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Interference of cardiac pacemaker and implantable cardioverter-defibrillator activity during electronic dental device use

Jason J. Roedig, DMD; Jignesh Shah, MD; Claude Samy Elayi, MD; Craig S. Miller, DMD, MS

Pacemakers and implantable cardioverter-defibrillators (ICDs) are electronic devices that emit electrical signals and are sensitive to electromagnetic signals in the vicinity. They are being implanted increasingly in people,^{1,2} especially elderly people, who also visit the dental office.

Surgically implanted pacemakers provide regulated pacing for cardiac bradyarrhythmias. Most pacemakers are implanted in people with severe complete heart block.^{3,4} Technological advances in permanent pacemakers across the past 30 years, however, have resulted in increased indications for their use including to treat sinus node dysfunction and to enable tolerance of atrioventricular nodal blocking agents.⁵ Owing to these advances and the aging population, there has been a significant increase in the incidence of permanent pacemaker implantation.¹ It is estimated that 3 million people worldwide have pacemakers, and more than 500,000 people in the United States, Canada

ABSTRACT

Background. The authors conducted a study to determine if electromagnetic interference of cardiac pacemaker and implantable cardioverter-defibrillator (ICD) activity occurs during the operation of electronic dental devices.

Methods. The authors tested nine electronic dental devices in vitro to assess their ability to interfere with the function of two pacemakers and two ICDs as determined by electrocardiographic telemetry.

Results. The pacing activity of both pacemakers and the dual-chamber ICD were inhibited during operation of the battery-operated composite curing light at between 2 and 10 centimeters from the generator or leads. The use of the ultrasonic scaler interfered with the pacing activity of the dual-chamber pacemaker at between 17 and 23 cm from the generator or leads, the single-chamber pacemaker at 15 cm from the generator or leads and both ICDs at 7 cm from the leads. The operation of the ultrasonic cleaning system interfered with the activity of the dual-chamber pacemaker at between 15 and 23 cm from the generator or leads, and of the single-chamber pacemaker at 12 cm. Operation of the electric toothbrush, electro-surgical unit, electric pulp tester, high- and low-speed handpieces, and an amalgamator did not alter pacing function.

Conclusion. Select electronic dental devices interfere with pacemakers' and ICDs' sensing and pacing activity in vitro.

Clinical Implications. Use of the ultrasonic scaler, ultrasonic cleaning system and battery-operated composite curing light may produce deleterious effects in patients who have pacemakers or ICDs.

Key Words. Cardiac pacemaker; defibrillator; electromagnetic interference; dental equipment.

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and Mexico have an implantable permanent pacemaker.⁶⁻⁸ ICDs also are being placed to prevent sudden cardiac death in patients with poor cardiac function. ICDs are placed in more than 60,000 people annually in the United States.² Thus, the average dental practice that provides care to adults, including elderly people, is expected to have at least one patient who has a permanently implanted cardiac device.

Physicians have cautioned patients with implanted cardiac pacemakers and ICDs that electromagnetic interference might occur and cause device malfunction, harm patients or do both.^{9,10} Advice has been disseminated to patients to avoid magnetic resonance imaging machines, cell phones and electrocautery devices.¹¹⁻¹³ The dental literature also includes articles that advise practitioners to avoid operating certain dental devices because they may produce electromagnetic interference and cause pacemakers to not function properly.¹⁴⁻²³ Evidence, however, suggests that electromagnetic interference of the activity of newer advanced-design pacemakers and ICDs during the operation of select electronic dental devices may be less of a concern.²⁴⁻²⁷ These findings lead to the question of whether past guidelines still are applicable. Thus, we conducted a study to determine whether electromagnetic interference of pacemaker and ICD activity occurs during the operation of electronic dental devices.

MATERIALS AND METHODS

We tested nine electronic dental devices (Table) *in vitro* for their ability to interfere with the function of a single-chamber cardiac pacemaker (Sigma SR, Medtronic, Minneapolis), a dual-chamber cardiac pacemaker (Kappa model KDR701, Medtronic), a dual-chamber ICD (Marquis DR model 7274, Medtronic) and a biventricular ICD (InSync II Marquis, Medtronic) by using a method we reported previously.¹⁵ The electronic dental devices, pacemakers and ICDs made up the convenience sample and were representative of their common use in the United States.

We placed the pacemakers and ICDs with their leads attached in a 1.5-liter saline solution that we adjusted to 400 to 800 ohms to replicate the electrical resistance of the human body. We programmed the pacemakers and ICDs to maximum sensitivity and immersed them in the saline solution. We placed the telemetry wand of a cardiac pacemaker and defibrillator programmer (Care-Link Programmer, Model 2090, Medtronic)

directly over the pacemaker or ICD to monitor the pacing patterns and connections. Two cardiologists who specialize in cardiac electrophysiology (J.S. and C.S.E.) used the programmer to monitor the atrial and ventricular pacemaker and ICD output and the electrocardiographic activity continuously beginning 30 seconds before each trial and continuing until the end of each trial.

We operated each dental device to simulate normal use (that is, turned it on and off and operated it continuously at all power levels). We placed each dental device directly on the pacemaker or ICD and slowly moved it away from the pacemaker and ICD generator and leads until we reached 3 feet or detected no interference. We then began operating each dental device at 3 feet from the pacemaker or ICD and moved it toward the pacemaker or ICD until it was directly on the pacemaker or ICD. We tested each dental device separately and repeated the test three times. If we detected interference, we recorded the minimum and maximum distances from the pacemaker or ICD at which the interference was registered.

After we completed the trials, the cardiologists printed electrograms for all of the dental devices and reviewed them to look for and verify normal intrinsic pacing patterns and interference of cardiac device function. We analyzed the data for differences in interference according to the pacemakers' unipolar and bipolar pacing mode, generator versus lead, and distance by using the McNemar test.

RESULTS

We found that each pacemaker and ICD exhibited a normal pacing pattern during the 30 seconds before each trial. The telemetric recordings of the pacemakers and ICDs with all of the dental devices were consistent in all three trials.

We detected inhibition of pacing activity when three electronic dental devices were operated in proximity to the pacemakers (Table). The use of the ultrasonic scaler interfered with the activity of both pacemakers. We detected interference at 15 centimeters from the single-chamber pacemaker generator in both the unipolar and bipolar pacing modes (Figure 1, page 524). The use of the ultrasonic scaler also interfered with the unipolar pacing mode of the dual-chamber pacemaker

ABBREVIATION KEY. ICD: Implantable cardioverter-defibrillator.

TABLE

Interference characteristics of cardiac pacemakers and ICDs* caused by electronic dental devices.

ELECTRONIC DENTAL DEVICE	SINGLE-CHAMBER PACEMAKER (SIGMA SR, MEDTRONIC†) (CENTIMETERS‡)		DUAL-CHAMBER PACEMAKER (KAPPA MODEL KDR701, MEDTRONIC) (cm)		DUAL-CHAMBER ICD (MARQUIS DR MODEL 7274, MEDTRONIC) (cm)	BIVENTRICULAR ICD (INSYNC II MARQUIS, MEDTRONIC) (cm)
	Unipolar Mode	Bipolar Mode	Unipolar Mode	Bipolar Mode	Bipolar Mode	Bipolar Mode
Amalgamator (Promix Model 400, Dentsply, York, Pa.)	0	0	0	0	0	0
Battery-operated Composite Curing Light (SmartLite IQ2, Dentsply Caulk, Milford, Del.)	≤ 3	≤ 3	≤ 10	≤ 7	≤ 2	≤ 3
Electric Pulp Tester (Vitality Scanner 2006, SybronEndo, Orange, Calif.)	0	0	0	0	0	0
Electric Toothbrush (Braun Oral-B Triumph Professional Care 9000, Procter & Gamble, Cincinnati)	0	0	0	0	0	0
Electrosurgical Unit (Sensimatic 600SE, Parkell Electronics, Farmingdale, N.Y.)	0	0	0	0	0	0
High-Speed Handpiece (Mira LUX 3 635B, KaVo Dental, Lake Zurich, Ill.)	0	0	0	0	0	0
Low-Speed Handpiece (Intra 20K 1:1 (Kavo Dental)	0	0	0	0	0	0
Ultrasonic Cleaning System (L&R Transitor/Ultrasonic, L&R Manufacturing, Kearny, N.J.)	≤ 12 [§]	≤ 12 [¶]	≤ 23	≤ 15	0	0
Ultrasonic Scaler (Cavatron Select SPS, Dentsply)	≤ 15	≤ 15	≤ 23	≤ 17	≤ 7	≤ 7

* ICD: Implantable cardioverter-defibrillator.

† Medtronic is located in Minneapolis.

‡ Distance from the generator unless otherwise noted.

§ Interference with respect to the lead also at ≤ 12 cm.

¶ Interference with respect to the lead also at ≤ 9 cm.

at 23 cm from the generator and with the bipolar pacing mode at 17 cm from the generator. The use of the ultrasonic cleaning system caused interference with both the single- and dual-chamber pacemakers at 9 to 12 cm and 15 to 23 cm, respectively, from the generator (Figure 2). The ultrasonic cleaning system was the only dental device to interfere with pacing activity with respect to the leads. The use of the battery-operated composite curing light inhibited pacing activity at 7 to 10 cm from the generator for the dual-chamber pacemaker, and at 3 cm from the generator for the single-chamber pacemaker (Figure 3, page 525). The interference we observed in these trials occurred during constant pacing mode (that is, absence of pacemaker sensing activity). However, we repeated the trials without any pacing activity by having the pacemaker sense electrical activity

that was artificially produced in the ultrasonic cleaning system. The interference that occurred during sensing was similar to that observed during pacing, and it occurred at a similar distance from each dental device (data not shown).

We also observed interference of ICD pacing function during the operation of the dental devices. The operation of both the ultrasonic scaler and the battery-operated composite curing light interfered with the ICDs' pacing function (Figures 1 and 3). The use of the ultrasonic scaler inhibited pacing at 7 cm from the leads, whereas the use of the battery-operated composite curing light inhibited pacing function only at 2 to 3 cm from the leads.

Pacing rate and rhythm remained normal for both pacemakers and both ICDs during the operation of the amalgamator, electric pulp tester, electric toothbrush, electrosurgical unit, and high-

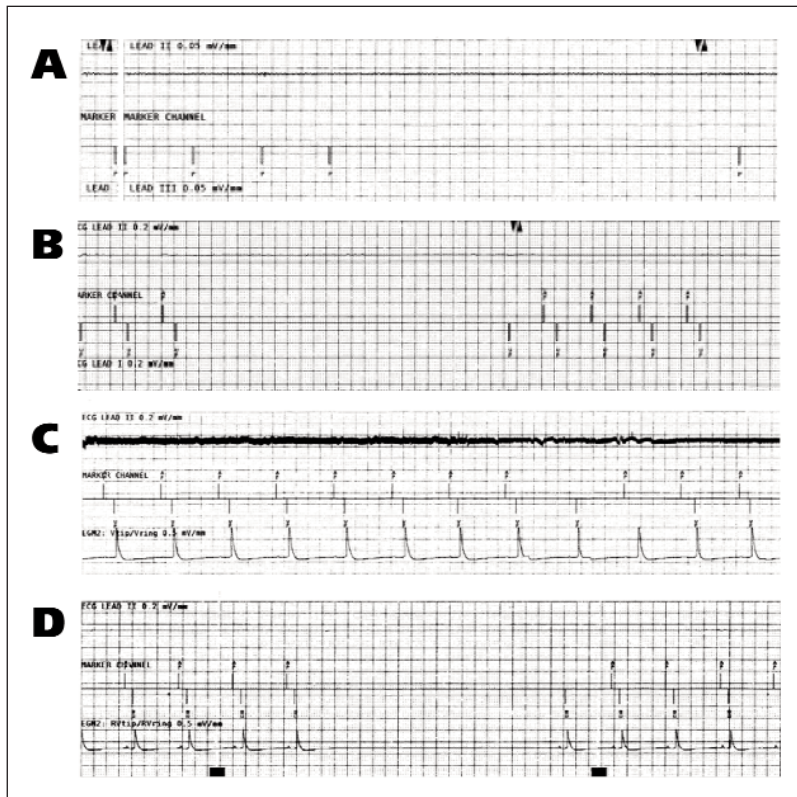


Figure 1. An electrogram showing the interference of pacing function caused by the operation of the ultrasonic scaler with (A) single-chamber pacemaker, (B) dual-chamber pacemaker, (C) dual-chamber implantable cardioverter-defibrillator (ICD) and (D) biventricular ICD.

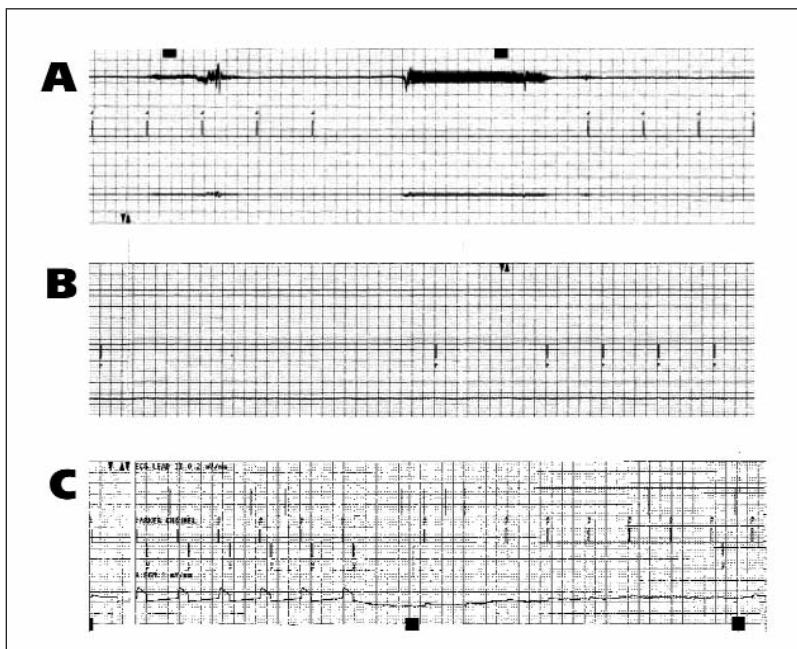


Figure 2. An electrogram showing the interference of pacing function caused by the operation of the ultrasonic cleaning system with single-chamber pacemaker in (A) unipolar and (B) bipolar modes and (C) dual-chamber pacemaker.

and low-speed handpieces.

When we analyzed pacing modes (unipolar versus bipolar) as independent tests and pooled data across all four devices and two modes, we found that the effect (interference) was significant for the generator compared with the leads for the ultrasonic scaler ($P = .04$) and for the battery-operated composite curing light ($P = .04$).

DISCUSSION

Although pacemakers today are smaller and have more protective features than those of the past, many common dental devices emit electromagnetic waves that can interfere with their functions. As the rate of pacemaker and ICD implantation is increasing,^{1,2} especially in elderly people, the elimination of electrical interference that could cause these cardiac devices to function improperly and, thus, adversely affect the cardiac health of dental patients is an important issue.

To our knowledge, ours is the first in vitro study to investigate electromagnetic interference of both pacemaker and ICD activity during the operation of electronic dental devices. We found that the operation of three electronic dental devices (an ultrasonic scaler, an ultrasonic cleaning system and a battery-operated composite curing light) inhibited the pacing function of the pacemakers. The effect occurred more often when we operated the electronic dental devices in proximity to the generator rather than the leads. These findings, in general, are similar to those of our 1998 study,¹⁵ in which we found that the operation of an ultrasonic scaler and ultrasonic cleaning system at less than 2 feet caused electromagnetic interferences of pacemaker activity. Other investigators also have shown that the operation of an ultrasonic scaler and ultrasonic cleaning system

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interfered with intracardiac telemetry pacemaker recordings.^{25,26} In our current study, we also found that the operation of the battery-operated composite curing light produced electromagnetic interference at close distances to both pacemakers. This type of interference has not been reported before. Also, the operation of the electrosurgical unit did not interfere with pacing activity in this study, which is in contrast to a finding of our 1998 study.¹⁵ One possible explanation for the difference in results is that the cardiac devices' shielding may have been improved in the newer pacemaker models. Alternatively, the newer electrosurgical unit we used in this study could have influenced the findings.

There is limited information regarding the interference of ICD activity during the operation of electronic dental equipment. In one study, investigators found that the operation of electronic apex locators and electric pulp testers did not interfere with ICDs.²⁸ In another report, investigators found that the use of an ultrasonic cleaning system produced electromagnetic interference, but the use of an ultrasonic scaler did not.²⁴ In contrast, we observed interference with the activity of both ICDs during the operation of the ultrasonic scaler and the battery-operated composite curing light, whereas the operation of the ultrasonic cleaning system did not interfere with the activity of either ICDs. Different models of electronic dental equipment, pacemakers and ICDs, as well as the methods for measuring interference (that is, telemetry interference versus device interference), could have contributed to the differences we observed in these studies, and we recognize that a limitation of our study was that the pacemakers and ICDs we tested *in vitro* were manufactured by the same company.

The number of dental devices that interfered with the pacing function of the pacemakers and ICDs was limited. Of the nine dental devices we tested, the operation of only three—the ultrasonic scaler, the ultrasonic cleaning system and the battery-operated composite curing light—inhibited pacing activity. The operation of the amal-

gamator, electric toothbrush, electric pulp tester, electrosurgical unit, and high- and low-speed handpieces did not produce electromagnetic interference.

CONCLUSIONS

Our findings together with those of other investigators suggest that using caution when operating ultrasonic scalers, ultrasonic cleaning systems and select composite curing lights around dental patients and health care workers who have pacemakers or ICDs is advisable. Experts also recommend using caution when operating electrosurgical units around these implanted cardiac devices.²⁹ Accordingly, dentists should consider the use of hand instruments for scaling and root planing for patients who have pacemakers or ICDs, as well as remove ultrasonic cleaning systems from clinical care areas.

Dentists should realize that electromagnetic interference with respect to dental devices is an evolving field in which different results and interpretations are obtained from trials using different

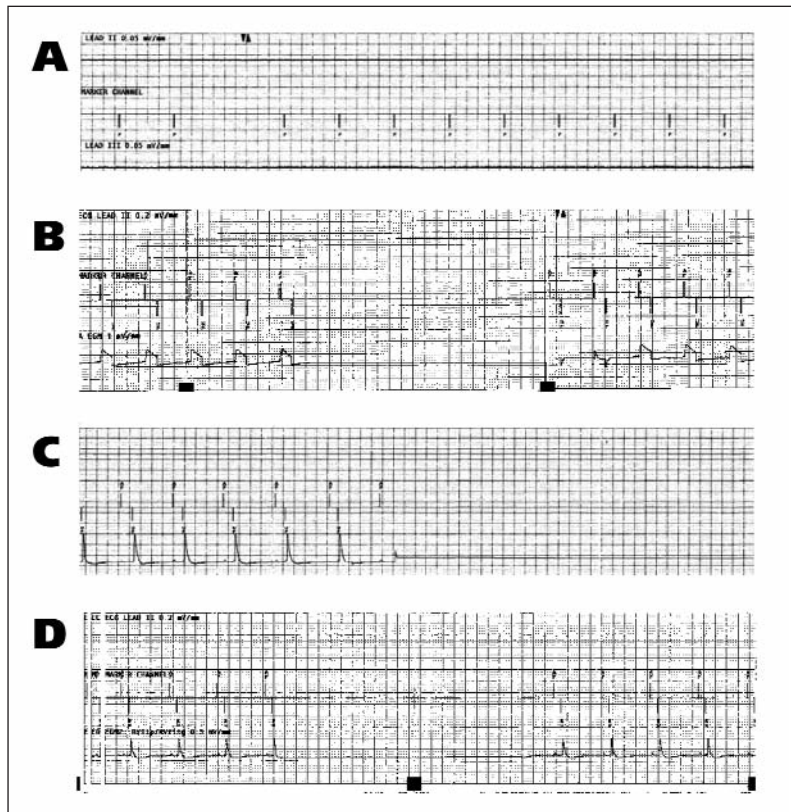


Figure 3. An electrogram showing the interference of pacing function caused by the operation of the battery-operated composite curing light with (A) single-chamber pacemaker, (B) dual-chamber pacemaker, (C) dual-chamber implantable cardioverter-defibrillator (ICD) and (D) biventricular ICD.

pacemakers, different electronic dental devices and settings (in vitro versus in vivo).^{26,27} Studies that address in vivo outcomes are needed to determine which electronic dental devices can be safely used in dental practice. Until then, it seems prudent to err on the side of caution. ■

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