Objective. We determined the effect of the angle of apical resection on apical leakage using a computerized fluid filtration device with a laser system and a digital air pressure regulator in 46 extracted single-rooted human teeth.

Orthograde endodontic treatment was performed. The root canals were prepared up to a size 50 K-type file with 17% EDTA solution (Roth International, Chicago, IL) and 5% NaOCl solution as the irrigant. Gates Glidden burs (Maillefer Instruments, Ballaigues, Switzerland) were used to flare the coronal two thirds of the canal. All canals were dried with paper points and then obturated with cold lateral condensation (except for the positive controls) of gutta-percha points and AH plus (Dentsply DeTrey, Konstanz, Germany). All 40 roots were sectioned 3 mm from the apex. Forty teeth were assigned randomly into 1 of 4 experimental groups of 10 teeth each: in group 1, the teeth were resected apically (90° angle) and the cavities were obturated with mineral trioxide aggregate (MTA); in group 2, after apical resection (90° angle), a root-end cavity was prepared using ultrasonic diamond retrotips and the cavities were obturated with MTA; in group 3, the teeth were resected apically (~45° angle) and the cavities were obturated with MTA; and in group 4, after apical resection (~45° angle), a root-end cavity was prepared using ultrasonic diamond retrotips and the cavities were obturated with MTA. An additional 6 teeth were used as controls (3 each, negative and positive controls). Apical leakage was measured using a computerized fluid filtration meter with a laser system.

Results. The mean apical microleakage was 2.0 ± 0.4 × 10⁻⁴, 1.6 ± 0.6 × 10⁻⁴, 1.6 ± 0.9 × 10⁻⁴, and 1.8 ± 0.7 × 10⁻⁴ μL/cmH₂O/min⁻¹ at 1.2 atm, in groups 1 to 4, respectively. Although the mean apical microleakage was greater in group 1, the differences among the 4 groups were not statistically significant (P > .05).

Conclusions. The results of these in vitro studies showed that when an adequate retrograde cavity depth is prepared, variation in the root-end cutting angle does not necessarily cause any difference in microleakage. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:e50-e55)

Studies have shown that bacteria are essential for the development of pulpal and periradicular diseases.

The goal of endodontic therapy includes the elimination of bacteria from the root canal system and the establishment of an effective barrier to prevent further passage of microorganisms or their products to the periapical tissues. Conventional endodontic treatment is successful in about 90% of cases. If root canal therapy fails, then retreatment is indicated, although retreatment then is not always possible and in these cases, endodontic surgery may be required.

Endodontic surgery involves a combination of curetage of infected tissue and removal of an infected or damaged root apex. Among the causes of failure in endodontic surgery, the most frequent is the incomplete sealing of all communications between the root canal system and periradicular tissues. Lin et al. showed that the bacteria that remain in the root canal system have access to the periradicular tissues after resection.

The angle of apical resection may influence root-end leakage. Access problems often result in the root being resected at an oblique angle to facilitate visibility, and the placement of the root-end filling material. This angled cut across the root introduces the possibility of creating another pathway for leakage to occur between the canal and apical tissues, through the exposed dentinal tubules. Tidmarsh and Arrowsmith showed that root ends resected at 45° to 65° angles have as many as 28,000 tubules/mm² in the area immediately adjacent to the canal and an average of 13,000 tubules/mm² at the cementodentinal junction, where they observed an area of potential communication with the root canal even in the presence of root end filling. Based on the number of dentinal tubules apparently communicating between the resected root face and the root canal, they suggested...
that the angle of the bevel be minimized and that the retrograde filling should extend coronally into the canal, at least to the level of the coronal end of the bevel. In contrast, Andreasen and Rud found no correlation between the degree of periradicular inflammation and bacteria in the dentinal tubules.

In this study, we examined the effects of different angles of apical resection on apical leakage using a computerized fluid filtration meter with a laser system and a digital air pressure regulator.

**MATERIAL AND METHODS**

**Root preparation**

The study examined 46 single-rooted human teeth that were extracted for various reasons; none had undergone endodontic therapy before extraction. All teeth were cleaned thoroughly, and then soaked in 5% NaOCl for 30 minutes, and stored in saline in the usual way. The crowns of the teeth were removed with a diamond disk (Diamond Wafering Blade, Buehler, IL) and water cooling, leaving roots 12 mm long. Ortho
grade endodontic treatment was then performed: the root canal length was determined by inserting a 15 K-type file into the coronal opening of the canal until it became visible at the apical foramen, and the working length was established as 1 mm shorter than that. The root canals were prepared up to a size 50 K-type hand file with a 17% EDTA solution (Roth International, Chicago, IL) and 5% NaOCl solution as the irrigant. Gates Glidden burs (Maillefer Instruments, Ballaigues, Switzerland) were used to flare the coronal two thirds of the canal. All canals were dried with paper points and then obturated with cold lateral condensation (except for the positive controls) of gutta-percha points and AH plus (Dentsply DeTrey, Konstanz, Germany). After root canal obturation, the roots were stored at room temperature in a 100% humidity environment.

**Root resection and placement of the retrograde filling**

All 40 roots were sectioned 3 mm from the apex: in half of the specimens, randomly selected, sectioning took place exactly as planned, the sectioning line was previously drawn on a wax base. The sectioning was made with a straight fissure diamond bur in a surgical hand piece (KaVo 3610 N1, W&H ImplantMED, Warthausen, Germany) with saline cooling.

- **Group 1:** the sectioning angle of the apex was 90° and a retrograde cavity was made with a stainless steel round bur Number 2.
- **Group 2:** the sectioning angle of the apex was 90° and a retrograde cavity was made with diamond-coated retrotips (E32D; NSK, Kanuma-Shi, Tochigi-ken, Ja).
- **Group 3:** the sectioning angle of the apex was ~45° and a retrograde cavity was made with a stainless steel round bur Number 2.
- **Group 4:** the sectioning angle of the apex was ~45° and a retrograde cavity was made with diamond-coated retrotips (E32D; NSK).

All 4 test groups had apical cavities prepared as follows. A 3-mm-deep root end preparation was made. Cold saline irrigation was used to avoid overheating. Retrograde sealing was performed using MTA (ProRoot, Dentsply, Tulsa Dental, Tulsa, OK).

**Determination of microleakage**

In this in vitro study, apical leakage was measured using the computerized fluid filtration meter method described by Orucoglu et al. (Fig. 1). For the leakage study, the apical root of the samples was inserted into a plastic tube from the apical side and connected to a stainless steel tube (18 gauge). Cyanoacrylate adhesive (Zapit, Dental Venture of America, Anaheim Hills, CA) was applied circumferentially between the root and plastic tube. The computerized fluid filtration meter with a laser system used in this study has a 25-µL micropipette (Microcaps, Fisher Scientific, Philadelphia, PA) mounted to it horizontally. Oxygen from a pressure tank at 120 kPa (1.2 atm) was applied to the apical side. The pressure was kept constant throughout the experiment by means of a digital air pressure regulator (DP-42 Digital pressure and vacuum sensors Red LED display SUNX Sensors, West Des Moines, IA, USA).
USA) connected to the pressure tank. The 25-μl micropipette (Microcaps, Fisher Scientific) was connected to the pressure reservoir by polyethylene tubing (Microcaps, Fisher Scientific). All pipettes, syringes, and the plastic tubes on the apical side of the sample were filled with distilled water. The water was sucked back approximately 2 mm with the microsyringe. This created an air bubble in the micropipette and the air bubble was adjusted to a suitable position in the syringe. A 5-minute pressurization preload of the system was completed before taking readings. The fluid movement was measured automatically for 2 minutes during the 8 minutes for each sample using computerized fluid filtration PC-compatible software (Fluid Filtration ‘03, Konya, Turkey; Fig. 2). The leakage quantity was expressed as μL/cmH2O/min−1 at 1.2 atm and the mean was determined.

Statistical analyses
Statistical analysis consisted of the Kruskal-Wallis test. The SPSS software (Ver. 10.0 for Windows; SPSS, Chicago, IL) was used.

RESULTS
The positive control group showed significantly more apical microleakage than all of the experimental groups, whereas the negative control group showed no evidence of apical microleakage. Fig. 3 shows the Kruskal-Wallis analysis results and apical microleakage values (mean ± SD) of the groups.

All of the experimental groups showed apical microleakage. The mean apical microleakage was 2.0 ± 0.4 × 10^{-4}, 1.6 ± 0.6 × 10^{-4}, 1.6 ± 0.9 × 10^{-4}, and 1.8 ± 0.7 × 10^{-4} μL/cmH2O/min−1 at 1.2 atm in groups 1 to 4, respectively. Although the mean apical microleakage was greater in group 1, the differences between the groups were not statistically significant (P > .05; Fig. 3).

DISCUSSION
This in vitro study tested the effect of different angles of apical resection on apical leakage using a computerized fluid filtration meter. In the past, the leakage of filling materials has been measured using the degree of penetration of a dye, radioactive isotope tests, bacteria or bacterial metabolite leakage tests, electrochemical means, or the glucose penetration model. These techniques have a variety of shortcomings. Derkson et al. developed a fluid filtration system to quantify the microleakage around coronal restorations. This technique was adapted by Wu et al. to measure the microleakage of root-end fillings. This type of system has various advantages. It provides quantitative, volumetric data. It uses positive pressure, which helps to eliminate the problems caused by entrapped air or fluid in dye leakage studies. It is non-destructive; thus, it allows repeated measurements on the same samples. The sensitivity of the system can be adjusted by altering the pressure used and the diameter of the measurement micropipette. The computerized
fluid filtration meter used in this study has some advantages over conventional ones with computer control and digital air pressure arrangements. Additionally, the movement of an air bubble can be observed with laser diodes under computer control, rather than visually.13

First, retrograde root fillings were performed on teeth with apical lesions after root resection. This technique is still used in endodontic surgery because teeth with lesions have more restorations than others and although root canal disinfection is performed, some foramens may stay infected.25 For maximum safety of the treatment, 3 mm of material has to be removed from the apical root end of the tooth.26,27 Accordingly, the roots in our study were sectioned 3 mm from the apex.

Root-end filling after root-end resection requires root-end cavity preparation. During preparation of this cavity, good visualization and easy access are the main criteria for choosing 30° or 45° resection angles.27-29 However, angled root-end resection also opens dentin tubules, which can increase the risk of bacterial contamination and microleakage, resulting in the failure of the endodontic surgery.30 Gagliani et al.10 stated that the microleakage increased significantly with increasing angulation of the resected root-end. In our study, the teeth were resected apically with angulations of approximately 45° and 90°, but there was no statistically significant difference in the microleakage among the groups (P > .05).

Other factors that affect microleakage include the type of retrograde filling material and depth of retrograde filling. Gagliani et al.10 showed that to obtain no microleakage, the ideal depth of the retrograde cavity for a 45° resection angle was at least 2.5 mm. They also claimed that an apical cavity of 3 mm or more along the vertical axis can produce a safe and effective seal. In our study, the root-end cavity depth in all groups was 3 mm.

The main purpose of the root-end filling material is to provide an apical seal that prevents the movement of bacteria and the diffusion of bacterial products from the root canal system into the periapical tissues. Gartner and Dorn31 proposed that the ideal root-end filling material should be easy to manipulate, radiopaque, dimensionally stable, nonabsorbable, insensitive to moisture, adhesive to dentin, nontoxic, and biocompatible. Many materials have been used for root-end fillings in endodontic surgery.32,33 Recently, an experimental substance, MTA, was suggested as a potential root-end filling material. In a series
of in vitro studies, Torabinejad et al.34-37 evaluated the sealing ability of MTA, compared with commonly used root-end filling materials. They showed that MTA had significantly less dye34,35 and bacterial36 leakage than amalgam, Super-EBA (Harry J. Bosworth Co., Skokie, IL, USA), or intermediate restorative material (IRM). Additionally, when the marginal adaptation of MTA root-end fillings was compared with those of amalgam, Super-EBA, and IRM using scanning electron microscopy, they reported no noticeable gap between the MTA and surrounding dentinal walls.37

In this study, white ProRoot MTA cement (Maillefer) was used as the root-end filling material. It was chosen in light of the many reports of the success of MTA.

Fogel and Peikoff38 evaluated the microleakage of MTA, Super-EBA, Clearfil Liner Bond 2 (J. Morita USA Inc., Tustin, CA), IRM, Permite C amalgam (Southern Dental Industries, Melbourne, Australia), and Zapit cyanoacrylate cement (Dental Ventures of America Inc., Anaheim Hills, CA) as root-end filling materials using a fluid filtration system. They studied 60 extracted human single-rooted teeth that were resected perpendicular to the long axis and the root-end cavities were prepared by ultrasonic tips. They found that the microleakage was 2.88 ± 1.03 × 10⁻⁵. In our study, group 2 followed a protocol similar to that of Fogel and Peikoff38 and we found microleakage of 1.6 ± 0.6 × 10⁻⁴. Fogel and Peikoff38 had higher microleakage; 2 reasons might be that they did not use a condensation of gutta-percha and did not use a sealer.

The results of these in vitro studies showed that when the root canal is confined hermetically, an adequate retrograde cavity depth is prepared, and variation in the root-end cutting angle does not necessarily cause any difference in microleakage.

REFERENCES

Reprint requests:
Hasan Garip, DDS, PhD
Department of OMFS
Faculty of Dentistry
Marmara University
Diş Hekimliği Fakültesi Nişantaşı
Kampusu, Büyük Çiftlik Sk.
No:6 34365 Nisantasi/Istanbul, Turkey
hasangarip@yahoo.com