturated immediately by Obtura Ⅱ and AH26 sealer. Group B: 2mm thick MTA was formed and was obturated 24hours later in the same manner as Group A. Group C: 4mm thick MTA was formed and immediately obturated. Group D: 4mm thick MTA was formed and was obturated 24hours later in the manner of Group C. Control group: canal obturated without apical matrix. Linear dye penetration of methylene blue was measured. The results were as

follows:

1. Experimental group with apical matrix of MTA showed less apical leakage than those without apical matrix ($p<0.05$). However, the thickness of MTA matrix and delay in the canal obturation after forming the MTA matrix had no influence on the apical leakage statistically.
2. During the obturation of the canal, any matrix dislodgment and gutta-percha extrusion did not occur in all experimental groups.

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