Abstract: The apical third of most root canals shows some degree of curvature, which is important in cleaning/shaping and obturation during root canal treatment. The present study evaluated the effect of master cone size on the apical seal of severely curved root canals. Thirty-eight mesial roots of human mandibular first molars were prepared using the crown-down technique. All samples were mature roots with closed apices, had no carious lesions or resorption, and had a canal curvature of > 45º to 60º. Two samples were used as a negative and positive control to evaluate the fluid filtration equipment, and the remaining 36 samples were equally divided into groups A, B, and C based on master cone size, namely, gutta-percha #20, #25, and #30, respectively. The fluid filtration method was used to evaluate microleakage. No significant difference in microleakage was observed among groups (P = 0.31). In conclusion, an increase in master cone size up to #30 does not significantly influence apical microleakage. 

Keywords: apical seal; master cone; severe curve.
important research goal in endodontics (4). The present study used a fluid filtration method to evaluate the effect of master cone (MC) size on apical microleakage in severely curved (dilacerated) root canals.

**Materials and Methods**

A total of 250 human mandibular first molars underwent preliminary assessment for inclusion in the study. All teeth that satisfied the inclusion criteria (i.e., mature roots with closed apices, absence of carious lesions or resorption, and canal curvature (C) of $45^\circ < C \leq 60^\circ$) underwent radiographic examination. Canal curvature was measured using the Schneider technique (5). Ultimately, 38 teeth that satisfied all inclusion criteria were analyzed: 12 with a canal curvature of $45^\circ < C \leq 50^\circ$ were included in group 1, 12 with a canal curvature of $50^\circ < C \leq 55^\circ$ were included in group 2, and 12 with a canal curvature of $55^\circ < C \leq 60^\circ$ were included in group 3 (Fig. 1). In addition, two teeth were used as positive and negative controls for evaluating the fluid filtration equipment. Because we aimed to evaluate the effect of MC size on the apical seal of severely curved root canals, the investigated samples were divided into three groups: A, B, and C. Each group consisted of 12 samples, which were randomly selected from groups 1, 2, and 3, as follows (each group comprised four teeth from group 1, four teeth from group 2, and four teeth from group 3; Table 1): group A, MC size equal to gutta-percha #20; group B, MC size equal to gutta-percha #25; and group C, MC size equal to gutta-percha #30. After sample collection, the root surfaces were cleaned with a periodontal curette to remove all calculi and soft tissue. Then, the samples were disinfected by 5.25% sodium hypochlorite for 1 h.

First, a standard access cavity was prepared using a fissure bur (Dentsply/Maillefer, Tulsa, OK, USA). The canals that could not retain a #15 K-file (Maillefer, Dentsply, Ballaigues, Switzerland) in the apical area were excluded from the study at this stage and were replaced by new, suitable samples. After the access cavity

![Fig. 1 The different curvatures, as measured by the Schneider technique (a: 45°, b: 53°, and c: 60° of curvature)](image)

<table>
<thead>
<tr>
<th>Table 1 Distribution of samples between groups A, B, and C</th>
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<tbody>
<tr>
<td>Included teeth</td>
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<td>----------------</td>
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<tr>
<td><strong>Group A</strong></td>
</tr>
<tr>
<td>4 teeth from group 1 (with curvature of $45^\circ &lt; C \leq 50^\circ$)</td>
</tr>
<tr>
<td>4 teeth from group 2 (with curvature of $50^\circ &lt; C \leq 55^\circ$)</td>
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<td>4 teeth from group 3 (with curvature of $55^\circ &lt; C \leq 60^\circ$)</td>
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<tr>
<td><strong>Group B</strong></td>
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<tr>
<td>4 teeth from group 1 (with curvature of $45^\circ &lt; C \leq 50^\circ$)</td>
</tr>
<tr>
<td>4 teeth from group 2 (with curvature of $50^\circ &lt; C \leq 55^\circ$)</td>
</tr>
<tr>
<td>4 teeth from group 3 (with curvature of $55^\circ &lt; C \leq 60^\circ$)</td>
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<tr>
<td><strong>Group C</strong></td>
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<tr>
<td>4 teeth from group 1 (with curvature of $45^\circ &lt; C \leq 50^\circ$)</td>
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<tr>
<td>4 teeth from group 2 (with curvature of $50^\circ &lt; C \leq 55^\circ$)</td>
</tr>
<tr>
<td>4 teeth from group 3 (with curvature of $55^\circ &lt; C \leq 60^\circ$)</td>
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</table>
was completed, canal preparation was performed using K-Flexofiles (Maillefer, Dentsply) and crown-down technique. To preserve canal curvature, all files were pre-curved before insertion into the canals. A 27-gauge needle was used to irrigate each canal with 1 mL of 2.5% sodium hypochlorite after each file.

During preparation, each file was completely coated with RC Prep (Premier, Philadelphia, MS, USA), and patency was confirmed with a #10 K-file (Maillefer, Dentsply) after each file. After apical preparation up to the proper size (#20, #25, and #30 in groups A, B, and C, respectively), the canals were first irrigated with 3 mL of 17% EDTA for 30 s, after which they were irrigated with normal saline and then dried with paper points (Ariadent Co, Tehran, Iran).

Lateral compaction technique with an AH26 sealer (Dentsply, DeTrey, Konstanz, Germany) and nickel-titanium (NiTi) spreaders (Maillefer, Dentsply, Switzerland) was used for canal obturation. In group A, the MC was #20. In groups B and C, the MC was #25 and #30, respectively. The sealer was placed in the canal using a K-Flexofile (Maillefer, Dentsply).

The fluid filtration method was used to evaluate microleakage according to the procedure of Moradi et al. (6) (Fig. 2). Data were analyzed using SPSS 11 software with one-way ANOVA, two-way ANOVA, and the Tukey test.

### Results

Apical microleakage did not significantly differ with respect to MC size ($P = 0.31$). The maximum and minimum microleakage values were observed with a MC #20 (0.00027) and MC #25 (0.00002), respectively (Table 2). A supplementary analysis was performed to compare apical microleakage for different curvatures. For a canal curvature of $> 45^\circ$ to $\leq 50^\circ$, there was no significant difference in microleakage with respect to MC size ($P = 0.39$; Table 3). For a canal curvature of $> 50^\circ$ to $\leq 55^\circ$, there was no significant difference in microleakage with respect to MC size ($P = 0.48$; Table 4). For a canal curvature of $> 55^\circ$ to $\leq 60^\circ$, there was no significant difference in microleakage with respect to MC size ($P = 0.59$; Table 5).

### Discussion

Endodontic treatment of severely curved root canals is complicated by the difficulty of achieving a hermetic seal, as failure to do so can result in treatment failure (7). The present in vitro study evaluated the effect of MC size on the apical seal of severely curved (dilacerated) root canals and showed that an MC size up to #30 did not significantly increase apical microleakage.
The definition of dilaceration is controversial. Chohayeb (8) defined it as a deviation from the normal axis of the tooth of ≥ 20° in the apical portion; however, some researchers maintain that a root is dilacerated if there is a ≥ 90° angle along the root axis (9,10). In the present study, a curvature of 45–60º was studied. This decision was based on a recent study by Dastmalchi et al. (7), which showed that most Diplomates of the American Board of Endodontics (ABE) believe that a dilacerated root should have a curvature of > 40°.

Apical transportation due to canal preparation of severely curved root canals may be an important factor in apical leakage of such canals. Crown-down technique was found to be the best method for preparing severely curved root canals (7) and was therefore used in present study.

Our decision to use stainless steel hand files in this study was based on a report by Szep et al. (11), which showed that, in preparing curved canals, stainless steel hand instruments caused significantly less transportation than did NiTi hand instruments. In addition, other studies found that NiTi rotary instruments were not suitable for dilacerated canals because of the severity and extent of the curvatures that must be negotiated (2,12). However, some researchers believe that NiTi instruments (rotary or hand) are better for preparing curved canals, as they may result in fewer procedural errors as compared with traditional stainless steel hand instruments (13,14). Thus, the use of stainless steel hand files may or may not be considered a shortcoming of our study.

It has been shown that smear layer removal improves the ability of filling materials to prevent fluid transport in vitro (15,16). In the present study, 17% EDTA was used for 30 s after mechanical canal preparation, which may not have been sufficient to remove the smear layer. This may be a concern; however, a 30-s EDTA irrigation was shown to remove the smear layer (17), although the same study found that a 1-min EDTA irrigation resulted in greater smear layer removal as compared with the 30-second irrigation (17). Thus, a 1-min irrigation with 17% EDTA may be preferred in future studies.

Although lateral compaction of curved canals may be effective in most teeth, it can be very difficult in severely curved canals. In cases where small, flexible spreaders cannot reach to approximately 1 mm of the working length, lateral compaction may not be the technique of choice (7,18). Although the survey of Dastmalchi et al. (7) showed that most ABE Diplomates chose thermoplasticized technique as the best method to obturate severely curved canals, lateral compaction was utilized in the present study because of its widespread use (it is the most commonly used technique in Europe and the United States) (19).

Sealer application in severely curved canals is another important point. Whereas most sealers shrink and dissolve over time, gutta-percha is a stable core material. Therefore, the amount of sealer used for canal obturation should be minimized. Namely, the sealer should be present only in a thin layer between the core material and dentinal walls (20). The great importance of using proper sealer was highlighted by Zarei et al. (21), who showed that canals with greater curvature had a larger apical gap in their canal fillings. Resin-based sealers may be more suitable for curved canals because of their lesser solu-

<table>
<thead>
<tr>
<th>Size</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
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<tbody>
<tr>
<td>20</td>
<td>0.00009</td>
<td>0.00027</td>
<td>0.00014</td>
<td>0.000085</td>
</tr>
<tr>
<td>25</td>
<td>0.00002</td>
<td>0.00012</td>
<td>0.00009</td>
<td>0.000047</td>
</tr>
<tr>
<td>30</td>
<td>0.00007</td>
<td>0.00024</td>
<td>0.000145</td>
<td>0.000071</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>0.00012</td>
<td>0.000068</td>
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Test result: $P = 0.48$, $F = 0.79$
bility in fluids (22). In the present study, the resin-based sealer AH26 was used in the proper manner. Different techniques are used to evaluate canal obturation quality, including dye penetration (23), clearing (24), bacterial penetration (25), and cone-beam computed tomography (CBCT) (20). In the present study, microleakage was evaluated by the fluid filtration method, as in a study by Moradi et al. (6). The only difference between their and our study was in camera magnification: we used a magnification of 0.55, and the accuracy of the computer in recording the movement of bubbles (based on the actual amount of movement) was 0.055 mm. The fluid filtration method was used because it is nondestructive and can be used in longitudinal studies. Another reason for selecting fluid filtration was that most other methods are not suitable under some experimental conditions, such as chemical reactions. In fact, some staining agents used in conventional testing methods react with dentin, which may lead to unfavorable results. The fluid filtration method avoids these disadvantages because it does not require any chemical agent for testing (6).

Our results regarding microleakage evaluation were consistent with the results of studies by Gutmann et al. (26) and Leung and Gulabivala (27), in which an increase in canal curvature resulted in a decreased apical seal. There are several studies of the effect of MC size on the apical seal and the extent of debridement. Yared and Dagher (28) found no significant difference in intracanal bacterial counts between master apical file (MAF) sizes #25 and #40. Coldero et al. (29) showed that enlarging the apical area did not decrease bacterial counts within canals. In studies by Card et al. (30) and Rollison et al. (31), an increase in MAF size increased removal of intracanal bacteria. However, the findings of these previous studies cannot be compared with the present results because those studies did not investigate severely curved canals. Because no similar studies of teeth with severe canal curvatures (similar to the curvatures in the present study) have been published, this study can be considered a pioneer in the field.

In conclusion, within the limitations of this study an increase in MC size (up to #30) did not significantly influence apical microleakage.

**Acknowledgments**

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**References**

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