CASE REPORT

Detection of atrial fibrillation during pulpal blood flow assessment using Doppler ultrasound: a case report

^{1,2}Chan-Hyun Lee, ^{3,4}Euseong Kim and ¹Dohyun Kim

¹Department of Conservative Dentistry and Oral Science Research Center, Microscope Center, Yonsei University College of Dentistry, Seodaemun-gu, Seoul, South Korea; ²The Armed Forces Capital Hospital, Bundang-gu, Seongnam-si, Gyeonggi-do, South Korea; ³Department of Conservative Dentistry and Oral Science Research Center, Yonsei University College of Dentistry, Seoul, South Korea; ⁴Department of Electrical and Electronic Engineering, Yonsei University College of Engineering, Seoul, South Korea

This report describes the case of a 52-year-old male patient who exhibited suspicious pulsation patterns during pulpal blood flow assessment using Doppler ultrasound. Initially, he was not aware of his cardiovascular problem; however, after referral to a medical clinic, he was diagnosed with atrial fibrillation. The patient was injured in a motor vehicle accident and referred to our clinic for management of multiple traumatized teeth. On clinical examination, several teeth exhibited negative responses to cold and electrical sensibility tests. For accurate diagnosis, pulpal blood flow assessment using a Doppler ultrasound device was performed. During the tests, irregular pulsation patterns were detected, indicating the possibility of a cardiovascular problem. As he denied any history of cardiovascular problems, he was recommended to visit a medical doctor for further evaluation. The following day, he visited a medical clinic, and a 12-lead electrocardiogram was performed. He was ultimately diagnosed with atrial fibrillation with idioventricular rhythm, and was started on anticoagulant medication for prevention of thrombogenesis, which is a possible complication of atrial fibrillation. As presented in this case, Doppler ultrasound can provide useful information, not only about blood flow in the dental pulp, but also about an individual's pulsation rhythm. When a patient presents with irregular pulsation patterns in certain situations, the possibility of cardiovascular problems should be considered.

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Introduction

The assessment of tooth vitality is critical in endodontic practice because it establishes the status of pulp tissue and provides valuable information for diagnosis and treatment planning. In dental clinics, tooth vitality is generally estimated through pulp sensibility tests, which examine nerve responses to thermal or electrical stimuli. Strictly speaking, however, the results of these

sensibility tests only reflect innervation, not the true vitality of the tooth. More specifically, there could be an adequate vascular supply in the pulp tissue even if it is not innervated. It is well known that sensibility tests can elicit false responses in several situations (*e.g.* teeth in elders, teeth with heavy restorations, traumatized teeth, immature teeth, or teeth under orthodontic force).¹

There have been attempts to directly measure pulpal blood flow to assess the true vitality of a particular tooth. Several methods, such as laser Doppler flowmetry, pulse oximetry, photoplethysmography, and spectrophotometry, have been introduced. Although they

Correspondence to: Euseong Kim, E-mail: andyendo@yuhs.ac; Dohyun Kim, E-mail: dohyun0kim@yuhs.ac; ijds@bawi.org

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†The authors Euseong Kim and Dohyun Kim contributed equally to the work.

are all plausible methods for measuring pulpal blood flow in a tooth, each have drawbacks that impede effective application in clinical situations.¹ More recently, researchers have begun to use Doppler ultrasound for the measurement of pulpal blood flow,² and a series of clinical studies have reported promising results.^{3,4}

Doppler ultrasound is generally used in medical diagnostics for measuring blood flow in a wide range of blood vessels. It is based on the Doppler effect: the change in frequency when an ultrasonic wave is reflected from a moving object.⁵ A Doppler ultrasound device detects a frequency shift when ultrasonic waves are reflected from moving red blood cells, and transforms the signal to an audible sound and visible spectrum. As every change in blood flow velocity is detected, the signals from arterial blood flow represent pulsations, which is the result of rapid movement of blood by contraction of the left ventricle. Therefore, an irregular pulsation pattern on the spectrum may reflect abnormal cardiac function or even cardiovascular problems.

Atrial fibrillation is one of the most common cardiac arrhythmias, and it is defined as a supraventricular tachyarrhythmia characterized by uncoordinated atrial activation and irregular ventricular contraction with consequent deterioration of mechanical atrial function.⁶ The present article describes a patient who exhibited suspicious pulsation patterns during pulpal blood flow assessment of traumatized teeth using a Doppler ultrasound device. While the patient was not initially aware of his cardiovascular problem, irregular pulsation rhythms were detected using the Doppler ultrasound device. He was ultimately diagnosed with atrial fibrillation on the basis of electrocardiography performed by a medical doctor.

Case report

Written informed consent for the case to be published (incl. images, case history and data) was obtained from the patient for publication of this case report, including accompanying images.

A 52-year-old male was referred from the Department of Critical Care and Trauma Surgery, Severance Hospital to the Department of Conservative Dentistry, Yonsei University Dental Hospital (Seoul, South Korea) for the management of multiple traumatized teeth. He was injured in a motor vehicle accident and underwent open reduction and fixation involving his left maxillo-facial region for zygomaticomaxillary complex fracture, orbital wall fracture, and maxillary Le Fort I fracture. Apart from hypertension, there was no remarkable medical or dental history. Panoramic and periapical radiographs obtained at the first visit are presented in Figure 1. Although there were no significant abnormal findings in the maxillary and mandibular anterior teeth in the radiographs, Teeth #13, 12, 11, 21, 31, and 41 exhibited negative responses to thermal and electrical sensibility tests. The possibility of pulp necrosis in these

Figure 1 Panoramic and periapical radiographs obtained at the first visit of the patient (a) Panoramic radiograph (b–g) Periapical radiographs of the anterior teeth.

teeth was accounted for, and they were scheduled to be re-evaluated 2 weeks later, in accordance with the Guidelines for Treatment of Traumatic Dental Injuries.⁷

The patient returned to the clinic 1 month later. He reported that he still experienced discomfort in the left maxillary region. In the clinical examination, Teeth #12, 11, 21, 31, and 41 continued to exhibit negative responses to sensibility tests, whereas the remainder of the teeth demonstrated positive responses. Subsequently, to make an accurate diagnosis, pulpal blood flow assessment was performed for each tooth using a Doppler ultrasound device and a 20-MHz continuous-wave transducer (MM-D-K; Minimax Ltd, St. Petersburg, Russia; Figure 2). All procedures were performed by a dental clinician (CL). After the surface of each tooth was dried, a small amount of ultrasound gel (Pro-gel II; Dayo Medical, Seoul, South Korea) was applied. The transducer was positioned on the labial surface at an angle of approximately 60° to the longitudinal axis of the tooth. The examiner searched for arterial blood flow by listening for pulsating sounds. The transducer was placed at the site with the clearest sound and held for approximately 10 s for steady and consistent signal recording. The Doppler

Figure 2 Doppler ultrasound device (MM-D-K; Minimax Ltd, St. Petersburg, Russia) used for pulpal blood flow assessment in the traumatized teeth (a) main device (b) 20-MHz continuous-wave transducer.

spectra were recorded using the Minimax Doppler 1.71 (Minimax Ltd, St. Petersburg, Russia) software program.

During pulpal blood flow assessment, Teeth #12 and 41 demonstrated uncertain signals, whereas all other teeth exhibited clear arterial pulsatile signals in both sound and spectra. Therefore, Teeth #11, 21, and 31 were considered vital, despite their negative responses to the sensibility tests. In contrast, Teeth #12 and 41 were diagnosed with pulp necrosis because they exhibited negative results in both sensibility tests and pulpal blood flow assessments. Consequently, root canal treatments were planned for Teeth #12 and 41. During the Doppler ultrasound test, an irregular signal pattern showing pulsatile sounds at arbitrary intervals was detected and matched with the peaks of the Doppler spectra (Figure 3a). This pattern

was not familiar when compared with patterns observed for most other patients who demonstrated regular pulsatile rhythms (Figure 3b). Because a characteristic pulsatile nature on display and sounds reflect ventricular contraction, a cardiovascular problem was suspected. He was asked again if he had any cardiovascular problems aside from hypertension; however, he answered that he was unaware of any problems. Consequently, he was recommended to visit a medical doctor for further evaluation of his cardiovascular status, because it could not be confirmed on the sole basis of Doppler ultrasound performed in a dental clinic. The following day, he visited a medical clinic and underwent 12-lead electrocardiography (Figure 3c), which revealed atrial fibrillation with idioventricular rhythm. He was started on anticoagulant medication for prevention of thrombogenesis, which is a possible complication of atrial fibrillation.

Discussion

Ultrasound has generally been used in medical diagnostics, and has several advantages as a real-time and non-invasive method. However, in the orofacial region, it has been used only for limited purposes, including the assessment of blood supply in the mandible⁸ or the evaluation and monitoring of intraosseous lesions.⁹ The application of ultrasound to teeth is significantly more complicated compared with its application to other tissues because they are composed of highly mineralized, hard tissues, more specifically, enamel and dentin.¹⁰ Most currently available transducers are not suitable for the high acoustic impedance of hard dental tissues. The complex and irregular internal tooth structures cause acoustic scattering, which make signal analysis and interpretation difficult. Additionally, the small dimensions of teeth, limited accessibility to the oral cavity, and micrometer-size blood vessels disrupt proper positioning of the transducer. Nevertheless, using high-frequency ultrasound has made it possible to detect and measure pulpal blood flow in human teeth.²⁻⁴ Cho and Park reported cases in which Doppler ultrasound was used for monitoring the vitality of teeth demonstrating discoloration after subluxation injuries.¹¹ Initially, the teeth exhibited negative responses to sensibility tests; however, they exhibited a normal pulsatile arterial blood flow pattern on Doppler ultrasound. A few months later, the discolorations disappeared and the teeth exhibited positive responses to sensibility tests. Similarly, Doppler ultrasound may be used as a supplemental tool for the assessment of tooth vitality, particularly for traumatized teeth that do not respond to sensibility tests. Ideally, tooth vitality could be more accurately estimated using both sensibility tests and pulpal blood flow assessment using Doppler ultrasound.

According to the principles of the Doppler effect, changes in frequency are proportional to the velocity of the moving object.⁵ Therefore, it is possible to estimate pulsation rhythms through signals from arteries

Figure 3 Findings of Doppler ultrasound performed for pulpal blood flow assessment in the patient and a healthy volunteer. (a) Doppler spectrum of the patient (Tooth #6) arrhythmical peaks can be seen (arrow heads). (b) Doppler spectrum of a healthy volunteer (33-year-old male). Peaks are shown at regular intervals (arrow heads). (c) Electrocardiogram of the patient irregular QRS complex intervals (arrow heads) and fibrillatory P waves (ellipses with dotted line) can be seen.

or arterioles. Because a patient's pulsatile patterns appeared as sounds and spectra during Doppler ultrasound, a part of cardiac function—particularly ventricular contraction—could be roughly evaluated. It has been also reported that the pulse width synchronizes with the cardiac cycle during pulpal blood flow assessment using laser Doppler.¹² Accordingly, high peaks of sounds or spectra during pulpal blood flow assessment using Doppler ultrasound would exhibit one's pulse. Abnormal signal patterns that are too narrow, wide, or arbitrary may represent cardiac arrhythmias such as tachycardia (over 100 bpm), bradycardia (below 60 bpm), or atrial fibrillation, respectively.⁶ Therefore, cardiac arrhythmia can be suspected on the basis of output signals during a Doppler ultrasound test.

Atrial fibrillation is the most common cardiac arrhythmia. During fibrillation, blood pools in the atria and clots may form in the atrial appendage, which could increase the risk for embolic stroke. It is believed that

atrial fibrillation is associated with a five-fold increased risk for stroke, as well as an increased risk for heart failure, mortality, poor quality of life, and decreased exercise capacity.¹³ Patients commonly complain of fatigue, palpitations, chest pain, syncope, dyspnea, and/or light-headedness. These symptoms are non-specific; therefore, they cannot be used to diagnose and determine the onset of atrial fibrillation. Suspected atrial fibrillation should always be confirmed using 12-lead electrocardiography. Electrocardiographic findings include replacement of normal consistent P waves (atrial activation) with fibrillatory waves. Moreover, erratic activation of the ventricles results in an irregular, rapid heart rate and a narrow QRS complex.⁶ Although accurate diagnosis should be performed using electrocardiography, it has been suggested that pulse palpation could be used for ruling out atrial fibrillation, given that pulsation has relatively low specificity but high sensitivity for the detection of atrial fibrillation.¹⁴ All these findings suggest that patients

showing irregular or arbitrary pulsatile patterns during pulpal blood flow assessment using Doppler ultrasound should be referred to a medical doctor for further evaluation of the cardiovascular status.

To date, ultrasound has been an unfamiliar modality for dental clinicians, as there is not a single ultrasound device that has been designed specifically for dental hard tissue and pulp. However, studies have demonstrated that it is possible to assess pulpal blood flow using Doppler ultrasound not only theoretically but also practically.²⁻⁴ Nevertheless, issues concerning the quantitative measurement of the pulpal blood flow rate remain unresolved. The acoustic properties of enamel and dentin are quite different from those of soft tissues,¹⁵ which prevents the accurate calculation of flow velocity using a conventional ultrasound device. Calibration of an existing device for dental hard tissues or, ideally, the development of a new device customized for dental examination, is needed. Additionally, further investigations are necessary to find an appropriate coupling material for dental hard tissues. Because only a few basic observational studies have been published till date, future clinical studies should be conducted to explore various possibilities for the clinical use of Doppler ultrasound in the field of dentistry. We believe that multidisciplinary convergence between medical and dental research will certainly contribute to the advancement of current technology.

To summarize, Doppler ultrasound can be a useful method for the qualitative assessment of blood flow

in the dental pulp, in addition to providing information about pulsation. In certain situations, it may raise suspicion for cardiovascular abnormalities, such as atrial fibrillation, which appears as an irregular sound and spectrum rhythm. When a patient exhibits irregular pulsation patterns in a dental clinic, cardiovascular problems should be suspected and the patient should be referred to a medical doctor.

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Informed consent

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