

Influence and safety of electronic apex locators in patients with cardiovascular implantable electronic devices: a systematic review

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ABSTRACT

The widespread use of cardiovascular implantable electronic devices has increased concerns regarding using electronic apex locators in patients with these devices. This systematic review investigated the effects and safety of using electronic apex locators in patients with cardiovascular implantable electronic devices.

Methods: An electronic search in the Cochrane Library, PubMed (MEDLINE), ScienceDirect, and Scientific Electronic Library Online (SciELO) databases for relevant articles published between December 2000 and December 2018 was performed. The search strategy centered on terms related to electronic apex locators use during root canal treatment in patients with cardiovascular implantable electronic devices.

Results: Seven studies (five *in vitro* and two *in vivo*) fulfilled the inclusion criteria for this review. It was found that electronic apex locators can be used safely in patients with cardiovascular implantable electronic devices, when general precautions are followed.

Conclusions: Although the present review suggests that electronic apex locators can be used safely in patients with implantable cardioverter defibrillators, consultation with patients' cardiologists remains advisable.

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Apex locator; pacemakers; defibrillators; electromagnetic waves; cardiovascular

1. Introduction

Cardiovascular implantable electronic devices are small lithium battery-operated electronic devices that are inserted surgically beneath the skin, generally near the left clavicle [1,2]. They have flexible insulated wires (leads) that run through the veins to the heart and monitor heart rate continuously to detect heart rhythm disorders (i.e. arrhythmias) [3,4]. There are two basic types of arrhythmia: heart rates that are too slow [bradycardia]; and those that are too fast [tachycardia] [5]. More than 66,000 implantable cardioverter defibrillators are implanted annually in the USA [6], where a permanent pacemaker was supplied to 2.9 million individuals between 1993 and 2009. In the USA, this number is still increasing each year [7,8]. Similarly, in Europe, the number of implanted implantable cardioverter defibrillators has increased annually [9].

This increased use of cardiovascular implantable electronic devices means that the number of patients with such an implanted device visiting dental offices will also increase. Electromagnetic waves released from electronic devices can disrupt the operation of these devices—an effect known as electromagnetic interference [10]. Accurate determination of working length is clinically very important when performing root canal treatment [11]. The electronic apex locator and periapical radiography are convenient tools to determine

root canal working length in routine clinical practice [11,12]. The electronic apex locators are useful adjuncts in determining working length during endodontic therapy, with a reported accuracy of up to 93% [13], which is higher than radiography [14]. The widespread use of implanted cardiovascular implantable electronic devices has increased the concern regarding the use of electronic apex locators in patients with cardiovascular implantable electronic devices [15]. Modern cardiovascular implantable electronic devices are usually well protected. Their covers are hermetically sealed against electromagnetic interference, and they are equipped with filters, rejection circuits, and bipolar modes [16]. Despite these properties, magnetic resonance imaging and ionizing radiation devices should be avoided in medical settings [17]. In dentistry, there is a conventional recommendation to avoid using electronic apex locators in patients with implanted cardiac pacemakers [15,18]. Over the past few decades, there has been debate on whether dental equipment could interfere with the correct functioning of pacemakers and implantable cardioverter defibrillators. Some authors have reported that electronic dental equipment can interfere with correct functioning [18], whereas others have concluded that dental equipment has no significant effect on cardiovascular implantable electronic devices [19].

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The present systematic review investigated the effects of electronic apex locators on cardiovascular implantable electronic devices, and the safety of effects of electronic apex locators use in patients with cardiovascular implantable electronic devices.

2. Methods

An electronic search of the Cochrane Library, PubMed (MEDLINE), ScienceDirect, and Scientific Electronic Library Online (Scielo), databases for articles published between December 2000 and December 2018 was performed. The search strategy centered on terms related to using electronic apex locators use during root canal treatment in patients with cardiovascular implantable electronic devices. A combinations of the following terms were used: 'apex locator,' 'cardiovascular,' 'implantable,' 'electronic devices,' 'pacemakers,' 'defibrillators,' 'cardiac,' 'pulp testers,' 'equipment safety,' 'endodontic,' and 'root canal working length.' In addition, a manual search for relevant articles was performed in the following journals: *Journal of Endodontics*, *International Endodontic Journal*, and the *Australian Endodontic Journal*.

The titles and abstracts of the identified articles were reviewed separately by two researchers to evaluate eligibility. Subsequently, the selected articles were assessed thoroughly for final decision for

inclusion in the systematic review. In case of any conflict, a third researcher was consulted for resolution. The inclusion criteria were English-language publication, and *in vivo* and *in vitro* investigations related to the topic. Review articles, case series, case reports, and studies based on surveys or expert opinion were excluded. In addition, *in vitro* studies designed without a model that simulated electrical resistance in the human body were excluded.

3. Results

The initial database search identified 701 articles. After removal of duplicates, the search strategy yielded 460 publications. The initial screening of the retrieved studies focused on titles and abstracts. A total of 445 studies were excluded, and the full-text of 15 studies were assessed for eligibility. Among these 15 articles, seven fulfilled the inclusion criteria: five *in vitro* [1,3,10,15,20]; and two *in vivo* [21,22] studies. Figure 1 summarizes the details and results of the search strategy. The main characteristics of these studies are summarized in Table 1. The quality of each study included in this review was given a grad out of 9. Four *in vitro* studies [1,3,15,20] reported that electronic apex locators do not interfere with cardiovascular implantable electronic devices and can be

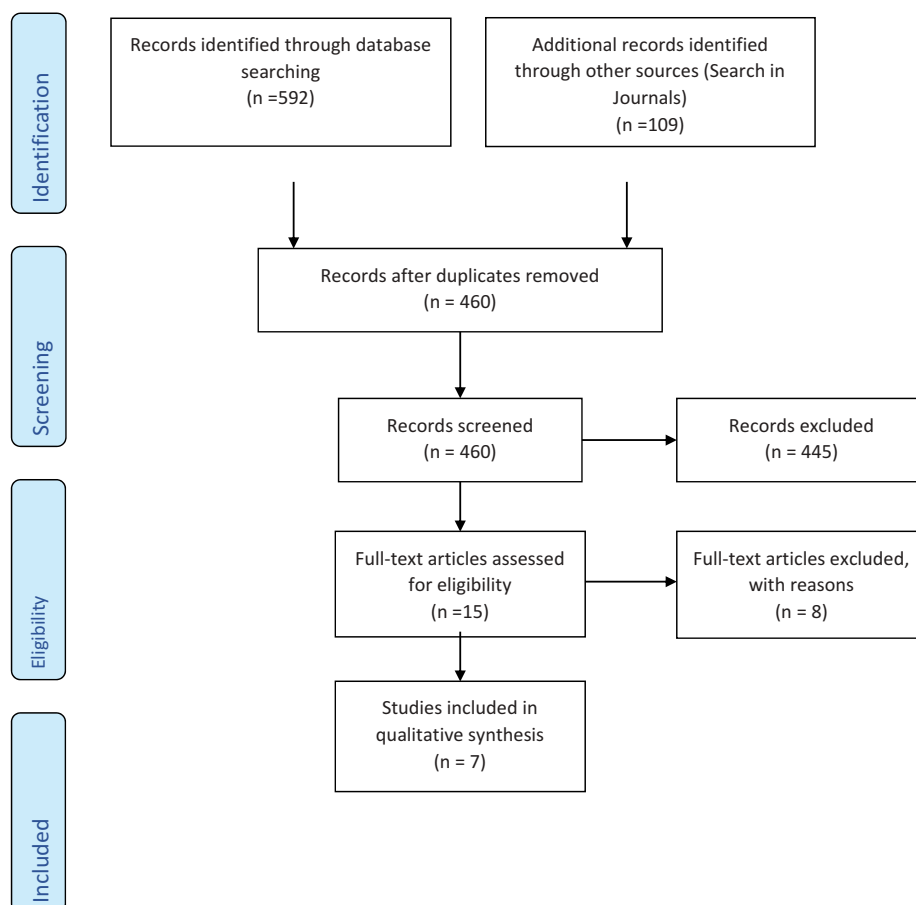


Figure 1. Diagram summarizes the details and results of the search strategy.

Table 1. The main characteristics of the included studies.

Authors	Year	Journal	<i>In vitro</i> / <i>In vivo</i>	Number of samples	Apex locator Brand	Cardiovascular implantable electronic devices	Results	Quality of the study grade
Wilson BL	2006	J Endod.	<i>In Vivo</i>	27 patients	Root ZX [Morita Corp, Irvine, CA] Endo Analyzer Model 8005 [Sybron Endo, Orange, CA].	Guidant Medtronic Ventritex Pacemakers Medtronic	There was no interfere with the functioning of any of the cardiac devices tested.	9
Gomez G	2013	Int Endod J.	<i>In vitro</i>	The tests were repeated 3 times for each device.	Mini Apex Locato [Sybron Dental, Glendora, CA, USA], Dentaport ZX [J. Morita MFG Corp., Osaka, Japan], Novapex [VDW, Munich, Germany] Root ZX mini [J. Morita MFG Corp., Osaka, Japan], Raypex5 [VDW, Munich, Germany] Justy II [Yoshida Dentscraft, Tokyo, Japan]	Identity ADxSR 5180 SSIR Saint Jude Medical [St. Paul, MN, USA]	No electromagnetic interference was detected when the electronic apex locators were placed near to or 15 cm from the sensing arc in this laboratory experimental model.	8
Idzahi K,	2014	J Endod.	<i>In vitro</i>	The tests were repeated 3 times for each device.	Root ZX Mini [Morita Corp, Irvine, CA], Apit 11 [Osada Electric Co, Ltd, Tokyo, Japan], Root ZX II [Morita Corp], VDW Gold [VDW, Munich, Germany]	Biotronik Lumax 540 VR-T [Biotronik SE & Co KG, Berlin, Germany]. Boston Scientific Cognis 100-D [Boston Scientific Co, Natick, MA] Medtronic Protecta XT CRT-D [Medtronic Inc, Minneapolis, MN] Protecta VR Viruoso; Medtronic, Minneapolis, MN Protecta-CRTD Consulta-CRTD, Medtronic	The tested apex locators did not interfere with the correct functioning of implantable cardioverter devices	8
Maheshwari KR	2015	J Endod.	<i>In vitro</i>	The tests were repeated 3 times for each device.	apex locator [J. Morita Corp]	Protecta VR Viruoso; Medtronic, Minneapolis, MN Protecta-CRTD Consulta-CRTD, Medtronic	No electromagnetic interferences were observed for the apex locator.	5

(Continued)

Table 1. (Continued).

Authors	Year	Journal	<i>In vitro/In vivo</i>	Number of samples	Apex locator Brand	Cardiovascular implantable electronic devices	Results	Quality of the study grade
Lahor-Soler E	2015	Eur J Oral Sci.	<i>In vitro</i>	The tests were repeated 3 times for each device.	Morita Root ZX; Morita, Irvine, CA, USA	[Medtronic Adapta DR ADDR01 [Medtronic, Minneapolis, MN, USA] Boston Scientific Insignia I Ultra [Boston Scientific, Natick, MA, USA] Biotronik Estella SR-T [Biotronik SE, Berlin, Germany] Medtronic Secura DR [Medtronic], Boston Scientific Teligen 100 [Boston Scientific] Biotronik Lumax 540 VR-T DX [Biotronik SE] Pacemaker: Medtronic [Minnesota, USA] Pacemaker: Biotronik [Berlin, Germany] Defibrillator: Medtronic [Minnesota, USA]	The electronic apex locators tested at a clinical application distance [20 cm] provoked only slight interference in the pacemakers and implantable cardioverter defibrillators employed, irrespective of manufacturer.	5
Dadalti MT	2016	J Dent.	<i>In vitro</i>	The tests were repeated 3 times for each device.	Bingo 10,121 [Dent Corp, White Plains, NY, USA] Novapex1 [VDW, Munich, Germany] NSK1 [NSK, Tokyo, Japan] RomiApex A-141 [Romidan LTD, Kiryat-Ono, Israel] Romiapex A-15 [Kiryat, Romidan [Kiryat, Israel] Novapex Romidan [Kiryat, Israel]	All apex locators caused of electromagnetic interference, without change in the cardiovascular implantable electronic devices functioning [e.g. background noise] when they were positioned horizontally to the axis formed by the components of the Medtronic pace maker, ranging according to the sensitivity and experimental distances. There was no change in the cardiovascular implantable electronic devices functioning. It is suggested that a minimum of electronic devices should be kept turned on in the dental office during the treatment of patients using cardiovascular implantable electronic devices.	6	
Moraes AP	2016	Int Endod J.	<i>In Vivo</i>	12 patients	Analyst DR [St. Jude] Anthem RF [St. Jude] Zephyr SR [St. Jude] Virtuoso II DR [Medtronic] Advisa DR [Medtronic] Sensia SEDR [Medtronic] Accent DR[St. Jude] Microny_SRI[St. Jude]	The electronic apex locators were capable of causing background noise detection or pauses in cardiac implants <i>in vivo</i> . The use of electronic dental devices nearby patients with cardiac implants should be carefully considered in clinical practice.	7	

used safely. One *in vitro* study [10], however, reported that electronic apex locators caused electromagnetic interference without altering cardiovascular implantable electronic devices function and suggested that electronic devices should be kept to use at minimum distances. One *in vivo* study [21] reported that electronic apex locators did not interfere with the functioning of cardiac devices. In contrast, the results of the other *in vivo* study [22] revealed that electronic apex locators are able to produce background noise interference or pauses in cardiovascular implantable electronic devices, and recommended caution when using electronic apex locators.

4. Discussion

Cardiovascular implantable electronic devices are used in the treatment of patients with arrhythmias (i.e. tachycardia, bradycardia, or irregular) and poor cardiac function [5]. They monitor heart rhythm continuously and, when necessary, impulses are delivered to restore normal heart function [23]. In this systematic review, we attempted to assess the effect of using an electronic apex locator during root canal treatment on these devices.

We reviewed seven studies (four *in vitro* studies and two *in vivo* studies) that investigated the influence of electronic apex locators on cardiovascular implantable electronic devices function. Owing to clinical heterogeneity in experimental designs, it was not possible to conduct a meta-analysis.

The results of four *in vitro* studies demonstrated that electronic apex locators did not interfere with cardiovascular implantable electronic devices function and can be used safely [1,3,15,20].

One *in vitro* study by Dadalti et al. [10] reported that electronic apex locators caused electromagnetic interference without altering cardiovascular implantable electronic devices function. The authors used four electronic apex locators from different manufacturers with two pacemakers and one defibrillator. The tests were performed at distances of 2 cm from the generator, electrode, and sensing arc and, in the case of electromagnetic interference, tests were performed at distances of 5, 10 and 15 cm. However, in real-world dental practice, electronic apex locators are not used at this distance.

There was also controversy in the results of the *in vivo* studies, in which one investigation [21] revealed that electronic apex locators did not interfere with the functioning of cardiac devices, while the other *in vivo* study conducted by Moraes et al. [22] demonstrated that electronic apex locators can produce background noise interference or pauses in cardiovascular implantable electronic devices and recommended caution when using electronic apex locators. No endodontic device produced permanent changes in implanted cardiac pacemakers or

implantable cardioverter defibrillators. Moraes et al. [22] used two electronic apex locators [Romiapex A-15 and Novapex] from the same manufacturer (Romidan, Kiryat, Israel). This study, however, included only 12 patients (i.e. a small sample size), and the implantable electronic devices were from two different manufacturers: St. Jude Medical (Fullerton, CA, USA) and Medtronic (Doral, FL, USA). Interpretation of the results may have been incorrect due to the possibility of telemetry interference.

Cardiovascular implantable electronic devices vary according to electrode polarity (unipolar or bipolar) [24,25], where the poles (anode and cathode) in the bipolar type were closer together than in the unipolar type [24]. This will lead to reduction in the probability of interpreting extremal signals as a cardiac event(s) [26]. Evidence in the literature suggests that unipolar devices are more prone to electromagnetic interference [27–29]. Interference signals with a frequency between 10 and 300 Hz can bypass the input circuits, as well as those calculated by the algorithm of the implanted cardiac pacemakers. Therefore, these devices may be unable to identify whether the signal source is the heart or an external source [30].

Technological advances in cardiovascular implantable electronic devices have reduced their susceptibility to electromagnetic interference [26,28,31]. Consequently, Crossley and Poole [32] suggested that data interpretation may be impacted more by telemetry interference than interference with pacemaker function.

The new-generation-implanted cardiac pacemakers are considered to be impervious to most sources of interference because of their construction, which encapsulates components in a stainless steel or titanium cover, and are equipped with an interference mode [7,15,33]. In addition, these new devices have bipolar leads and capacitors that effectively filter out electromagnetic interference and, thus, reduce external interference [34,35]. Direct contact between the electronic apex locator and pacemaker is not possible in practice [15,36], where electronic apex locators produce fields around the head with distance ranging from 25.5 to 30.5 cm from the heart [36]. In addition to built-in precautions, electric and magnetic fields decrease inversely with the square of the distance from the source [3,37]. The patients' body bulk (i.e. skin, fat, muscle, bone, and teeth) may resist the conduction of electromagnetic currents and act as a 'second capsule' for implantable electronic devices [34,38–40].

The increased pacing observed during the use of dental devices in some patients is a normal, proper response of implantable electronic devices to a slowing of the patient's natural underlying heart rate, and not to dysfunction of or interference with cardiac devices [21].

5. Conclusion

The present review suggests that electronic apex locators can be used safely in patients with cardiovascular implantable electronic devices, especially when general precautions are followed to keep electrical appliances at least 10–20 cm away from an implantable cardioverter defibrillator and its leads. However, consultation with the patient's cardiologist remains advisable.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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