Letter to the Editor

Dear Professor Dummer

I am writing to comment on a recent review article published in the *International Endodontic Journal* on electronic apex locators (Gordon & Chandler 2004). I have several comments concerning their description of the classification and fundamental electronics of these devices.

The protocol followed by the authors was commendable. They reviewed more than 113 relevant articles in English and attempted to simplify, clarify and classify them. On page 428 of the article in a paragraph entitled 'The first generation' it was stated that: '…It used the resistance method and alternating current as a 150 Hz sine wave.' According to numerous articles (Sunada 1962, Suchde & Talim 1977, McDonald 1992, Kim & Lee 2004) the first generation of electronic apex locators were similar to the electronic ohmmeter that used direct current and measured the resistance between the periodontal ligament and the oral mucosa. Direct current (DC) is fixed throughout time, whereas alternative current (AC) alternates with time. The sine wave, the frequency of which is measured in units of hertz (Hz), is fundamental to alternative current and voltage. To measure resistance, a direct current is sufficient; in other words, it is not practical to use alternative current in resistance based apex locators. The devices that use alternative current measure impedance that is comprised of resistance and capacitance. They are usually classified as second generation or impedance type devices (Glickman 1969, McDonald 1992).

Under the heading 'The second generation' the authors stated that: 'Second generation apex locators were of the single frequency impedance type which used impedance measurement instead of resistance to measure location…' and continued: 'The property is utilized to measure distance in different canal conditions by using different frequencies'. These two descriptions are obviously in contradiction. In the former they wrote about the single frequency, although in the latter they mentioned different frequencies utilized in the second generation. According to many articles (McDonald & Hovland 1990, Keller *et al.* 1991, McDonald 1992) and textbooks (Glickman 1996, Chong 2004) the second generation or the impedance type devices (that use alternative current) measure impedance instead of resistance. Thus, the wave is sinusoidal and they have their own single frequency. There are two main types of alternative current based electronic apex locators: absolute and gradient impedance. Absolute impedance electronic apex locators measure impedance using an electric current of one frequency. Gradient impedance electronic apex locators employ two or more frequencies. Gradient impedance is utilized in the third generation or frequency type devices. Some authors refer to them as ratio type (Glickman 1996) because they employ two or more frequencies and calculate the ratio of feedback impedances belonging to each frequency. However, in the Endocater® (Hygenic Corp., Akron, OH, USA) – a second generation device – the manufacturer used a single frequency and insulated files to eliminate the need to have a dry canal (McDonald & Hovland 1990, McDonald 1992, Himel & Schott 1993, Kim & Lee 2004). There is also another modification of electronic apex locators that has a dual circuitry system. This particular apex locator (Ultima EZ®, Satelec Inc., Mount Laurel, NJ, USA) uses multiple frequency technology for measurements in wet conditions and a second resistance-based circuitry for measurements in dry canals. The locator has digital readout and an audible indicator for determining when the desired point in the canal has been reached (Nekoofar *et al.* 2002).

On the top of page 429 it states: '…the change in frequency method of measuring was developed by Inoue in 1971 as the Sono-Explorer…'. However, based on Inoue's articles (Inoue 1972, 1973, Inoue & Skinner 1985) he only modified the analogue indicator of the device with an audible component. This indicator is a low frequency oscillator. In the Sono-Explorer, a modification was made to the oscillation circuits so that changes in the quality and type of sound were indicative of the position of the endodontic file in the root canal system. Inoue (1973) clearly stated that: '…experiments were conducted with a device employing the principle of electrical resistance and modified by addition of an audible 'marker tone'.

I believe that the confusion outlined above arises from the fact that previous articles have not described these devices in sufficient detail. To address this

problem I sincerely hope that any future articles classify and describe devices according to their fundamental electronics.
Sincerely yours,

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Response from authors

We thank Dr Nekoofar for his interesting letter. We are pleased that his aim is not to criticize, and that he agrees there is confusion arising from a lack of clarity in some publications. The main aim of our review was to review modern instruments and draw together some data on their accuracy. This could not be done without delving into a certain amount of history. For completeness the early machines were mentioned and the literature of the time was surveyed. We chose not to investigate in much greater depth as recent developments (the last 10 years, say) have provided us with machines far more tolerant of the variations in conditions found in root canals. They also offer practitioners much greater accuracy than before. Even with these limitations we ended up with approaching 120 articles, and at 13 pages one of the largest reviews to appear in the IEJ. We would hope future workers might approach the history from a purely electronic standpoint, but perhaps the result would not be of great interest to the current readership.

We are pleased to report that the review has generated significant interest from all around the world. With the sole exception of Dr Nekoofar, all our correspondents have asked what machine they are using! From manufacturer's addresses and digital photographs sent electronically we have been able to identify them all. It is of major concern that the marketing of electronically identical devices around the globe under different names leaves clinicians unable to relate their instrument to others which appear in research publications and advertisements.

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