# Detection of a Second Mesiobuccal Canal in Maxillary Molars by Swept-source Optical Coherence Tomography

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## Abstract

**Introduction:** The purpose of this study was to investigate the ability of swept-source optical coherence tomographic (SS-OCT) imaging to detect a second mesiobuccal canal (MB2) in maxillary molars compared with visual inspection (VI) and dental operating microscopy (DOM). **Methods:** Forty extracted human maxillary molars were examined. After the removal of half the crown and access cavity preparation, the existence of MB2 canals was confirmed based on cross-sectional images of each tooth obtained by micro–computed tomographic scanning as the reference standard. Then, the pulp chamber floor was scanned by SS-OCT imaging. Three dentists independently evaluated the SS-OCT images and the pulp chamber floor under VI and DOM for the presence of MB2 canals. The detection rate of MB2 canals for SS-OCT imaging, VI, and DOM was calculated, and statistical analysis was performed. **Results:** MB2 canals existed in 19 of 40 teeth (47.5%) using micro-CT imaging. Sensitivity of DOM (0.947) was significantly higher than that of SS-OCT imaging (0.632). Specificity of SS-OCT imaging (0.714) was significantly higher than that of DOM (0.333). No statistically significant differences were found for accuracy among the 3 methods. Kappa values of SS-OCT, VI, and DOM were 0.526, 0.417, and 0.326, respectively. **Conclusions:** SS-OCT imaging is noninvasive, involves no ionizing radiation, and is accurate for the detection of MB2 canals. *(J Endod 2014;40:1865–1868)*

## Key Words

Canal detection, mesiobuccal canal, molar, optical coherence tomography

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Maxillary molars often have 2 canals in the mesiobuccal (MB) root. The frequency with which this second MB root (MB2) is observed ranges between 36% and 95% *in vitro* (1, 2) and 17% and 65 % *in vivo* (3, 4). The detection rate of MB2 *in vivo* is generally lower than that *in vitro* (5, 6). Seidberg et al (5) reported a large difference in the detection rate between *in vivo* (33%) and *in vitro* (62%) examinations. Pomeranz and Fishelberg (6) reported similar results, with only 31% of teeth with an MB2 identified correctly *in vivo* compared with 69% *in vitro*. Furthermore, Wolcott et al (7) showed significant differences in the identification of the MB2 between the initial treatment and retreatments. They mentioned that the failure to find and treat existing MB2 canals worsened the long-term prognosis.

In clinical settings, limited access and visibility as well as the risk of perforation may explain the lower detection rate of an MB2 (5, 6). Some studies have reported that the detection rate of MB2 canals increases under magnification such as with a microscope, dental loupes, or the combined magnification and dentin removal technique (4, 8–10). Other studies have found that the use of magnification does not significantly increase the number of detected MB2 canals, mainly because of pulpal calcification (11). The use of a microscope did not increase the detection rate of MB2 canals *in vivo* compared with reports of different access preparations without microscopy (12). Although both magnification and dentin removal under magnification increased the detection rate of MB2 canals over that with direct visualization, 13% of MB2 canals could not be detected because of canal calcification or apically located branching (10).

Optical coherence tomographic (OCT) imaging is a nondestructive imaging technique that uses low-coherence interferometry to generate images of internal biological structures (13, 14). In endodontics, OCT imaging is a proven and reliable technique for nondestructively evaluating intracanal anatomy, root perforations, and vertical root fractures (15, 16). Recently, a swept-source variant of OCT (SS-OCT) imaging has been developed. SS-OCT imaging offers resolution higher than that of plain radiographic or current computed tomographic (CT) images, and advanced variations of the fast Fourier transformation algorithm result in reduced noise (17). Therefore, SS-OCT imaging was evaluated as a putative new technique for the detection of MB2. The purpose of this study was to evaluate the detection rate of MB2 canals in maxillary molars using SS-OCT imaging compared with visual inspection (VI) and the use of a dental operating microscope (DOM).

## Materials and Methods

### Tooth Selection and Preparation

Forty extracted human maxillary molars with no caries, restoration, or root canal treatment were selected for this study. The teeth were stored in distilled water at room temperature. The reasons for extraction and other patient information were unknown. The use of these teeth was approved by the Institutional Review Board of Tokyo Medical and Dental University (no. 923), Tokyo, Japan.

Initially, the crown was removed at the level of pulp exposure with a water-cooled low-speed saw (Isomet; Buehler, Lake Bluff, IL) perpendicular to the tooth axis. Standard cavity access was then performed. An ultrasonic tip (Piezon Master400; EMS, Nyon, Switzerland) was used for the removal of gross tissue, whereas the pulp chamber was soaked in 6% sodium hypochlorite solution. The coronal third of the MB canal was preflared with drills (sizes 5–2 [ProFile O.S. Orifice Shaper; Dentsply Tulsa Dental, Tulsa, OK]). After each instrumentation, the MB was irrigated with 6% sodium hypochlorite solution. The tooth was mounted with autopolymerizing resin (OSTRONII; GC, Tokyo, Japan) at an angle to allow direct observation of the MB.

## Micro-CT Scanning as the Reference Standard

The presence or absence of MB2 canals was determined using a micro-CT scanner (inspeXio SMX100CT; Shimadzu, Kyoto, Japan) with exposure parameters set at 100 kVp and 20 $\mu$A. The image voxel size was 25 $\mu$m. The area ranging from the pulp chamber floor to the middle third of the MB was scanned to assess the number of canals in the MB root.

## SS-OCT System and Scanning

This experiment involved the use of a SS-OCT system (Prototype 2; Panasonic Health Care Co Ltd, Tokyo, Japan) with a 1330-nm center wavelength and a 30-kHz sweep rate. The handheld probe power was less than 10 mW, which is within the American National Standards Institute limit. The high-speed frequency swept laser beam was projected onto the target and moved across the cross-sectional plane of interest using a handheld probe. The backscattered light from the sampled plane was transmitted back to the system, digitized according to the time scale, and analyzed using the Fourier algorithm to determine the depth information of the plane. This procedure can be reconstructed as 2-dimensional images. The system can also acquire serial 2-dimensional sections and reconstruct them as 3-dimensional (3D) images. Axial resolution of the image is 12 $\mu$m in air, which is equal to 8 $\mu$m in tissue. A 500 $\times$ 130 $\times$ 1019 voxel (3D) image (7 $\times$ 7 $\times$ 7 mm) can be generated within 4.5 seconds, including data acquisition and process time.

The pulp chamber floor was 3D scanned using SS-OCT imaging. These cross-sectional images were reconstructed, and an animation of the serial horizontal slice images was made for 20 seconds (30 frames/s) using 3D image processing software (Amira5.4.5; FEI Visualization Sciences Group, Burlington, MA).

## Evaluation with SS-OCT Imaging, VI, and DOM

The examiners were 3 dentists who each had more than 5 years of clinical experience in the Department of Endodontics, Tokyo Medical and Dental University Hospital. The examiners independently evaluated the SS-OCT animation and the pulp chamber floor under VI and DOM and scored the techniques as follows:

1. Obvious single MB root canal
2. Probable single MB root canal
3. Probable MB2 root canal
4. Obvious MB2 root canal

After the animation was observed in duplicate on a liquid crystal display (ProLite X2377HDS; Iiyama, Tokyo, Japan) at 1920 $\times$ 1080 pixel resolution on a desktop computer (MDV-AQX9210SH4-WS; Mouse Computer, Tokyo, Japan), the existence of an MB2 canal was assessed in accordance with the scores. The examiners had been instructed in evaluation using 6 animations that were not included in the main study. For VI, the pulp chamber floor was lightly air blown and observed without magnification or instrumentation. Each sample was set at the epigastric height of each evaluator. The search time was limited to 10 seconds. For DOM, the examiner observed 40 samples in random order, scanning the pulp chamber floor of each sample for the presence of an MB2 canal using DOM (OPMIpico; Zeiss, Oberkochen, Germany) at 21.3 $\times$ magnification without instrumentation. The search time was limited to 10 seconds.

## Statistical Analysis

Statistical analysis was performed using SPSS v17.0 statistics software (SPSS Inc, Chicago, IL). The diagnostic results obtained from SS-OCT imaging, VI, and DOM were compared with the reference standard (micro-CT imaging), and sensitivity, specificity, the positive predictive value (PPV), the negative predictive value, and accuracy were determined for each technique. A receiver operating characteristic curve analysis was also performed, and the area under the receiver operating characteristic curve was calculated. Sensitivity, specificity, and accuracy were analyzed by the Wilcoxon test with Bonferroni correction at a significance level of 5% to compare SS-OCT imaging, VI, and DOM. Interexaminer agreement was assessed using kappa statistics.

# Results

MB2 canals existed in 19 of 40 teeth (47.5%) based on the reference standard. The cross-sectional horizontal images generated by micro-CT and SS-OCT imaging are shown in Figure 1. The MB2 canal is presented in the micro-CT image as a dark round area (*arrow*, Fig. 1*A*) and as a dark hole in a bright area on SS-OCT imaging (*arrow*, Fig. 1*B*). On SS-OCT images, the MB2 orifice observed is still dark but is

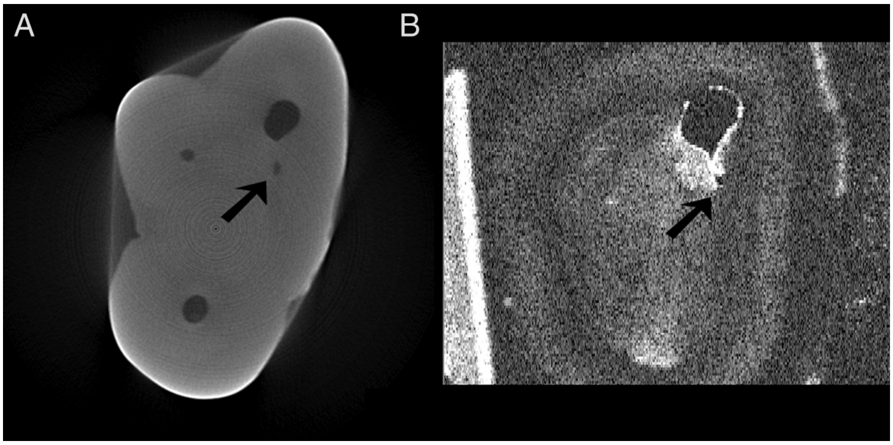


**Figure 1.** Cross-sectional images of the same sample on (*A*) micro-CT imaging and (*B*) SS-OCT MB2 is indicated by the *arrows*.