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# Curved Root Canals: Effects of Dimensional Parameters on the Insertion Depth of Irrigation Needles

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## Abstract

**Objective**: To investigate the effects of size and taper of the apical preparation, root canal curvature and cannula diameter on the insertion depth of irrigation cannulas into root canals.

**Study Design**: One hundred and four root canals were divided into four curvature groups (0-5°; 6°-15°; 16°-25°; >25°). After apical enlargement to size 25.06 a 25G and a 30G irrigation cannula were inserted until binding. The distance between the cannula tip and the working length was related to the root canal length. The insertion procedure was repeated after enlargement to 40.04.

**Results**: In curved canals (>6°), the cannula never reached WL. With an apical preparation of 40.04 the 30G cannula could be introduced nearly to WL even in moderately curved canals (<26°).

**Conclusion:** Only a 30G cannula allows delivery of the irrigant to the apex of a curved root canal. The cannula could be inserted closer to WL when the apical preparation size was wider with a smaller taper compared to a small apical preparation size with a wider taper.

**Keywords:** Apical preparation; Insertion depth; Irrigation; Needle; Root canal curvature

## Introduction

The complexity of the root canal system is thought to be the strongest limitation to root canal disinfection as it impedes complete mechanical instrumentation of the root canal. Therefore, irrigants with chemical and mechanical effects are required to reach the regions of the root canal that remain untouched by mechanical preparation alone. To enhance the cleaning and disinfection of the apical region of the root canal, various aspects have to be considered. Canal size, canal taper, diameter of the irrigation cannula and its insertion depth into the root canal as well as irrigant volume are important variables influencing the delivery of the irrigant [1-9]. Also, elements of the design of the irrigation cannula such as location of the opening, pressure applied, fluid properties and velocity of the irrigant at the tip of the cannula have an impact [3-11]. Optimisation of these factors seems to be a step forward to improve conventional irrigation.

Root canal irrigants should flush out debris and remove the smear layer, dissolve organic tissue, eliminate microbes and their by-products [3-7]. To fulfil these demands, the irrigation solution needs to reach the apical and intractable canal regions, and the exchange of the irrigant should be enabled [12,13]. Studies have suggested that the tip of the injection cannula should be placed as close as possible to the apical end of the canal for effective cleaning [3-15]. Significant differences in the reduction of bacterial counts were found when cannulas were inserted 1 and 5 mm from the apex [8]. A recent study found that flushing of the apical region is possible when the tip of an open-ended irrigation cannula is placed 3 mm from the apex [15]. However, all of these studies evaluated straight root canals. Walton and Torabinejad even reasoned that the delivery system, and not the irrigation solution *per se*, might be the most important factor [14].

Increased size of canal instrumentation at working length produces an increase in canal cleanliness [16,17], demonstrating that adequate apical preparation size is needed to assure sufficient disinfection. Particularly in infected cases, root canals should be prepared apically to larger sizes than are normally recommended, i.e., at least six file sizes larger than the first apical binding file [18]. An increased taper may also facilitate irrigation and help improve efficacy in curved canals. The taper of the preparation has been investigated in the context of ultrasonic irrigation and found to have a significant effect [19]. Moreover, taper of preparation has been found to be a significant factor in removing stained bio-molecular film from root canals by syringe irrigation ex vivo [20]. To the best of our knowledge, there are no data about the insertion depths of different irrigation cannula types in curved canals in relation to the taper and apical preparation size.

The aim of this study was to investigate the effects of size and taper of the apical preparation, root canal curvature and cannula tip diameter on the insertion depth of irrigation cannulas into root canals.

## Materials and Methods

Thirty-five extracted molars and premolars with 104 root canals were collected. The apices of all roots were fully formed. They were cleaned and stored in Ringer solution until usage. The roots of the teeth were embedded in silicone (Coltène Whaledent Coltoflax, Switzerland) formed in a cuboid shape, allowing identical projections for the radiographs. The root apices remained visible to facilitate length measurement. Access to the root canal system was obtained, and the canal entrances were located. A coronal reference point (P) was defined for each root canal, and the distance from this point to the canal entrance (E) was recorded in mm to the nearest 0.5 mm using a periodontal probe. After checking the root canal for patency, canal length was measured. Tooth length was individually determined by

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inserting a file until it was just visible at the apical foramen (A). To establish working length (WL), 0.5 mm was subtracted from the tooth length. Root canals were initially prepared manually with K-Files until #15. To record the root canal curvature, hand files were inserted into the root canals. The embedded teeth were attached to Kodak ultra-speed film (Kodak, Stuttgart, Germany), and radiographs of each tooth were taken in the mesio-distal (proximal) and bucco-oral (clinical) directions perpendicular to the central X-ray beam under standardised conditions. The radiographs were digitized and the degree of curvature measured according to the method of Schneider [21] using Corel Draw X3 (Version 13.0). Root canals were divided into four groups based on the degree of maximum curvature: straight (0-5°), slightly curved (6-15°), moderately curved (16-25°) and severely curved (>25°).

In a first step, the root canals were prepared with Mtwo files (VDW Dental Munich; Germany) 10.04, 15.05, 20.05 and 25.06 to working length (WL) using the Endo IT Professional motor (VDW Dental Munich, Germany). Between each instrument, the root canal was irrigated with 2 ml of Ringer solution. Four root canals had to be excluded due to instrument fractures or apical obliteration.

Irrigation cannulas with a lateral opening (Max-I-Probe 30G ≙ 0.3 mm, Dentsply International; York, USA) were placed in the root canals until binding was felt. The insertion depth of the cannula was measured by adjusting a silicone stop to the coronal reference point (P). The insertion depth of the irrigation cannula was measured to the nearest 0.5 mm with a Minifix Endo Gauge (VDW Dental Munich, Germany). This procedure was repeated with the wider 25G irrigation cannulas (Max-I-Probe 25G ≙ 0.5 mm, Dentsply International), and the insertion depth was confirmed by X-ray.

In a second step, root canals were further shaped with Mtwo instruments up to 40.04, and a second X-ray was taken after setting the Max-I-Probe 30G or the Max-I-Probe 25G (see Figure 2).

The distance (X) between the tip of the irrigation cannula and the WL was recorded in mm and quantified as a percentage of the canal length ( $\overline{EA} = \overline{PA} - \overline{PE}$ ). All values under 10% were rated as acceptable because they represented a distance of ≤1 mm to the WL. For statistical analysis, mean values of 'X' and the 95% confidence intervals (CIs) were calculated. For group comparisons, the mean differences in X and the corresponding 95% CIs were calculated. A significant difference between two groups was indicated when the CI did not include 0.

## Results

A total of 100 root canals were analysed. The results are summarised in Figure 1. Two thirds of the root canals were either slightly or moderately curved. Using the 25G irrigation cannula at an apical size of 25.06, the mean value of X was 40%, whereas X was reduced to 28% at an apical size of 40.04.

The use of the smaller 30G irrigation cannula resulted in a reduction of the mean value of X from 16% to 3%, particularly when increasing the apical preparation size from 25.06 to 40.04.

In curved root canals (>6°), the cannula never reached WL. Regardless of the cannula diameter, X decreased with decreasing root canal curvature and increasing apical preparation size. Use of a 25G irrigation cannula resulted in X values that represented approximately 20% to 46% of the canals' length. The 30G irrigation cannula could nearly be inserted to the WL even in moderately curved canals (< 26°) when the apical preparation size was 40.04 (0.9-9.1%). The CIs revealed significant differences between the insertion depths of 25G and 30G irrigation cannulas in the four curvature groups (Table 1). The increase in insertion depth when using the smaller 30G irrigation cannula was more pronounced than that observed after apical enlargement from 25.06 to 40.04 (Figure 2).

## Discussion

This study focused on the relationships between insertion depth of conventional irrigation cannulas, root canal curvature, apical size and taper of preparation. Although contemporary manual and machine-assisted agitation devices have advanced during the last decade, the correlation of the clinical efficacy of these devices with improved treatment outcomes has not been proven to date [22]. Manual syringe irrigation with irrigation cannulas is needed and can be considered as a standard in root canal treatment.

In the present study, the 25G irrigation cannula, which is widely

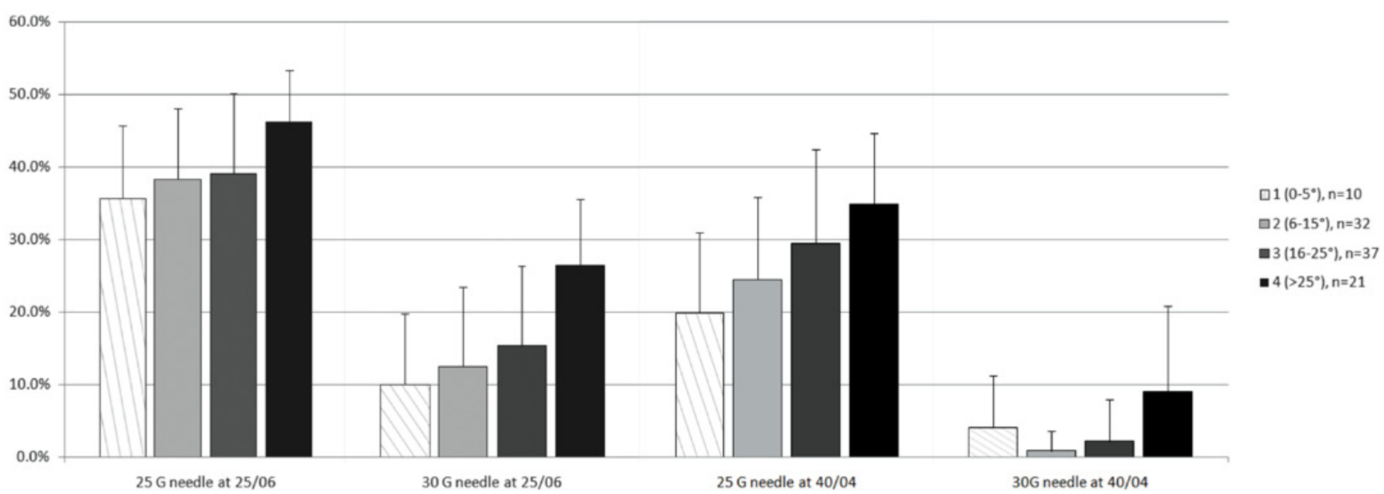


**Figure 1:** Portion of apex not reached by irrigation cannula tip in % (mean values and standard deviations).

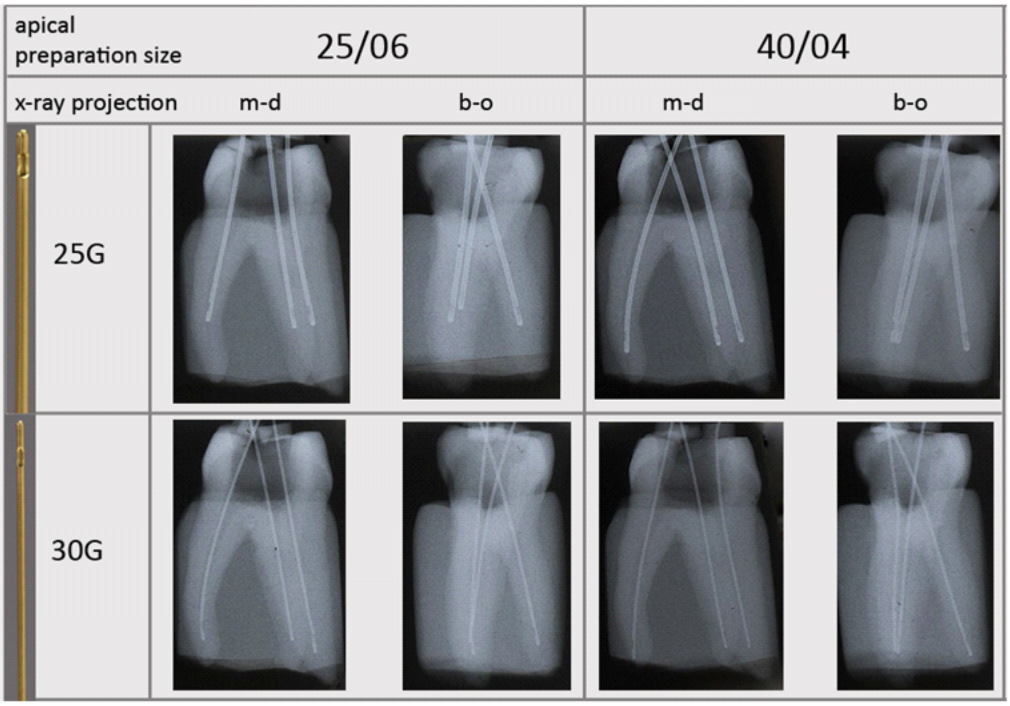


**Figure 2:** Examples of insertion depth of irrigation cannulas depending on preparation size, taper and diameter of the irrigation cannula. The example demonstrates that the increase in insertion depth derived from decreased cannula size at a given preparation size is more pronounced than that derived from increased preparation size at a given cannula diameter (see Table 1).

| | **Influence of needle size at a given preparation size** | | **Influence of preparation size at a given needle diameter** | |
|---|---|---|---|---|
| | **25/06** | **40/04** | **25 G** | **30 G** |
| **Group** | **Δ 25 G to 30 G** | **Δ 25 G to 30 G** | **Δ 25/06 to 40/04** | **Δ 25/06 to 40/04** |
| 1 (0-5°); n=10 | 2.7 mm (CI: 2.09-3.41) | 1.7 mm (CI: 0.79-2.51) | 1.8 mm (CI: 0.9-2.7) | 0.8 mm (CI: 0.00-1.40) |
| 2 (6-15°); n=32 | 2.9 mm (CI: 2.35-3.31) | 2.5 mm (CI: 2.10-2.93) | 1.6 mm (CI: 1.04-2.1) | 1.2 mm (CI: 0.83-1.64) |
| 3 (16-25°); n=37 | 2.7 mm (CI: 2.27-3.02) | 2.9 mm (CI: 2.50-3.47) | 1.2 mm (CI: 0.74-1.48) | 1.4 mm (CI: 1.1-1.8) |
| 4 (>25°); n=21 | 2.1 mm (CI: 1.72-2.47) | 2.7 mm (CI: 2.09-3.29) | 1.3 mm (CI: 0.93-1.64) | 1.9 mm (CI: 1.24-2.52) |
| **Mean** | **2.63** | **2.61** | **1.41** | **1.38** |

**Table 1:** Differences (Δ) in millimetres with CIs, reflecting the influences of preparation size and irrigation cannula diameter on the apical part of the WL not reached by the irrigation cannula.

accepted amongst clinicians, was compared to a 30G safety-ended irrigation cannula with a markedly smaller diameter. Boutsioukis [23] reported insignificant aberrations in the diameters of cannulas of the same size.

Wider diameters of the irrigation cannula correlate with higher flow rates when applying the same pressure to the syringe plunger. However, when delivering the irrigant 1 mm or more beyond a small cannula tip, the pressure far exceeds that normally applied in clinical practice [24]. Irrigant replacement under clinical flow rate conditions can only be obtained less than 1 mm beyond the cannula tip [5-24]. Therefore, placement of the cannula tip within 1 mm of the WL is required.

In the present experiment, the penetration depth of the cannula, defined by the position where the cannula was bound, yielded reproducible results. The irrigation tip was inserted to this point with soft pressure until binding was felt. Clinically, it is recommended to place a safety-ended irrigation cannula 1 mm short of this binding point. In contrast, a recent study demonstrated by thermal imaging that placement of a cannula 3 mm from the apex permits the irrigant to reach the apex [15]. However, this experiment used open-ended cannulas in artificial straight root canals with different apical diameters. Peak pressure might have been higher due to the use of an open-ended cannula which may cause a “water cannon effect” with undesirable clinical complications. Another in vitro study confirmed that 25G open-ended cannulas and laser disinfection led to extrusion of irrigant over the apex [25]. When using a 25G safety-ended cannula, no irrigant extrusion could be detected. Bradford et al. showed that cannula tip design had no significant effect on apical pressure, whereas diameter of the cannula, distance to the apex and dimensions of the root canal played more important roles [26]. This was confirmed by Hsieh and co-workers, who found that larger cannula or root canal diameters correlated with stronger apical pressure [15]. Moreover, an in vitro study showed that significantly more bacteria could be eliminated by using safety-ended cannulas than by using anaesthesia cannulas or double side-port cannulas [27].

The present results demonstrate that both adequate apical preparation size (#40) and increased taper permit insertion of the cannula deeper into the root canal regardless of its curvature. The largest differences were observed when the 25G cannula was compared to the 30G cannula at a given preparation size (Figure 1). This demonstrates that the cannula size has the strongest influence under consideration of the root canal taper.

Likewise, apical enlargement significantly decreases bacterial amounts [28-30], and increased taper helps to remove infected dentine in the middle and coronal third of the root canal [31]. On the other hand, a small apical preparation with an increased taper does not guarantee that the most heavily infected dentine layer is removed in the apical third [17]. Furthermore, syringe irrigation is less effective when the root canals are enlarged to less than #40 [2-32]. However, the role of the taper should not be underestimated: with an apical preparation of #40 but a taper of only 2%, a 25G irrigation cannula could not be placed 3 mm short of the apex in straight root canals [15]. This is in line with the results of the present study: the influence of the cannula size on the insertion depth was even more pronounced when preparation size was 25/06 compared to 40/04 (Figure 1, Table 1). This demonstrates, that a wider taper alleviates the protrusion of a smaller cannula to the apical region. The 25G cannula tip could not be placed closer than 2.2 mm to the WL in straight root canals, even though they were enlarged to size 40.04. In curved root canals, the same cannula could not be inserted to the apical 3 mm of the root canal. In contrast, the 30G irrigation cannula could be placed to within 1 mm of the WL in all cases.

The results of the current study support the idea that greater curvature requires an appropriate apical preparation that facilitates the insertion of the cannula into the apical part of the root canal. In addition to the increased apical preparation size, use of the smaller 30G cannula eased the approximation of the cannula tip to the apical region due to its higher flexibility as compared to the 25G cannula. The utility of pre-bending of irrigation cannulas was not investigated in this study. A mean gain of about 4 mm (95% CI: 3.72 mm; 4.24 mm) was recorded when inserting a 30G cannula into a size 40.04 root canal as compared to a 25G cannula in a smaller size 25.06 root canal. The variations detected when using the 30G irrigation cannula at size 40.04 might be due to the distribution of different canal types within the curvature groups. Groups 2 and 3 included many palatal root canals of maxillary molars and distal root canals of mandibular molars. These root canals are mostly characterised by large curvature radii [33], enabling the approximation of the irrigation cannula to the apex even with increasing curvature. Severe curvature angles (group 4) are mostly associated with smaller radii [33].

It can be concluded that, regardless of the degree of canal curvature, sufficient approximation to WL is not possible with a 25G cannula, even when the root canal is prepared to a size of 40.04. A wider taper with a smaller apical preparation size does not show advantages in terms of irrigant transportation to the apex. In curved root canals, placement of the irrigation cannula near WL requires a larger apical preparation size, preferably not less than 40.04, and an irrigation cannula with a diameter of 30G.

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