The effects of pressure *in vitro* on three methods of root canal obturation

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Key words
Barotrauma; Dental; Diving; Endodontics

Abstract
(Safai P, Farzaneh B, Fekrazad R. The effects of pressure *in vitro* on three methods of root canal obturation. Diving and Hyperbaric Medicine. 2019 March 31;49(1):16–20. doi: 10.28920/dhm49.1.16-20. PMID: 30856663.)
Introduction: The seal of root canal fillings depends on the anatomy of the root canal system and on the properties of filling materials and their bond to the walls of the root canal. Alterations in pressure may influence these properties. The current study investigated and compared microleakage in a tapered single-cone method versus lateral and vertical condensation after diving simulation.
Methods: One hundred and thirty five extracted single-rooted teeth were used. Following instrumentation and irrigation to #30.06 Mtwo rotary system, obturations were performed in three groups of 45 teeth: Group 1, tapered single-cone with Endoseal MTA sealer; Group 2, lateral condensation with AH26 sealer; Group 3, vertical condensation with AH26 sealer. Then all specimens were divided into three groups and incubated at ambient room pressure (101.3 kPa), 203 kPa or 304 kPa for 120 minutes respectively 20 times over one month to simulate diving conditions. Microleakage quantitative analysis was recorded by using a 2% Methylene blue dye for 24 hours.
Results: The amounts of microleakage increased with increasing pressure in all obturation groups; however, the differences were not statistically significant ($P > 0.05$). At all three pressures, the least microleakage was recorded in Group 3, vertical condensation. Although the differences between vertical condensation, lateral condensation, and tapered single-cone methods were statistically significant ($P < 0.001$), the vertical condensation and lateral condensation groups did not differ from each other ($P > 0.05$).
Conclusions: Vertical condensation may be the best technique, based on sealing ability, for people who frequently experience pressure alterations.

Introduction

Appropriate nonsurgical endodontic treatment is associated with knowledge of root canal morphology, cleaning and shaping, and finally proper obturation using appropriate sealant, filling materials and obturation techniques.[1–4] In addition, with the growing number of scuba divers and aircrew members, dentists will increasingly encounter oral conditions relating to pressure changes and these require careful attention.[5–7] These phenomena are mainly related to Boyle's Law which states that at a constant temperature, the volume and pressure of an ideal gas are inversely proportional. Amongst these oral conditions, barodontalgia is the term used to describe toothache related to ambient pressure changes.[8–10] Odontocrexis is another term used to describe tooth or restoration structure destruction associated with pressure changes.[11] Dental barotrauma is a more general term describing the damage to the tooth structure resulting from pressure changes with or without pain. Dental barotrauma is a potential cause of incapacitation that could jeopardize the safety of scuba diving or flight.[12]

Pressure changes may lead to structural alterations and microleakage in applied dental materials.[13,14] There are a few studies that address other physical impacts of pressures in pulp chamber and root canals.[6,13] Previous studies reported trapped gas bubbles in tooth root canal and chamber after the completion of root canal treatment and also the existence of microleakage between the restoration and the walls of the pulp chamber.[15,16] Hence, changes in pressure may influence the strength and physical properties of dental materials. This could influence recommendations about when patients should not dive.

The current study investigated the effect of repeated pressure exposure on microleakage in three different obturation methods after simulation *in vitro* of typical recreational diving pressures.

Materials and methods

The teeth used were extracted from patients for orthodontic reasons after written informed consents were obtained. The study was approved by the Ethics Committee of AJA University of Medical Sciences, Tehran, Iran.

SAMPLE PREPARATION

Specimens used were 135 sound, single-rooted premolars, with less than 20 degrees root curvature, extracted over a six-month period and stored in chloramine-T 1% (Sigma-Aldrich, Nst. Louis, Mo, United States) at room temperature. All teeth were evaluated by a qualified endodontist via radiography to determine that the root canals and teeth were suitable for inclusion in the study. Collected teeth were randomly divided into three groups, 45 teeth in each group. Twenty-eight other teeth were excluded because of ribbon-shaped canal anatomy.

ENDODONTIC TREATMENT

A single endodontist (PS) with special training in the respective filling techniques performed all root canal preparations and obturations in a standardized manner in order to minimize procedural variations. In all groups, access cavity preparation was done by D+Z diamond burs 837 (D+Z, KalletalT, Diamant GmbH, Germany) and working length was determined by inserting a size 15 K-file (Dentsply Maillefer) into the root canal until it was visible at the apical foramen and subtracting 1 mm from that length. The preparation of root canals was executed with the Mtwo rotary system, starting with #15.05 and continued to #30.06 (VDW, Munich, Germany). Irrigation with 5 ml 2.5 % sodium hypochlorite was done between successive instruments. At the end of preparation, the canal was irrigated with distilled water. After drying the canal with sterile paper points, specimens were obturated by the following techniques;

Group 1: Teeth were obturated using the tapered single cone method. Sealing cement Endoseal (MTA Endoseal, Maruchi, South Korea) was inserted into the canal with its syringe. Then, the master cone (#30.06 tapering) was impregnated with sealing cement and positioned to the working length.

Group 2: Teeth were obturated using a cold lateral condensation technique and sealing cement AH 26 (AH 26, Dentsply Maillefer, Ballaigues, Switzerland) was prepared and inserted into the canal with a lentulo. Then, the master cone (#30.02 tapering) was impregnated with sealing cement and positioned to the working length. Accessory gutta-percha cones with spreader #25 were applied in this group .[17]

Group 3: Teeth were obturated with a vertical condensation method and sealing cement AH26. In this group, gutta-percha and pluger were utilized for obturation.[18]

Finally, all obturated teeth were radiographically evaluated by another, blinded endodontist (BF) and the specimens in each of the three groups were randomly divided into three subgroups for the pressure simulations (n = 15 in each subgroup). For setting of the root canal sealers, the access cavity was sealed with temporary restoration material (Cavisol, Golchai, Karaj, Iran) and the teeth were stored for 24 hours (h) at 37°C and humidity of 90%. Prior to pressure simulation, all the specimens were sectioned mesiodistally at the cementoenamel junction with a diamond disc (D+Z, KalletalT, Diamant GmbH, Germany).

PRESSURE SIMULATION

To simulate pressure changes typical of shallow water diving, a custom-made chamber with an external pressure gauge was used. The chamber was pressurised with air, and an air vacuum pump was used to decrease pressure. In each of the three groups, one subgroup was exposed 20 times over one month to a pressure of 203 kPa for 120 min; a second subgroup to 304 kPa and the third acted as a control group at ambient room pressure. In the control group, specimens were incubated in 90% humidity, 37°C for one month. The pressurised subgroups were kept in the same ambient conditions as the control group between compressions.

MICROLEAKAGE TEST

Except for 2 mm in the coronal part, the entire tooth surfaces were covered with two layers of nail polish. The root apices were sealed with sticky wax. The specimens were immersed in 2% methylene blue for 24 h then rinsed under running water to remove excessive dye. The teeth were subsequently sectioned buccolingually with a diamond disc (D+Z, KalletalT, Diamant GmbH, Germany). Two sections of each specimen were examined under the stereomicroscope at 16X magnification. In order to quantitatively assess microleakage, dye penetration was measured (millimetre) from orifice to apical constriction via stereomicroscopy (SZX9, Olympus, Japan) and OLYSIA Zoom soft imaging system GmbH software by an experienced oral and maxillofacial radiologist (BF) blinded to the pressure grouping.

STATISTICAL ANALYSIS

Sample size was based on a similar study,[19] due to the nature of the study in which rigorous inclusion criteria were required to make specimens as similar to each other as possible. Data analysis was carried out using SPSS software (SPSS version 18.0, SPSS, Chicago, IL, USA). A Kolmogorov-Smirnov test determined that the data were not distributed normally. Therefore, a Kruskal-Wallis H test was used as a nonparametric analysis to evaluate the statistical significance of all results and pair-wise comparisons ($P < 0.05$).

Table 1
Dye penetration (mm) after repeated exposure to three different pressures; mean (median, interquartile range); see text below for statistical differences between methods

Obturation method	Mean of dye penetration (mm)		
	Ambient room pressure	203 kPa	304 kPa
Single cone	8.0 (8.0, 6.5–9.2)	8.0 (8.0, 6.7–9.1)	8.2 (8.1, 7.9–9.2)
Lateral condensation	4.5 (4.0, 2.9–5.0)	4.8 (4.4, 3.2–5.2)	4.8 (4.7, 3.1–5.1)
Vertical condensation	3.9 (2.8, 1.9–3.8)	4.1 (3.6, 2.6–4.0)	4.1 (3.6, 2.8–4.1)

Results

AMBIENT ROOM PRESSURE

Stereomicroscopy photographs showed the least dye penetration with the vertical condensation method at all three pressures (Group 3). Mean of dye penetration for each group at each pressure are shown in Table 1. The difference between lateral and vertical condensation techniques was not statistically significant ($P = 1$). However, vertical and lateral condensations methods had significantly less dye penetration in comparison with the tapered single-cone method ($P = 0.001$).

203 kPa PRESSURE

Stereomicroscopy again showed the least dye penetration in the vertical condensation group. The difference between lateral and vertical condensation techniques was not statistically significant ($P = 1$). However, vertical and lateral condensations methods had significantly less dye penetration in comparison with tapered single-cone method ($P = 0.001$ and 0.01 respectively) (Table 1).

304 kPa PRESSURE

Stereomicroscopy showed the least dye penetration in vertical condensation group (Figure 1). The difference between lateral and vertical condensation techniques was not statistically significant ($P = 1$). However, both of them had significantly less dye penetration in comparison with tapered single-cone method ($P = 0.01$) (Table 1).

Discussion

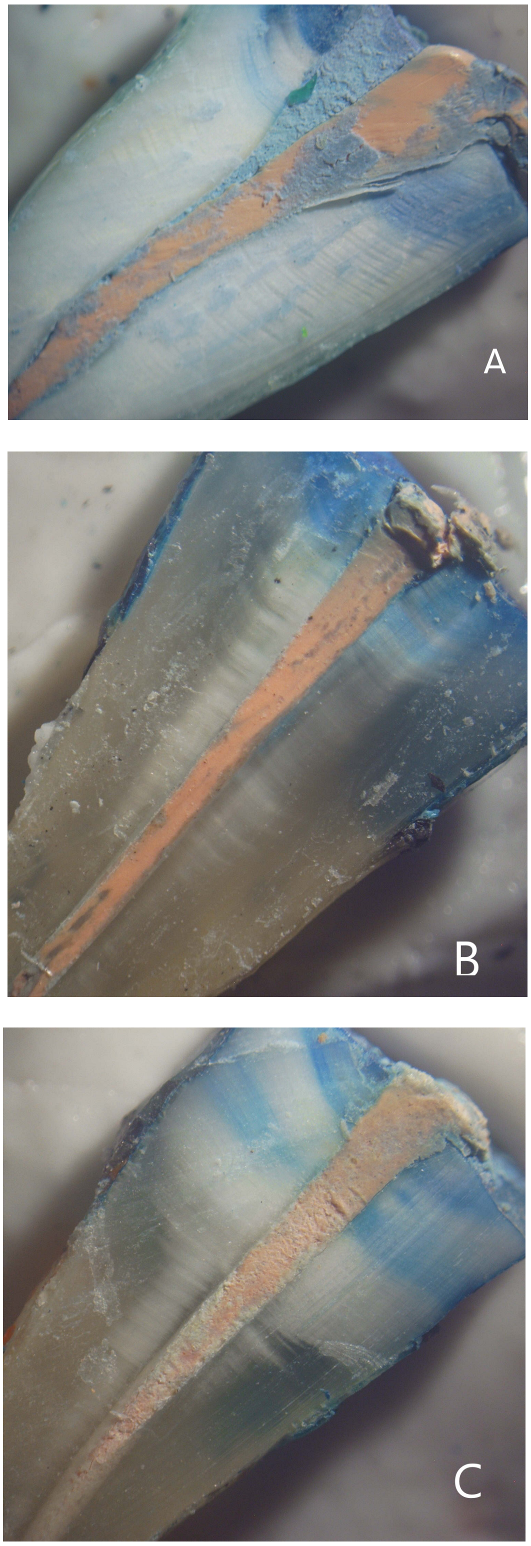
Simulated root canals in plastic blocks or extracted natural teeth have proved to be useful in systematically examining root fillings *in vitro*. In this context, natural teeth are superior to plastic blocks since they better reflect the dentin surface and the resulting mechanical properties at the interface between dentin and root filling material. Depending on the configuration of the root canal, natural teeth differ widely in the anatomy of the root canal system. In addition, root curvature plays an especially important role in the preparation and obturation of the root canal system. Therefore, in this study, only single-root extracted teeth with a root canal curvature of less than 20 degrees were used in order to facilitate comparisons.

Microorganisms present inside root canals may remain active in the dentinal tubules even after vigorous chemico-mechanical preparation. Thus, perfect apical sealing is desirable to prevent bacteria and their endotoxins from reaching the root apex. Coronal leakage is considered to be the common cause for endodontic failure and is influenced by many variables such as different filling techniques, chemical and physical properties of root canal filling materials and the presence or absence of a 'smear' layer. There are several assessment methods for microleakage such as dye penetration, dye extraction or dissolution, bacteria and toxin infiltration, air pressure, scanning electron microscopy, transmission electron microscopy and micro-computed tomography.[20] In the present study, methylene blue penetration was used as it is relatively inexpensive, safe and results in high penetration because the dye is a small molecule.[21]

In the current study, AH-26 and Endoseal MTA were used as sealers. For a sealer to penetrate the narrow root canal, its flowability should be good. The flowability of Endoseal MTA which is prepared from a powder, is not significantly different from the paste type AH-26.[22] The penetration of the sealer within dentinal tubules improves the sealing ability by increasing the contact surface between the filling material and dentin.[23] Penetration of Endoseal MTA to dentinal tubules is significantly lower than AH-26.[24] On the other hand, MTA has been shown to be an effective root apex filler and Endoseal MTA was better than other MTA products for root canal filling.[24,25]

A variety of systems are available for obturating root canals.[26] Gutta-percha is the most widely used filling material. It is

Figure 1
Stereomicroscopy of three sectioned teeth after repeated exposure to 304 kPa pressure (magnification x16); A) tapered single-cone method, B) lateral method and C) vertical condensation method; microleakage of methylene blue is obvious between gutta-percha and canal walls in tapered single-cone method but in other methods microleakage mostly occurs through dentinal tubules in the coronal region not covered by nail polish



suitable for both cold and warm obturation techniques. In the literature, studies comparing cold and warm methods of obturation in terms of leakage under standard conditions are not uniform. Cold lateral condensation is one of the most widely used obturation techniques. Compared with thermoplastic obturation techniques, cold lateral condensation is reported to have possible disadvantages such as inhomogeneity, an increased risk of canal fracture and poor adaptation to the canal walls.[27]

Regarding the microleakage test, this study showed statistically significant differences between the tapered single-cone method and other methods. Possible explanations are a potentially increased proportion of sealer in the root filling or a poor marginal seal under higher pressure levels. Contradictory results reported by different studies may be because of the variations in leakage evaluation techniques, test conditions, cavity design and dimensions, type of teeth and observation time. These contrasting results underline the obvious importance of standardizing testing parameters of leakage studies.[28]

Regarding the effects of pressure, no significant differences were seen between the control and pressure-cycled groups. Although after repeated pressure exposure there was a tendency towards increasing microleakage, these differences were not statistically significant. Although the pressure changes had no effect on the root canal filling irrespective of the method used, the use of vertical condensation appeared to have superior sealing ability compared to lateral condensation and the tapered single-cone method and, therefore, may be the most suitable method for use in divers and aviators. According to our literature review, this study is the first evaluation of various environmental pressures on microleakage after endodontic treatment.

Conclusion

Within the limitations of this study based on the sealing ability of three assessed obturation methods, vertical condensation would seem to be the most suitable technique for use in divers and aviators. Typical diving pressure cycles demonstrated no significant adverse effects on sealing in endodontically treated teeth. However, further investigation is required applying new assessment methods and more highly sensitive detectors.

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Conflicts of interests: nil

Funding

The study was funded by a grant provided by the Vice-Chancellor of Research of AJA University of Medical Sciences, Tehran.

Submitted: 11 February 2018; final revision 23 January 2019
Accepted: 30 January 2019