The Effect of Needle-insertion Depth on the Irrigant Flow in the Root Canal: Evaluation Using an Unsteady Computational Fluid Dynamics Model

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Abstract

Introduction: The aim of this study was to evaluate the effect of needle-insertion depth on the irrigant flow inside a prepared root canal during final irrigation with a syringe and two different needle types using a Computational Fluid Dynamics (CFD) model. **Methods:** A validated CFD model was used to simulate irrigant flow from either a side-vented or an open-ended flat 30-G needle positioned inside a prepared root canal (45 .06) at 1, 2, 3, 4, or 5 mm short of the working length (WL). Velocity, pressure, and shear stress in the root canal were evaluated. **Results:** The flow pattern in the apical part of the root canal was similar among different needle positions. Major differences were observed between the two needle types. The side-vented needle achieved irrigant replacement to the WL only at the 1-mm position, whereas the open-ended flat needle was able to achieve complete replacement even when positioned at 2 mm short of the WL. The maximum shear stress decreased as needles moved away from the WL. The flat needle led to higher mean pressure at the apical foramen. Both needles showed a similar gradual decrease in apical pressure as the distance from the WL increased. **Conclusions:** Needle-insertion depth was found to affect the extent of irrigant replacement, the shear stress on the canal wall, and the pressure at the apical foramen for both needle types. *(J Endod 2010;36:1664–1668)*

Key Words

Computational Fluid Dynamics, insertion depth, irrigation, needle

Irrigation of root canals with antibacterial solutions is an integral part of chemomechanical preparation, aiming at the removal of bacteria, debris, and necrotic tissue, especially from areas of the root canal that have been left unprepared by mechanical instruments (1). Irrigants are commonly delivered using a syringe and needle (2, 3), even before passive ultrasonic activation of the solution (4). The significance of the needle position in relation to the apical terminus of the preparation, also described as needle insertion depth or penetration, has been highlighted in a series of *in vitro* (5) and *ex vivo* studies (6-9). It has been hypothesized that positioning the needle close to the working length (WL) could in fact improve the debridement and irrigant replacement (6, 10). However, previous studies have mainly focused on the removal efficiency of debris and bacteria and provided little understanding of the etiology (ie, the flow pattern developed in the root canal that leads to debridement and irrigant replacement). Limited insight in the fluid dynamics of the flow inside the root canal has been presented using thermal image analysis (9) because this approach could only provide a coarse estimation of the irrigant flow.

A Computational Fluid Dynamics (CFD) model was recently introduced as a method to study root canal irrigation (11). This model was subsequently validated by comparison with experimental high-speed imaging data (12) and used to evaluate the effect of needle tip design on the flow (13). In these previous studies, needles were positioned at 3 mm short of the WL. A similar approach has also been reported (14, 15), but the effect of needle insertion depth on the irrigant flow has not been studied in detail. The aim of this study was to evaluate the effect of needle insertion depth on the irrigant flow inside a prepared root canal during final irrigation with a syringe and two different needle types using the validated CFD model.

Materials and Methods

The root canal and apical anatomy were simulated similarly to a previous study (11), assuming a length of 19 mm, an apical diameter of 0.45 mm (ISO size 45), and 6% taper. The apical foramen was simulated as a rigid and impermeable wall, corresponding to a closed system.

Two different needle types, a side-vented and an open-ended flat needle, were modeled using commercially available 30-G needles as references, similar to a previous study (13). The external and internal diameter and the length of the needles were stan-

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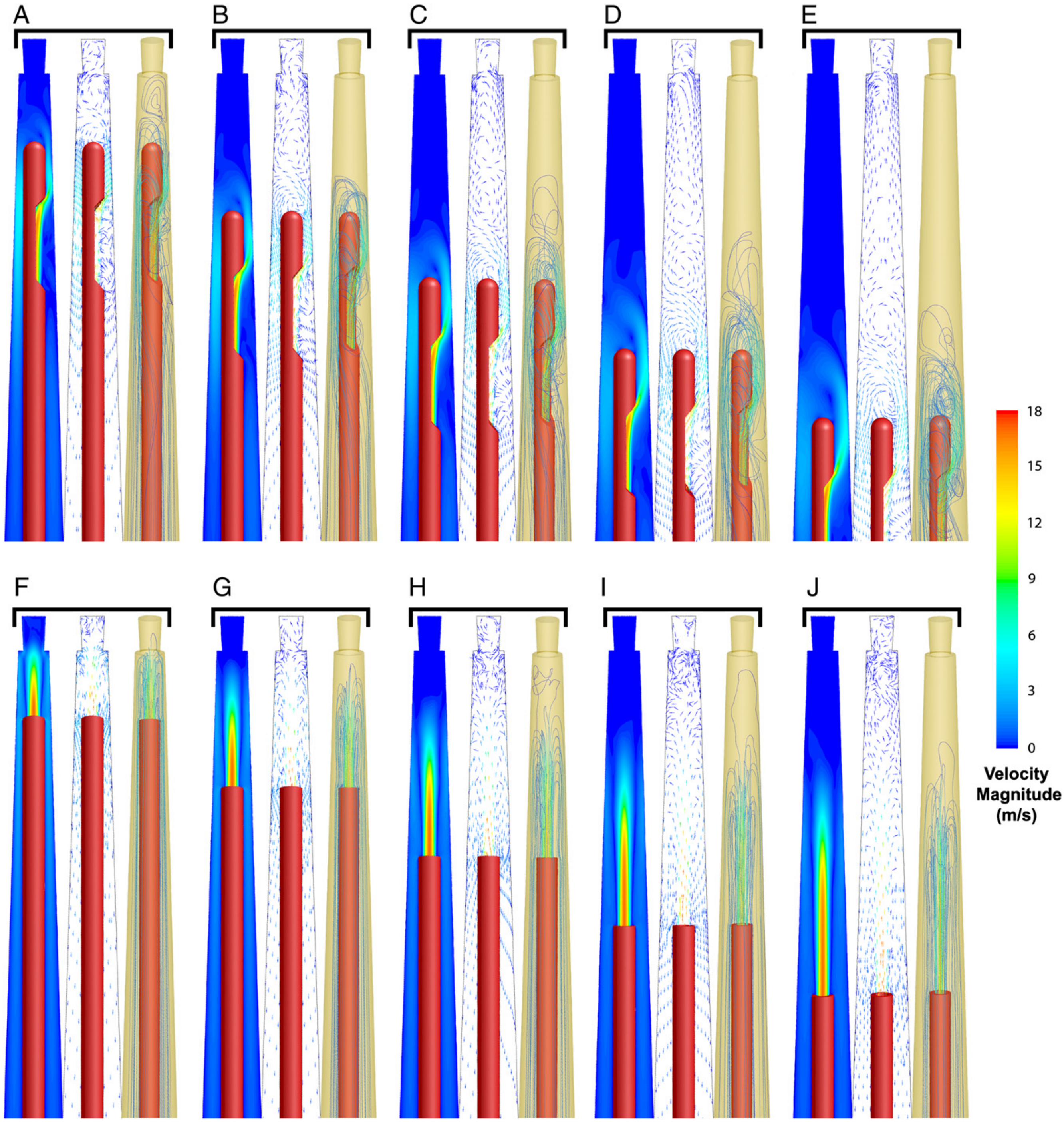

Figure 1. Triads of time-averaged contours of velocity magnitude (*left*) and vectors (*middle*) along the z-y plane in the apical part of the root canal and streamlines indicating the route of mass-less particles released downstream from the needle inlet and colored according to the time-averaged velocity magnitude (*right*) for the (*A-E*) side-vented and (*F-J*) flat needle positioned at 1 to 5 mm short of the WL, respectively. Particle trajectories provide visualization of the fresh irrigant main flow in three dimensions. (*A-E*) A series of counter-rotating vortices (flow structures where the fluid is rotating) apically to the side-vented needle was identified regardless of needle position. The size and position of the vortices varied, and the number or vortices increased as the needle was positioned further away from the WL. (*F-J*) A high-velocity jet of irrigant along the longitudinal axis of the root canal (z-axis) was identified apically to the flat needle, which extended even further than the apical constriction in the 1-mm case. The jet appeared to break up gradually because of the recirculating flow and damping by the irrigant already present in the canal. Jets extended longer away from the tip of the needle as the needle moved further away from the WL. Needles are colored in red. (This figure is available in color online at www.aae.org/joe/.)

dardized (D_{ext} = 320 μm, D_{int} = 196 μm, and l = 31 mm, respectively). The needles were fixed and centered within the canal. Five different depths were simulated for each needle type, namely 1, 2, 3, 4, and 5 mm short of the WL.

The preprocessor software Gambit 2.4 (Fluent Inc, Lebanon, NH) was used to build the three-dimensional geometry and the mesh. A hexahedral mesh was constructed and refined near the walls and in the areas in which high gradients of velocity were anticipated, such as