Ultrasound Assessment of Bone Healing after Root-end Surgery: Echoes Back to Patient's Safety

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Abstract

Introduction: The aim of this study was to present ultrasound imaging (UI) techniques as promising and safe tools for the follow-up of root-end surgery (RES) *in vivo*. **Methods:** The study included 8 patients who underwent RES. All were followed up using UI at 1 week, 1 month, 2 months, 3 months, and 6 months (if necessary) after RES. The bony crypt was defined on the ultrasound image, and the following observations were made during follow-up: cortical bone interruption and surface area measurement of the residual echoic bony crypt image. **Results:** In all cases, the hypoechoic image became hyperechoic, indicating gradual bone healing of the crypt. Compared with baseline, at 3 months a remaining cortical opening of 51.2% (±12.6%) and a bony crypt surface area of 24.3% (±10.8%) was detected for all patients. For 50% of the patients, the echographic follow-up ended at 3 months because the ultrasound waves could no longer enter the bony crypt. For 4 patients who attended the 6-month recall, a remaining cortical disruption of 43.2% (±9.9%) and a bony crypt surface area of 17.2% (±7%) compared with the baseline was noted. **Conclusions:** UI is a promising follow-up tool for RES. It helps clinicians understand the initial stages of bone healing, allows close healing monitoring, and is radiation free. *(J Endod 2017;■:1–6)*

Key Words

Echography, endodontics, follow-up study, microsurgery, ultrasonography

Significance

Ultrasound imaging is a promising follow-up tool for root-end surgery. It helps to understand the initial stages of bone healing, allows close healing monitoring, and is radiation free.

Ultrasound imaging (UI) techniques are being widely used in the medical field. UI uses the reflection of ultrasound waves at the interfaces of tissues with different acoustic properties (1, 2). These acoustic waves are generated by electromechanical transducers and piezoelectric materials. Unlike X-ray, ultrasound requires a medium to transmit energy. The propagation of sound waves is faster in solids than in liquids and slowest in gases. Because soft tissues behave like viscous fluids, the energy transportation is mainly via longitudinal waves. Variations in the speed of sound are caused by temperature changes or heterogeneity of soft tissues (3). Nevertheless, hard tissues, such as tooth and bone, are more complex and vary more in the speed of sound than soft tissues. Not only longitudinal waves but also shear modulus–dependent waves develop in hard tissues. The associated interface effects and energy loss between different tissue types may be a limiting factor for brightness mode imaging (4). The reflected waves, in the same direction as the original waves, are captured and converted into radiofrequency voltage traces and images. This technique is called pulse echo ultrasound. Brightness mode imaging, in which electrical energy is transformed into a light spot using a grayscale on a monitor, is the preferred display mode for dental purposes. Diagnostic ultrasound frequencies are expressed in MHz. Lower frequencies are less absorbed and penetrate deeper into tissues but have a lower image resolution. High-frequency waves penetrate less into tissues and produce high-resolution images of more superficial tissues (5).

The first data of diagnostic UI in dentistry were published in 1963 by Baum et al (6), who tried to visualize the internal structures of teeth with a transducer. Many other applications of UI in dentistry have been explored since, such as the detection of caries, dental and maxillofacial fractures, crack visualization, soft tissue lesions, periodontal defects, temporomandibular and implant disorders, and the measurement of muscle and gingival thickness (3, 7).The most promising use of ultrasound is the ability to make a differential diagnosis of bone defects of pathologic origin in the jaw (5). Any given tissue might be echogenic (reflecting), anechoic (no reflection), or transonic. This implies that a differential diagnosis can be made by UI between a cyst (hypoechoic to anechoic = less or no reflection from ultrasound waves) or a granulomatous tissue (hyperechoic = high reflection of waves) (8). UI is of growing interest because of the following advantages: it is noninvasive, inexpensive, and painless. In comparison with

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conventional radiography (CR) and computed tomographic imaging, UI does not cause ionizing radiation.

Root-end surgery (RES) is a reliable method for the treatment of teeth with persistent periapical lesions or when orthograde retreatment is not feasible. Successful outcomes of above 80% have been reported in recent studies (9, 10). This high success rate was achieved because of the integration of modern surgical techniques such as magnifying devices, microsurgical instruments, ultrasonic tips, and improved root-end filling materials (11–13). However, most of the studies reporting RES outcomes are based on periapical radiographic assessment (14). Periapical radiographs have been used as the gold standard to evaluate healing of endodontic lesions (15). Computed tomographic and cone-beam computed tomographic (CBCT) imaging are useful to provide information on the actual healing progress. However, because of the lack of standardization in treatment and study assessment protocols, it is very difficult to draw relevant clinical conclusions (16). Two major limiting factors in the evaluation of success are the use of 2-dimensional radiographs and the follow-up time after RES. More research is needed to explore alternative imaging techniques with less radiation exposure for periapical healing evaluation. The objective of this study was to evaluate UI as a safe early-stage bone healing assessment method for RES.

Materials and Methods

Patient Selection

All patients presented in this study were the subjects of a randomized controlled clinical trial (registration number: NCT02528240) approved by the Medical Ethics Committee of UZ KU Leuven (KU Leuven, Leuven, Belgium). During the intake consultation performed by the main investigator (N.M. [an endodontist]), radiographic (periapical radiography and CBCT imaging), demographic, and clinical data were collected. The exclusion criteria were as follows: unlikely to be able to comply with the study procedures, orthograde endodontic (re)treatment was indicated, a known history of malignancy, metabolic diseases, bleeding disorders, human immunodeficiency virus disease, or chemotherapy or radiation within 5 years before the study. Eight included patients who had the longest UI follow-up were selected for this preliminary UI assessment (Table 1).

Surgical Procedure

All surgical procedures were performed by 2 surgeons (O.S. and A.V.H.) trained in RES using a dental operating microscope (OPMI PICO; Carl Zeiss Meditec, Oberkochen, Germany). The incisions, flap elevation, and suturing were performed using magnifying loupes. After administering local anesthetics, a flap was raised, and an osteotomy was performed. After removing the soft tissue debris, the root tip was sectioned with a 0° to 10° bevel using a burr under copious physiologic water irrigation. Methylene blue was used to stain the resected root surfaces. The root-end preparation was then inspected microscopically to search for missed anatomic details. The root-end preparation was performed using ultrasonic retro tips. After drying, the root-end preparation was filled with ProRoot Mineral Trioxide Aggregate (MTA) (Dentsply Tulsa, Tulsa, OK). Depending on which group the patient was randomly allocated to, the bony crypt was treated as follows:

(1) application of leucocyte- and platelet-rich fibrin (L-PRF) clots supplemented with an overlying L-PRF membrane;
(2) application of L-PRF clots plus a Bio-Gide (Geistlich, Wolhusen, Switzerland) membrane with an overlying L-PRF membrane;
(3) application of a Bio-Gide membrane, or
(4) nothing. Afterward, the wound site was closed, pressure was applied, and the flap was sutured using Vicryl Rapide 3.0 and 6.0 (Ethicon, Somerville, NJ). The patient was given an ice pack and postoperative instructions.

Ultrasound Examination

All treated teeth were investigated by an endodontist (N.M.) using an UI device (Flex Focus 800; BK Medical, Analogic Ultrasound, Peabody, MA). A high-definition, high-frequency, and linear ultrasonic probe operating at a frequency of 12 MHz was used. After the probe was covered with ultrasound gel (Aquasonic; Parker Labs, Fairfield, NJ), it was placed extraorally against the skin corresponding to the apical region of the tooth of interest. Once the bone defect was identified, the probe was slightly moved from apical to coronal to define the bone defect, and still images and video trails were made. The patient underwent this examination at 1 week, 1 month, 2 months, and 3 months after surgery (Fig. 1). When ultrasound revealed some relevant cortical bone interruption 3 months after RES, ultrasound was also applied 6 months after treatment. To achieve the best reproducible and matching images, the previous images were always displayed simultaneously to compare positions during the ultrasound examination. All ultrasound images were taken at a resolution of 3/27 Res/Hz.

Data Analysis

Two independent observers (F.C. and M.V.M. [postgraduate trainees in endodontics]) evaluated the ultrasound images. All images were viewed in a dimmed room on a Dell computer screen (Dell Inc, Round Rock, TX). Ultrasound images are difficult to compare because of positioning irregularities (compared with normal radiographies), but while displaying the previous images during examination and the multiple successive images, it was reasonably possible to achieve comparable images. The ultrasound images were investigated for cortical bone repair and the bone healing rate. The surface area of the residual bony crypt (mm^2) and the cortical bone opening (mm) at the largest

TABLE 1. Demographic Details of the Included Subjects, Involved Teeth, and Reason for Root-end Surgery (RES)

Patient	Age	Sex	Tooth number	Diagnostic reason for RES	Allocated study group
1	52	F	Second maxillary premolar	PAPE	L-PRF and BG
2	52	F	First mandibular molar	PAPE and ledge	L-PRF and BG
3	62	M	Lateral mandibular incisor	PAPE (cyst suspicion)	L-PRF and BG
4	53	F	First mandibular molar	PAPE and overfilling	L-PRF and BG
5	25	M	First mandibular premolar	PAPE	L-PRF
6	40	M	First mandibular molar	PAPE (cyst suspicion)	L-PRF
7	62	F	First maxillary premolar	PAPE and well-adapted post and crown	L-PRF
8	35	M	First maxillary molar	PAPE and non-retrievable broken instrument	No L-PRF and no BG

BG, Bio-Gide; F, female; L-PRF, leukocyte- and platelet-rich fibrin; M, male; PAPE, persistent apical periodontitis after endodontic treatment.