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ORIGINAL ARTICLE

Electromagnetic interference of dental equipment with implantable cardioverter defibrillators

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ABSTRACT

Objective: Implantable cardioverter defibrillators (ICDs) are subject to electromagnetic interference (EMI). The aim of this study was to assess both the EMI of dental equipments with ICDs and related factors.

Materials and methods: High- and low-speed handpieces, an electric toothbrush, an implant motor and two types of ultrasonic devices were tested next to an ICD with different sensitivity settings. The ICD was immersed in a saline solution with electrical resistance of 400–800 ohms to simulate the resistance of the human body. The dental equipments were tested in both horizontal (0°) and vertical (90°) positions in relation to the components of the ICD. The tests were performed with a container containing saline solution, which was placed on a dental chair in order to assess the cumulative effect of electromagnetic fields.

Results: The dental chair, high- and low-speed handpieces, electric toothbrush, implant motor and ultrasonic devices caused no EMI with the ICD, irrespective of the program set-up or positioning. No cumulative effect of electromagnetic fields was verified.

Conclusions: The results of this study suggest that the devices tested are safe for use in patients with an ICD.

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Introduction

Implantable cardioverter defibrillators (ICDs) and pacemakers (PMs) are cardiovascular implantable electronic devices (CIEDs) whose purpose is to regulate the natural pace of the heart [1]. Both types of CIED consist of two main parts: a generator, which is hermetically sealed with a titanium case housing an electronic system, and electrodes [2].

However, ICDs have been developed more recently than PMs [3]. Both of these CIEDs comprise a generator and electrode (often two), but ICDs have a larger generator, containing two batteries and a capacitor, since a higher voltage is required to defibrillate the heart [4].

The number of patients with CIEDs is rising due to the aging population [5], and their use increases the chances of survival and quality of life [6]. Despite the technological advances, the electromagnetic waves emitted by an electronic source or device can prevent the normal functioning of CIEDs [6], an event referred to as electromagnetic interference (EMI). The EMI can affect circuits and prevent them from working in the way that was intended and can arise from many sources, either man-made or natural. The consequences of EMI on ICDs are unpredictable and can be severe, causing temporary reversal, deactivation, incorrect stimulation, damage to the internal circuitry or even defibrillation shocks [3,7].

Studies evaluating the risk of EMI with ICDs [8–18] are fewer than studies assessing the risk with PMs [8,10,14–24]. Among the studies evaluating its effects on ICDs, it was found that light-curing units [10], ultrasonic devices [10,17] and ultrasonic cleaners [9,10] may cause some degree of EMI, which varied according to the device brand and ICD involved. Nonetheless, EMI also depends on the sensitivity, mode of stimulation and positioning of the ICD relative to the source of EMI [25].

Therefore, the aim of this *in vitro* study was to assess the EMI of electronic dental equipment with ICDs as well as the cumulative potential effect of several electromagnetic fields and to evaluate whether the positioning of dental equipment towards the ICD increases the occurrence of EMI.

Materials and methods

This *in vitro* study was based on the models by Luker [19] and Miller et al. [20], with modifications [23,24]. The ICD was immersed in a plastic container with 1.5 L of saline solution whose electrical resistance was adjusted to 400–800 ohms, maintained with the addition of sodium chloride or distilled

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water. The ICD selected for study was the Medtronic Secura VR® (Medtronic Inc., Minneapolis, MN, USA), tested with atrial stimulation and bipolar electrode (Biotronik®Setrox S 53). The electrode was placed at a distance of 20 cm from the generator to simulate the positioning of the ICD in the body.

Electromagnetic interference assessments were performed by using a telemetry device (Medtronic CareLink® 2090) in which the telemetry wand was placed below the container under the generator. A cardiologist, specialist in the monitoring and control of the heart rate stimulation, assessed the telemetry results, while a single operator performed the tests. The resistance of the solution was also measured by using the telemetry device.

Both the container with saline solution and the ICD were placed on a dental chair (B-Safe®, DabiAtlante). The dental equipments used in this study were as follows: KaVo® high- and low-speed handpieces (KaVo, Biberich, Germany), Oral B® electric toothbrush (Procter &Gamble, Cincinnati, USA), Nouvag AG 7/8000® implant motor (Nouvag AG, Goldbach, Switzerland) and Cavitron® (Dentsply, New York, NY, USA) and Delsonic® (Deldent, Petach-Tikva, Israel) ultrasonic devices.

To assess the cumulative effect of electromagnetic fields, the tests were performed with the dental chair remaining switched on, which was shown to cause no EMI. In the event of EMI from any device being tested, the dental chair was switched off and the tests were repeated.

Initially, a negative control test was carried out with the equipment turned off in order to rule out any external interference, while a positive control for the presence of EMI was conducted by allowing direct contact between the electrode and the tip of a K#20 file, which was attached to the Bingo 1012® (Dent Corp, New York, NY, USA) electronic apex locator. The tests were conducted with the ICD set at maximum sensitivity (0.15 mV), then reset for minimum sensitivity (1.2 mV).

The tests were performed at a distance of 2 cm from the generator, electrode and arc sensor, and in the case of EMI, tests were performed at distances of 5, 10 and 15 cm, respectively. In a pilot study, the components of dental equipment caused no EMI. Thus, only handpieces and related dental instruments mounted on other devices (i.e. parts of the equipment that are used close to or in contact with the patient) were tested. All the dental equipments were operated for 10 seconds at maximum power and then switched off.

In addition, all the dental equipments were employed in two orientations, defined as horizontal (0°) and vertical (90°) in relation to the axis formed by the components of the ICD. Although different angles were tested during the pilot study we found that they did not cause EMI. Based on the fact that Lakshmanadoss et al. [25] predict that only two angles are possible to cause interference and Dadalti et al. [18] employed only the horizontal and vertical position, we used these works as basis for performing this step of the methodology.

All tests were repeated in triplicate. The ICD was checked after each test to ensure it was working normally, with the resulting data being categorized as: EMI-0 (absence of EMI); EMI-1 (presence of EMI, without change in ICD function, e.g. background noise); EMI-2 (presence of EMI, with change in ICD function, e.g. inhibition).

Results

The telemetry readings were similar for all three tests, with the positive control producing an EMI-2 result in which the ICD function was inhibited.

All the dental devices tested, including negative control, produced no EMI, thus being categorized as EMI-0 (Table 1). No evidence of EMI-1 or EMI-2 was found. No EMI was detected when the dental equipments were switched on and off or left in operation at maximum and minimum ICD sensitivity, or when placed close to the generator, arc sensor and electrode.

By assessing the cumulative effect of electromagnetic fields, it was found that no dental equipment caused EMI when used at the same time that the dental chair was switched on. The dental equipment caused no EMI when positioned horizontally or vertically to the axis formed by components of the ICD. Also, no dental equipment caused temporary or permanent damage to the ICD tested.

Discussion

The latest PMs and ICDs have been designed to be more resistant to EMI, as they are hermetically sealed within a titanium case and have a filter and a rejection circuit [7,26].

Table 1. Results according to the ICD sensitivity.

Equipment		ICD		EMI type		
Type	Brand	Sensitivity	Distance (cm)	Test 1	Test 2	Test 3
High-speed handpiece	Kavo®	Maximum	2	EMI-0	EMI-0	EMI-0
		Minimum		EMI-0	EMI-0	EMI-0
Low-speed handpiece	Kavo®	Maximum	2	EMI-0	EMI-0	EMI-0
		Minimum		EMI-0	EMI-0	EMI-0
Electric brush	Oral B®	Maximum	2	EMI-0	EMI-0	EMI-0
		Minimum		EMI-0	EMI-0	EMI-0
Implant motor	Nouvag AG 7/8000®	Maximum	2	EMI-0	EMI-0	EMI-0
		Minimum		EMI-0	EMI-0	EMI-0
Ultrasonic device	Cavitron®	Maximum	2	EMI-0	EMI-0	EMI-0
		Minimum		EMI-0	EMI-0	EMI-0
	Delsonic®	Maximum	2	EMI-0	EMI-0	EMI-0
		Minimum		EMI-0	EMI-0	EMI-0

However, some sources of EMI can still interfere with the functioning of CIEDs. With regard to electronic dental equipment, there is no consensus on the safety of its use in patients with CIEDs, and the manufacturers' product information is vague [27,28]. Indeed, Meditronic considers that the ultrasound and the handpiece offer no risks [27], while Biotronik states that dental treatment in general, including the use of ultrasound, offers no risk if the 15 cm distance between the device and the cardiac device is respected [28]. These guides do not specify the type and model of CIED or dental equipment.

Electromagnetic force is involved in practically all the physical phenomena that exist in daily life, and can even interfere in intermolecular relations. According to Lakshmanadoss et al. [25], EMI signals in the 10–60 Hz frequency range may affect cardiac devices because they overlap with the cardiac signal range. The electromagnetic frequency of dental equipment tested in this study was in the range of 45–60 Hz and thus had the potential to cause EMI in the CIEDs.

The present study has used a stimulation model resembling that adopted by the majority of *in vitro* studies assessing the EMI of electronic dental equipment with CIEDs [9–11,18,20,23,24], except that by Garofalo et al. [21], who directly connected PM components to an apex locator. This method was adopted in this study because it simulates the resistance of the human body and it has been shown that the human body itself causes dispersion of EMI [29]. In addition, the potential for EMI of dental equipment needs to be tested *in vitro* before clinical use, regardless of inherent limitations of in vitro testing.

Although there are different brands and models of ICD, only two types were tested. However, the model of ICD employed in this analysis differed from previously tested models [9–11,13,14,17]. In addition, in the present study, only EMI was evaluated, and dental equipments that release electric current directly from the patient, such as the electric pulp test, were not used.

In the present study, the dental chair, high- and low-speed handpieces, electric toothbrush, implant motor and ultrasonic devices caused no EMI with the ICD. Similar results were also obtained by other authors for the dental chair [9], handpiece [9,10], and electric toothbrush [10]. However, to the knowledge of the authors, the implant motor has not been assessed up to now.

Ultrasonic devices incorporate two types of mechanisms: piezoelectricity, in which a crystal becomes distorted when a charge is applied to it; and magnetostriction, in which electromagnetic energy is converted into mechanical energy [30]. In the present study, the Delsonic® piezoelectric-type ultrasonic device was found to cause no EMI. No previous studies assessing this brand of ultrasonic device were available. Other authors failed to detect EMI in this type of ultrasonic device with PMs or ICDs [9,19,20,24], thus corroborating the results of the present study. Also, an *in vivo* study assessing the effect of a piezoelectric-type ultrasonic device on 12 patients with ICDs found no EMI [12].

The Cavitron® is a magnetostrictive-type ultrasonic device which reportedly causes EMI at distances between 15 cm [10,20] and 23 cm [10] from a PM and of 7 cm from an ICD [10], a finding not confirmed in the present study. This discrepancy may stem from the difference in the ICD models tested, given that some devices are more vulnerable to EMI than others [26]. Thus, the authors believe that this type of ultrasonic device has a higher propensity for causing EMI [31]. Gomez et al. [24], however, observed no EMI when using magnetostrictive-type ultrasonic devices close to a PM.

The effects of EMI depend on factors such as the intensity of the electromagnetic field [18,22], the distance between the source and the CIED [25], the CIED and dental equipment type and model [5,15,18], the placement position of the equipment relative to the CIED [18,32] and the source of EMI [25,32]. In the present study, even when the dental equipments were placed at a distance of 2 cm from the ICD, no EMI was observed.

A pilot study was conducted and the occurrence of EMI was verified in different positions. This was despite basing our methodology on the studies by Lakshmanadoss et al. [25] and Dadalti et al. [18], who evaluated only two positions. No difference was found for the positioning of the dental equipment, whether horizontally or vertically, in relation to the axis formed by the components of the ICD. This finding disagrees with a previous study, which demonstrated that EMI occurred when the equipment was placed next to the ICD horizontally [18].

All the dental equipment tested has an electromagnetic field. According to the World Health Organization [33], an electromagnetic field is a force field generated around an electric current, equivalent to an electric field and a magnetic field at right angles to each other. The sum total of the electromagnetic fields may occur when several sources are present in the same environment, causing more pronounced effects than expected [25]. Considering that this is common in dental office environments, the equipments were tested on a dental chair turned on and with the plastic container on it, simulating a patient undergoing dental treatment. However, no equipment showed EMI. This finding disagrees with a previous study, as it was demonstrated that the gutta-percha heat carrier caused EMI [18].

Another variable assessed in the present study was sensitivity, which is the lowest amplitude of a cardiac electrical event that the CIED can detect, where this threshold increases inversely with amplitude (in mV) [25]. Although studies have shown that greater sensitivity can increase the susceptibility to EMI [22,25], no EMI was detected in the present study at maximum or minimum settings, despite reports that ICDs are more sensitive than PM [12].

Although the current finding showed that dental equipment caused no EMI with ICDs, other authors have reported the opposite result [9,10,13,14,17]. Therefore, prior to performing dental treatment, it is advisable for the dental professional to consult the cardiologist of patients with cardiac implantable devices for more detailed information on the ICD in question, such as the model, manufacturer, programmed mode and set rate. Although the dental equipments tested here were considered to be safe, it is recommended to keep power sources and cables as far away as possible from the implanted device. This is advisable because, in cases of EMI, inappropriate shock discharges can be released, which may cause discomfort for patients resembling a shock from a power socket or a kick in the chest [4,34]. As a result, the patient may jerk suddenly, putting him/herself at risk in the dental surgery. Indeed, inappropriate shocks may frighten and traumatize patients which can jeopardize the therapeutic relationship.

Conclusions

Based on the results of this study, the dental chair, handpiece, electric motor, implant motor and ultrasonic device caused no EMI with the ICD tested, irrespective of the sensitivity and positioning of the dental equipment relative to the ICD components. No cumulative effect of electromagnetic fields was verified.

Disclosure statement

No potential conflict of interest was reported by the authors.

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