In 1967, Schilder had postulated that the final objective of endodontic procedures should be the total three-dimensional filling of the root canals and all accessory canals, in addition to the elimination of all organic debris, bacteria, and bacterial toxin. Therefore, the ability of filling lateral canals has been regarded as a measure of the endodontic treatment quality.

Nevertheless, the substantive need for filling lateral and accessory canals is still a controversial issue among clinicians. Kasahara et al. reported the incidence of accessory canals in the maxillary central incisors to be over 60%, and Dammaschke et al. showed 79% of molars had lateral/accessory canals. Large numbers of lateral/accessory canals exist in the roots, but the frequency of periapical lesions related with these ramifications is not as high as anticipated. The answers for these clinical observations are still not clarified. The differences in size between main apical foramen and lateral/accessory foramen might explain why the apical lesions were observed more frequently than lateral lesions. The amount of bacteria existing in the small ramifications might not be sufficient to raise inflammation which can be detectable on radiographs. Occasionally, the lateral lesion is healed without lateral canal filling because simple canal treatment could stop the diffusion of bacterial products from the main canal which might reach periodontal ligaments through lateral/accessory canals maintaining vitality. However, if periapical lesions originate from bacteria surviving in some spaces derived from lateral canals and irregularities of root canals, such as isthmuses, ramifications, deltas, then the treatment seems to be particularly challenging for clinicians.

Since it is unlikely to kill all pathogens in entire root canals, Buchanan suggested that the embedding of remaining bacteria with filling materials can achieve the same results as from complete disinfection in the canal systems. Thermo-plasticised gutta-percha filling techniques have been considered preferable means to achieve this goal due to remarkable frequency of lateral canal filling based on case reports and in vitro studies. Two major concerns for using thermoplastic techniques would be the periodontium damage by temperature increase and overextension of root canal filling materials, especially gutta-percha. The application of lasers in endodontic treatment is an attempt to minimise these potential risks.

The investigation of laser applications in endodontics was first reported in the early 1970s. Among a variety of conceivable uses, most researches emphasised the efficiency of debridement and the possibility of shaping the root canal by laser. It seems that the disinfection and cleaning of the root canals would be the most practical use of laser devices in endodontic
The maximum disinfecting effects in root canals can be achieved by laser-activated irrigation with NaOCl solution due to the pulsation of laser output and the easy access to root canals by an optical fibre. The acoustic streaming, caused by the collapse of laser-induced bubbles, was identified as an effective mechanism for dentin debridement in the apical portion of root canals. The pressure produced by the pulsation of laser beam in a narrow space like a root canal is a unique feature of laser devices.

No study addresses the application of laser pulsation on canal filling so far. This report documents three cases of traditional endodontic treatment that were supplemented with the use of the Nd:YAP laser which resulted in the radiographic identification of sealer in apical ramifications.

Material and methods

Three patients of this case report received root canal treatment necessitated by carious exposure of the pulp or apical periodontitis. Endodontic treatment consisted of the following procedures: access opening, canal preparation by hand and rotary instruments, canal irrigation, and canal filling. The canals were enlarged conservatively providing adequate proximation of the optic fibre to the apical third of the root canal. Three-percentage NaOCl solution and EDTA paste (RC-Prep, Premier) were used during instrumentation; saline was used between application of NaOCl and EDTA. Gutta-percha cones (Gutta Percha Points, Meta Biomed) and zinc-oxide eugenol-based sealer (ZOB Seal, Meta Biomed) were used for canal obturation.

The exposure to the Nd:YAP laser (Lokki YAP, Lokki), using 220 µm optical fibre (Fig. 1) with 160 mJ/pulse and 30 Hz, was conducted during canal irrigation. The optical fibre was put into a root canal 2–3 mm short of working length as a starting point for pulsed radiation. Radiation of the laser was followed with upward movement of the optical fibre against the canal wall and stopped when the optic fibre was close to the orifice. Laser irradiation was repeated throughout all canals as mimicking circumferential filing until no debris was noted in the pulp chamber followed by drying of the canals with paper points. The 220 µm optical fibre with the mode of 180 mJ/pulse and 5 Hz was chosen for canal filling. After root canals were filled with sealer by using a lentulo spiral, a single pulse of laser beam was radiated at a position 2–3 mm short of working length at first, and then another two single pulses of laser beam were emitted in the middle of the root and at a location 2–3 mm below the orifice consecutively. Cold lateral condensation was accomplished with the placement of a master gutta-percha cone followed by accessory cones for complete obturation. Periapical X-ray films were taken to evaluate the quality of the root canal obturation. No medications were prescribed during treatment or postoperatively for patients.
Case presentation

Case 1 (Figs. 2a–e)
A 45-year-old woman sought treatment for severe pain associated with a mandibular left canine. Clinically there was severe vertical mobility and cuspal interference existed when the patient moved her mandible in lateral excursion. Radiographic examination revealed a radiolucent lesion extending along the mesial aspect of the root. Before beginning access opening, the canine was splinted to the mandibular left, lateral incisor and first premolar, and the occlusion was adjusted to eliminate lateral interference. Purulent exudate was drained not only from the periodontal pocket, but also from the canal orifice after the chamber was opened. An accessory canal mimicking a bifurcated apical canal was sealed. At the ten-month recall, bone density was increased around the root and no inflammatory signs were observed in the periodontal pocket.

Case 2 (Figs. 3a & b)
A 46-year-old woman with missing restorations on the mandibular right first and second premolars complained of toothache. The fracture of the crowns was a result of secondary caries at the cervical portion of premolars. A large apical lesion was observed around the root of the first premolar. A prostodontic treatment of splinted crowns on the mandibular right first and second premolars with crown lengthening and cast posts was planned due to the patient’s desire to retain teeth. All symptoms subsided after endodontic treatment was completed. There was radiographic evidence of sealer in the apical ramifications.

Case 3 (Figs. 4a–c)
A 40-year-old woman sought treatment for a labial sinus tract related to the maxillary right first premolar. Extensive pulpal calcification was noticed on the periapical radiograph. The gutta-percha cone indicated that the labial sinus tract which appears to originate from a lateral canal. A dilaceration of the apical third and calcification of the canal made access difficult, resulting in a perforation on the mesial aspect of the root. The working length was adjusted and the canal was obturated to this point. A lateral canal was filled with sealer on the distal aspect of the root. The patient returned for follow-up in two weeks. The sinus tract healed and she was asymptomatic.

Discussion
Microbial infection is considered a major cause of endodontic failure. Several studies reported that periapical lesions did not develop without bacteria, although pulp tissue had been devitalised\textsuperscript{6,23}; therefore, thorough disinfection is strongly recommended before obturation is performed. The complexity and variability of the root canal system make it difficult to achieve ideal goals of endodontic treatment. A laser system which transmits energy through a flexible and
small-diameter optical fibre can provide convenient access to root canals. Consequently, direct and indirect disinfection by laser possibly takes place while irradiating the inside of root canals. De Andrade AK et al.\textsuperscript{24} reported laser disinfection is an effective way to decrease bacterial colonies when the mean power of laser exposure was over 3 Watts. The energy of the Nd:YAP laser is powerful enough to eliminate microbes because the average output of the Nd:YAP laser is 10 Watts and the peak power may reach 2.6 kW. Only 0.00015 seconds of laser energy is emitted for every pulsed irradiation,\textsuperscript{25} so the fleeting moment of emission minimises the risk of overheating surrounding tissues and has bactericidal effects by direct contact. Two possibilities may explain the indirect disinfection of laser. When the mode of 30 Hz is used in narrow space such as a root canal filled with irrigation solution, shock waves may occur repeatedly and be transmitted into dentinal tubules to kill bacteria. Pulsed irradiation causes vibrations in narrow spaces similar to ultrasonic devices.\textsuperscript{25} This laser energy caused by high frequency emission of the Nd:YAP laser help maintain the integrity of the root because it is not necessary to eliminate excessive contaminated dentin of canal wall. Minimal enlargement is sufficient, if the space can allow 220 µm optical fibre to move passively through the canal. The laser energy also causes temperature of the NaOCl solution to rise resulting in increased efficiency of dissolving organic debris and disinfection in canals.\textsuperscript{26} This enhanced cleanliness gains space in apical ramifications for sealer placement.

In the clinical practice, the warm vertical condensation technique is widely used to obturate the canal, but keeping a gutta-percha cone warm enough to obtain favourable sealing in the ramifications may cause lasting discomfort because of thermal damage to periodontal tissues.\textsuperscript{27,28} On the other hand, the mechanism of sealer placement by the Nd:YAP laser is different from thermoplastic techniques. Sealer is placed in the canal with a lentulo spiral followed by application of the Nd:YAP laser to disperse the sealer into ramifications by the fleeting pressure of laser beam. Although the pressure causes slight discomfort, the post-filled sensation is not overt and dissipates clinically within a few hours. In most cases, there was radiographic evidence of sealer being forced into lateral/accessory canals. Puffs of sealer from the periapical foramen are considered an evidence of tight seal.\textsuperscript{1} Zinc-oxide and eugenol-based sealer was chosen in this case report because working and setting time are conducive to completion of the entire obturation process before the sealer sets. The heat from laser irradiation induces fast setting and burning of epoxy resin-based sealer; these types of sealers are not recommended with this technique. Taking periapical films during obturation is recommended to confirm whether the sealer is placed into canal adequately.

Another advantage of using the Nd:YAP laser is that the need for analgesics/antibiotics after treatment can be decreased. The Nd:YAP laser has a strong antibacterial effect and an excellent potential for promoting tissue healing induced without a more invasive procedure\textsuperscript{29,30}, therefore, using the Nd:YAP laser may be more efficient in disinfection and obturation of the root canal system resulting in a higher success rate of non-surgical root canal treatment. Based upon personal experience and observation for four years in laser application, Nd:YAP laser-assistant endodontic treatment is less technique sensitive and easy for general practitioners to acquire the skill and follow this method.

Further histological analysis is needed to verify the significance of laser disinfection and sealer placement with the use of the Nd:YAP laser. These additional investigations will hopefully add to the store of knowledge relative to canal disinfection and the benefits of adequate obturation of auxiliary canals.

Conclusion

Obturation of lateral canals and apical ramifications were observed on postoperative radiographs. This indicates enhanced canal cleanliness and sealing of these small ramifications. The Nd:YAP laser can be utilised as adjuncts to disinfection, canal irrigation and canal filling to improve the quality of obturation in the canal system. The efficiency of Nd:YAP laser-assistant endodontic treatment could simplify the procedure of root canal treatment without purchasing additional equipment to provide an advanced level of treatment._

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