Plasmas in Tooth Root Canal

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***Abstract*—Using the plasma generated inside the root canal rather than the afterglow of the plasma will significantly improve the inactivation efficiency. In this paper, images of three kinds of atmospheric-pressure low-temperature plasma devices driven by different power supplies in the tooth root canal are reported. The images of an R-needle device driven by a dc power supply inside the root canal using different gases (He, Ar, and surrounding air) are also presented.**

***Index Terms*—Discharge, inactivation efficiency, plasma jet devices, tooth root canal.**

IT HAS been reported that the low-temperature plasmas could effectively inactivate bacteria [1]. In this paper, three kinds of atmospheric-pressure low-temperature plasma devices are used to generate plasma inside the tooth root canal under different conditions. One device is the so-called single-electrode plasma jet device [2], another is an RC-needle plasma device [3], and the third one is an R-needle plasma device driven by a dc power supply [4]. Details about the three devices can be found in [2]–[4]. The length of the root canals used in all the experiments is about 1.5 cm.

Fig. 1 shows the schematic of three plasma devices (top) and the images of the plasma inside the root canal (bottom). Both the single-electrode plasma device and the RC-needle plasma device are driven by a pulsed dc power supply. The R-needle device is driven by a dc power supply. The working gas used in all of these experiments is He with a flow rate of 1 L/min. For the pulsed dc power supply, the applied voltage V_a of 8 kV, the frequency of 8 kHz, and the pulsewidth of 1600 ns [used in Fig. 1(a) and (b)] are fixed, while the dc power supply used in Fig. 1(c) is fixed at an amplitude of 16 kV. In Fig. 1(a), the nozzle of the syringe is put vertically on the top of the root canal to allow the plasma to flow into the root canal. Two discharge currents pulse in each voltage pulse period (rising edge and falling edge), and the plume current is about 300 mA. It shows clearly that the plasma inside the root canal is very weak. This is due to the short lifetime of the plasma and the narrow channel of the root canal. However, this device could decrease about two orders of *Enterococcus faecalis* within only 5 min [5]. In order to improve the inactivation efficiency, plasma is better generated locally, i.e., inside root canals. In Fig. 1(b), the needle is placed into the root canal. The plasma inside the root canal is very bright, which indicates that the plasma is more active in the inactivation of microorganisms. Three current peaks ($\sim$0.1 A) appear in each voltage pulse period when the plasma is on, but the actual discharge current is $\sim$10 mA. In Fig. 1(c), the device uses a dc power supply. The needle is connected to the power supply through a 100-MΩ resistor. The discharge current with the amplitude of about 17 mA appears periodically with a frequency of $\sim$25 kHz, and the current pulsewidth is less than 100 ns. Although the plasma inside the root canal is not as bright as that in Fig. 1(b), the dc power supply used in this device is much cheaper than the pulsed dc power supply.

In Fig. 2, the images of the plasma created by the R-needle plasma device using different gases (He, Ar, and air) inside the root canal are shown. Fig. 2(a) shows the schematic of the R-needle plasma device driven by the dc power supply (16 kV). Fig. 2(b)–(d) shows the images of the plasma inside the root canal using He, Ar, and air with the flow rate of 1 L/min, respectively. As we can see from the images, we are capable of generating plasmas inside the root canals using the three kinds of gases. When air is used, we can actually generate plasma without the airflow. As we can see from the three photographs, the brightness of the plasma for the three cases has no obvious difference. For practical applications, using air as the working gas is the most convenient and cheapest.

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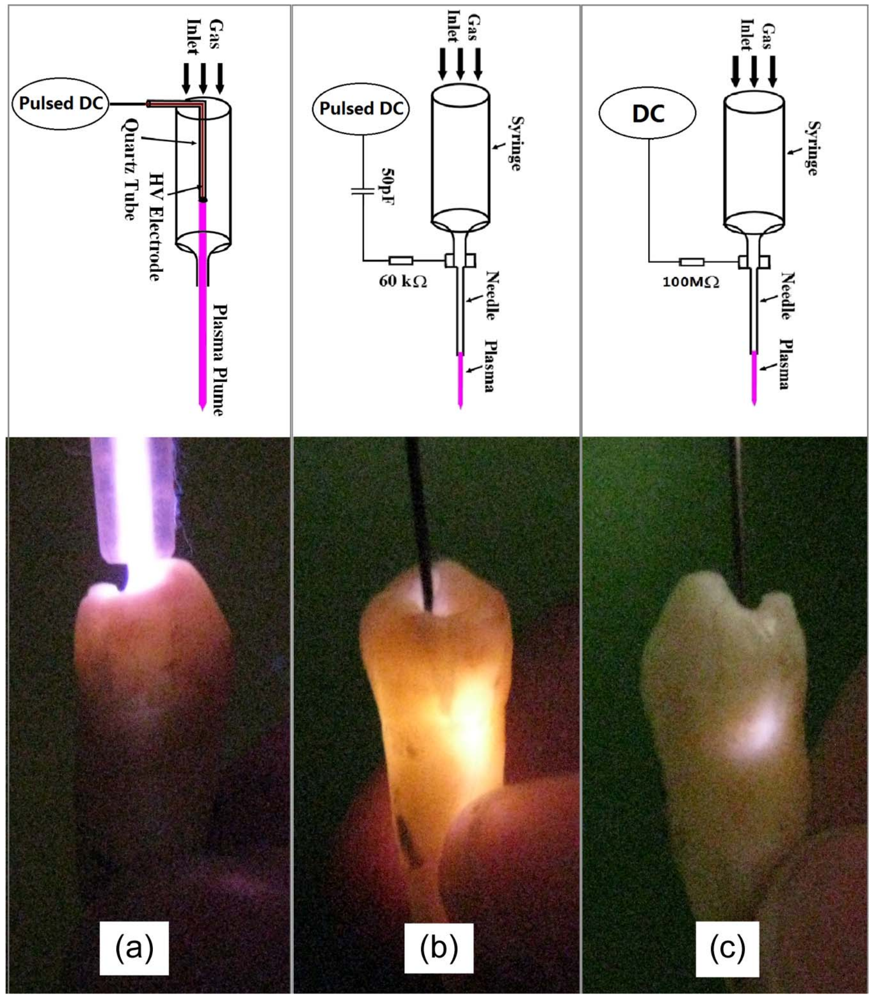

Fig. 1. Schematic of the plasma devices and the images of plasmas inside root canals. (a) Schematic of the single-electrode plasma jet device and the photograph of the plasma in front of the root canal. (b) Schematic of the RC-needle plasma device and the photograph of the plasma inside the root canal. (c) Schematic of the R-needle device and the photograph of the plasma inside the root canal.

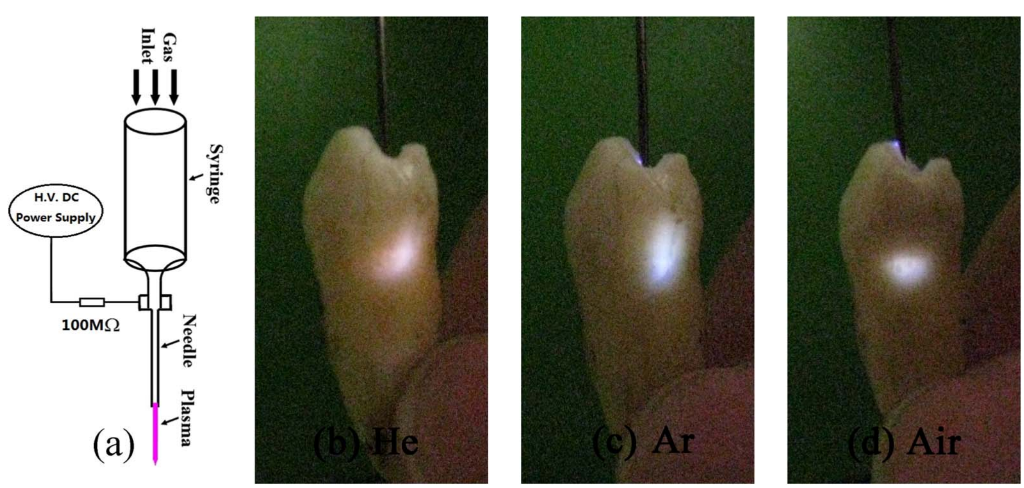

Fig. 2. Schematic of the R-needle plasma device and plasmas inside root canals using different gases. (b) He. (c) Ar. (d) Air.