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Comparison Of Apical Centring Ability Between Incisal-Shifted Access And Traditional Lingual Access For Maxillary Anterior Teeth

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Comparison of apical centring ability between incisal-shifted access and traditional lingual access for maxillary anterior teeth

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Abstract

The aim of this study was to compare the apical centring ability of incisal-shifted access (ISA) with that of traditional lingual access (TLA). Fifteen three-dimensional printed resin models were prepared from the computed tomography data for a human maxillary central incisor and divided into ISA (n=7), TLA (n=7), and control (n=1) groups. After access preparation, these models were shaped to the working length using K-files up to #40, followed by step-back procedures. An apical portion of the model was removed at 0.5 mm coronal to the working length. Microscopic images of each cutting surface were taken to measure the preparation area and the distance of transportation. TLA created a larger preparation area than ISA ($p < 0.05$). The distance of transportation (mean ± standard deviation) was 0.4 ± 0.1 mm for ISA and 0.7 ± 0.1 mm for TLA ($p < 0.05$). Access cavity preparation has a significant effect on apical centring ability. ISA is beneficial for maintaining apical configuration.

Keywords

cone-beam computed tomography; dental pulp cavity; incisor; root canal preparation; 3D printing

Introduction

Appropriate access cavity preparation is essential during root canal treatment. Several authors have suggested that the objectives of access cavity preparation include ensuring straight-line access, removing all debris from the pulp chamber, and securing the seat for the temporary seal (1–3). Smaller access cavity preparation prevents creation of straight-line access in curved root canals, thereby complicating the procedure (4). Access cavity

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Disclosure Statement
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preparation is the first step in root canal treatment and has a significant impact on subsequent procedures.

In the anterior teeth, the outline of access cavity preparation has been traditionally located at the centre of the lingual surface, with a triangular outline form (5, 6). In most cases, the direction of traditional lingual access (TLA) cavity preparation is different from the direction of the root canal, especially in its apical third. This is because a discrepancy usually exists between the long axis of the crown and the long axis of the root canal. Laturno and Zillich (7) and Zillich and Jerome (8) have reported that TLA achieved straight-line access in the maxillary central and lateral incisors in only 10% and 0.8% of cases, respectively. In these studies, they also demonstrated that shifting the location of access from the centre of the lingual surface to the incisal edge increases accessibility from the coronal aspect of the root to the apex. Such incisal-shifted access (ISA) allows a greater area of the root canal wall to be accessible to instruments such as Gates Glidden Drills and K-files (9). Therefore, ISA could be an alternative approach to improve straight-line access.

Iatrogenic mishaps such as ledging, zipping, and apical transportation can occur after excessive removal of dentine caused by a number of errors during endodontic procedures (10). Such events may leave sources of infection inside the root canal, leading to a negative prognosis for endodontically treated teeth (11–13). Thus, the ability to maintain the original morphology of the root canal could be directly linked to the clinical success of root canal treatment (10). The improved straight-line access afforded by ISA could maintain the original curvature of the root canal, which in turn could avoid excessive removal of dentine and reduce the chance of iatrogenic mishaps.

Recently, three-dimensional (3D) printing technology has been used to fabricate duplicate physical models to aid in treatment planning (14, 15). With the use of cone-beam computed tomography (CBCT) data from a patient or an extracted tooth, clinicians can obtain a physical model of a tooth with the same external and internal morphology as that of the natural tooth. Moreover, the latest 3D printing technology has improved the ‘feel’ of cutting by using modified resin as the raw material (16). Thus, 3D printed models can be used for ex vivo study and can reduce the bias that may result from use of extracted teeth, which have a wide variety of morphologies, without losing natural tooth morphology.

Previous studies have shown that ISA provides better access to the root canal (7–9) for anterior teeth. However, little is known about the effect of ISA on canal shaping in the apical area. Therefore, the aim of this study was to compare the apical centring ability of ISA with that of TLA. This was achieved using 3D printed tooth models to measure the area of dentine removed and the distance of transportation. The null hypothesis was that there would be no difference between the apical centring ability of ISA and that of TLA.

Materials and methods

3D printed plastic tooth model

Fifteen identical plastic models fabricated from one extracted human tooth without caries or restorations were used. Original tooth data were obtained from a CBCT scan of an extracted maxillary right central incisor. The acquired CBCT scan data were converted into stereolithography files so that the 3D printer (ProJet 3500 HDPlus, 3D Systems, Rock Hill, SC, USA) could be used. The 3D tooth models were printed using a modified urethane acrylate photopolymer (VisiJet Crystal, 3D Systems, Rock Hill, SC, USA). The photopolymer was injected and cured one layer at a resolution of 16 μm (Fig. 1). The length of the tooth model was 21 mm and the angles of curvature for the mesiodistal and labiopalatal directions were 7.8 and 12.6 degrees, respectively, as determined by the Schneider technique (17).

Root canal preparation

Access cavity preparation was carried out in 14 models; thereafter, the models were divided into a TLA group and an ISA group (n=7 each). A tooth model without access cavity preparation and root canal instrumentation was used as the control. Fig. 2 shows the representative outline forms of both methods of access cavity preparation. A round-ended tapered diamond bur (F102R, Shofu, Kyoto, Japan) was used for preparation. In both groups, preparation began at the centre of the lingual surface. In the TLA group, the outline of the cavity was then enlarged to form a triangle and extended until the pulp horn was completely removed. In the ISA group, the cavity was enlarged and shifted in the incisal direction; the outline tended towards an oval shape.

After access cavity preparation, all tooth models in the experimental groups were subjected to the following procedure. First, the coronal third of the root canal was enlarged using Gates Glidden Drills (MANI, Tochigi, Japan) sized #1–#4. A #15 K-file (SybronEndo, Orange, CA, USA) was inserted into the canal until the tip of the file became visible at the major apical foramen. The distance between the incisal edge and the tip of the file was measured followed by subtraction of 1 mm from the measurement length; the difference was defined as the working length (WL). K-files from #20 to #40 were taken to the WL by both watch-winding, which is a 30–60-degree backwards and forwards oscillating motion, and by turn-and-pull cutting motions, accomplished by a quarter-turn clockwise rotation and withdrawal. The #40 file was set as the master apical file size. Step-back preparation in increments of 1 mm was performed up to a #55 K-file. The #15 file was used to recapitulate the canal between each file in order to maintain patency. The canal was rinsed with 2 mL of physiologic saline solution, which was delivered with a syringe and a 30-gauge needle inserted up to 2 mm short of the WL between each instrument. All procedures were performed by one operator.

Measurement

After completion of root canal preparation, each root tip was removed at 0.5 mm coronal to the WL by means of an Isomet low-speed saw (Buehler, Lake Bluff, IL, USA). Cross-sectional images of all specimens were captured by digital microscopy (SMZ800, Nikon, Tokyo, Japan) at a magnification of 40×. From these images, the area created by the canal preparation and the distance of transportation were measured and analysed using Photoshop CS3 (Adobe, San Jose, CA, USA).

The preparation area was measured by counting the number of pixels inside the border of the preparation. The borders of the preparation area were semi-automatically defined by the Magnetic Lasso Tool in the software according to pixel contrast and modified by the observer.

The distance of transportation was obtained by comparison of each post-preparation specimen with the control specimen. An inscribed circle was fitted to the border of the canal preparation space for all cross-sectional images. In cases where the shape of the border was oval, the outermost surface was adapted to make an inscribed circle. Pre-inscribed and post-inscribed circles were superimposed, and the centre of the inscribed circle was identified. The distance of transportation was defined by measurement between the centres of these inscribed circles (Fig. 3). The areas and distances were measured by an examiner who was blinded to the experimental groups. Measurements were obtained by one observer, other than the operator, who was blinded to the groups being tested.

The data were evaluated using SAS University Edition statistical analysis software (SAS Institute Inc., Cary, NC, USA). The Mann-Whitney *U* test was used to identify significant differences between ISA and TLA for both preparation areas and values for distances of transportation. The statistical significance level was set at $\alpha = 0.05$.

Results

Typical cross-sectional images for both TLA and ISA are shown in Fig. 4. All specimens showed root canal transportation labially. The results for preparation area and distance of transportation are summarized in Table 1. The area created after canal preparation for TLA was significantly larger than that for ISA ($P = 0.0106$). The preparation area (mean ± standard deviation) in the TLA and ISA groups was 65.5 ± 7.1 mm^2 and 51.8 ± 6.9 mm^2, respectively. The distance (mean ± standard deviation) between the centres of the inscribed circles was 0.7 ± 0.1 mm in the TLA group and 0.4 ± 0.1 mm in the ISA group. The tooth models treated with ISA showed a significantly smaller distance of transportation than those treated with TLA ($P = 0.0017$). Thus, our null hypothesis was rejected, which means that ISA could improve the apical centring ability for maxillary central anterior teeth.

Discussion

Numerous studies have emphasised the importance of straight-line access as an essential step for correct root canal instrumentation in posterior teeth (18–20). Early flaring of the coronal third of the root canal (21) is widely used by clinicians for successful straight-line access.

In anterior teeth, there is controversy regarding TLA (7–9), which is critical to gain straight-line access because the long axis of the tooth crown and the axis of the root canal are usually at an angle. TLA is still used clinically and is included as part of academic curricula (5, 6). ISA would be an ideal approach to ensuring straight-line access because it works closer to the long axis of the root canal.

In this study, TLA created a larger preparation area and showed a greater distance of transportation in the cross-sectional images than did ISA; nevertheless, the master apical size was set at #40 for all tooth models in the TLA and ISA groups. These results suggest that TLA leads to excessive removal of dentine and alters the original root canal configuration, which may lead to iatrogenic mishaps. A retrospective study (12) has shown that iatrogenic mishaps, such as creation of a ledge during the initial root canal treatment, have a significant negative impact on the treatment outcome. Further, Mannan et al. (9) reported that TLA leads to less instrumentation of the root canal walls, especially on the palatal side, when compared with ISA, by creation of a un-instrumented area that could become a source of refractory infection. Therefore, TLA is more likely to be associated with iatrogenic mishaps and an increased proportion of root canal walls that are inaccessible by instruments.

Decisions in favour of the use of ISA for restorations after root canal treatment should be carefully considered with a view to future revisions of standard clinical protocols. In brief, the thickness of the residual enamel around the incisal edge after ISA is thinner than that after TLA, and hence the physical strength of this area may decrease. This drawback will be resolved by use of a direct resin composite restoration after root canal treatment for a class IV cavity (23), which includes both the incisal edge and the proximal surface, with a high (90%) estimated overall success rate after 10 years (24). Further, the presence of enamel at the cavity margin affords an opportunity for long-term clinical success of a restoration due to durable and reliable resin-enamel bonds (25–27). Thus, the ISA outline approximates the incisal edge and creates thin enamel, although it is likely to have little impact on failure of restoration after root canal treatment.

The present study used 15 identical 3D printed tooth models fabricated from one tooth extracted from one human subject. The physical properties of tooth models should be similar to those of natural teeth. However, acrylic resin, which has been used in ex vivo studies (28), obviously had different hardness (29). The Shore D hardness of the 3D printed material used in this study is reported to be 85 (16), which is higher than that of acrylic resin (30). In addition, 3D printed models fabricated from the same materials as those used in this study have been reported to have excellent cutting properties (29). Thus, 3D printed material may have mechanical properties more similar to those of dentine than to those of acrylic resin. Owing to the limitation of the Shore D hardness test, no study has compared the mechanical properties of 3D printed materials with those of natural teeth. Further studies are needed to compare the mechanical properties of 3D printed materials with those of dentine by using different experimental methods. Use of extracted teeth for research has become difficult because of the strong demand to save patients' teeth and the requirement for strict compliance with a code of ethics. This 3D printed model has the advantage of being able to be used in ex vivo studies comparing different root canal procedures and can provide opportunities for clinical training. However, it should be remembered that neither CBCT or 3D printing can reproduce the microscopic structures of natural teeth, so there is a limit to its utilization for the target bacteria inhabiting microscopic structures such as the dentinal tubules.

In this study, only hand stainless steel files were used. The usefulness of ISA is unknown if nickel-titanium rotary files, which are more flexible and have the ability to maintain the original canal curvature, are used. Furthermore, we only used a maxillary central incisor in this study, so the usefulness of ISA when applied to the maxillary lateral or mandibular incisors is unclear, especially when these mandibular teeth have two separate root canals. However, given that maxillary lateral incisors have a more curved apical third, there is a greater likelihood of iatrogenic mishaps, which might explain why ISA has a benefit in regard to maintaining apical curvature when compared with TLA.

The clinical implication of this study is that it shows how the first step of the root canal procedure, access cavity preparation, has a significant effect on the entire root canal treatment procedure, and hence should be performed with great care if the treatment is to be successful. Incisal-shifted access for maxillary anterior teeth is a possible alternative to traditional access and is worth incorporating into clinical and educational processes. However, future studies should evaluate the effectiveness of access cavity design for resistance to fracture after restoration, the removal of bacterial pathogens, and, most importantly, clinical outcomes.

Conclusions

Access cavity preparation has a significant effect on apical centring ability. ISA is beneficial for maintaining the apical configuration under the experimental condition that uses 3D printed tooth models instrumented by K-file.

Acknowledgments

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Figure 1.
Mesial view of the three-dimensional printed model.

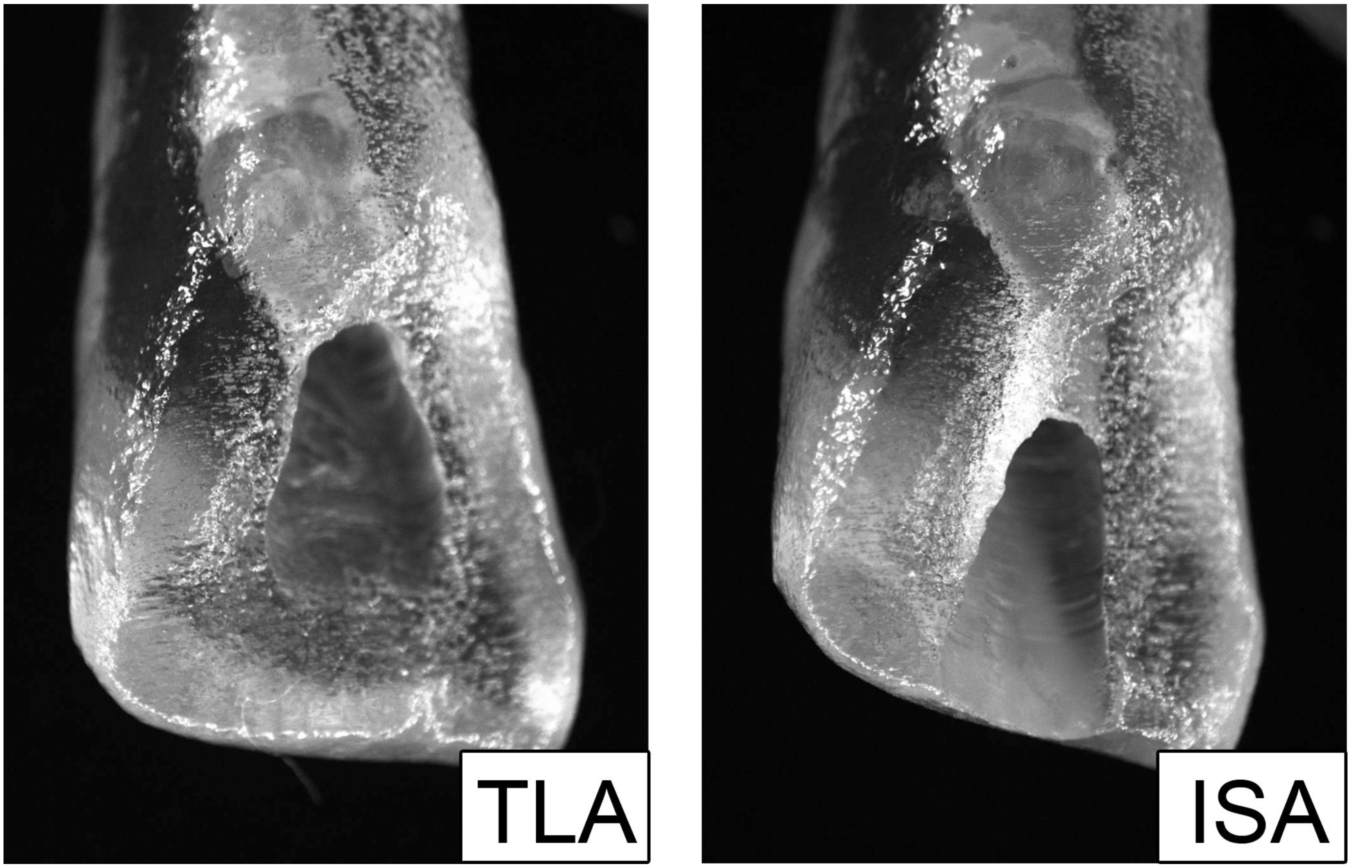

Figure 2.
Representative image of the outline of access cavity preparation. Left, TLA; right, ISA.

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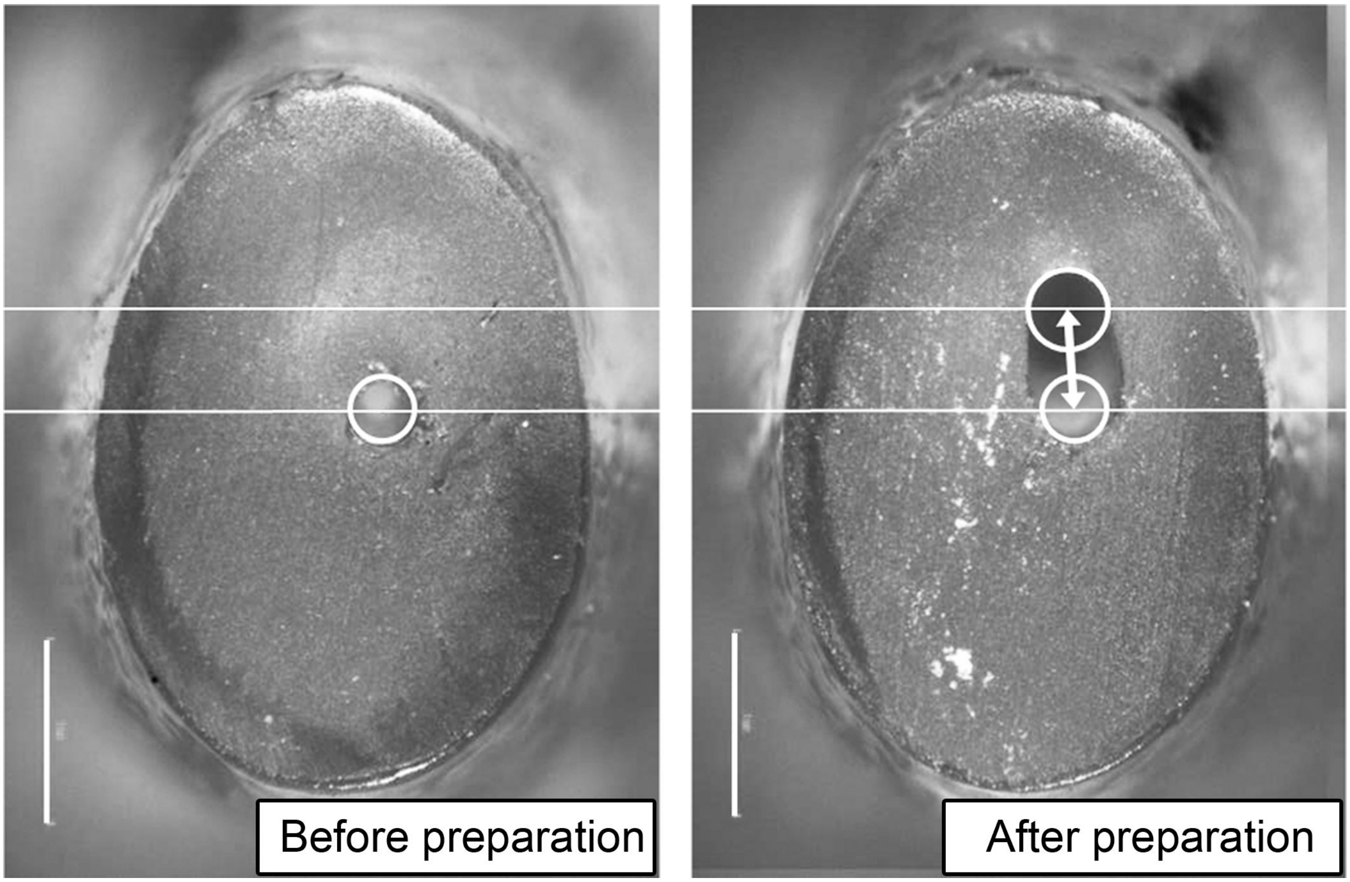

Figure 3.

Cross-sectional image of the tooth model before (left) and after (right) preparation. The distance of transportation (right; arrow) was obtained by measurement of the distance between the centres of the inscribed circles for the cross-section before and after preparation. The vertical scale bar represents a length of 1 mm.

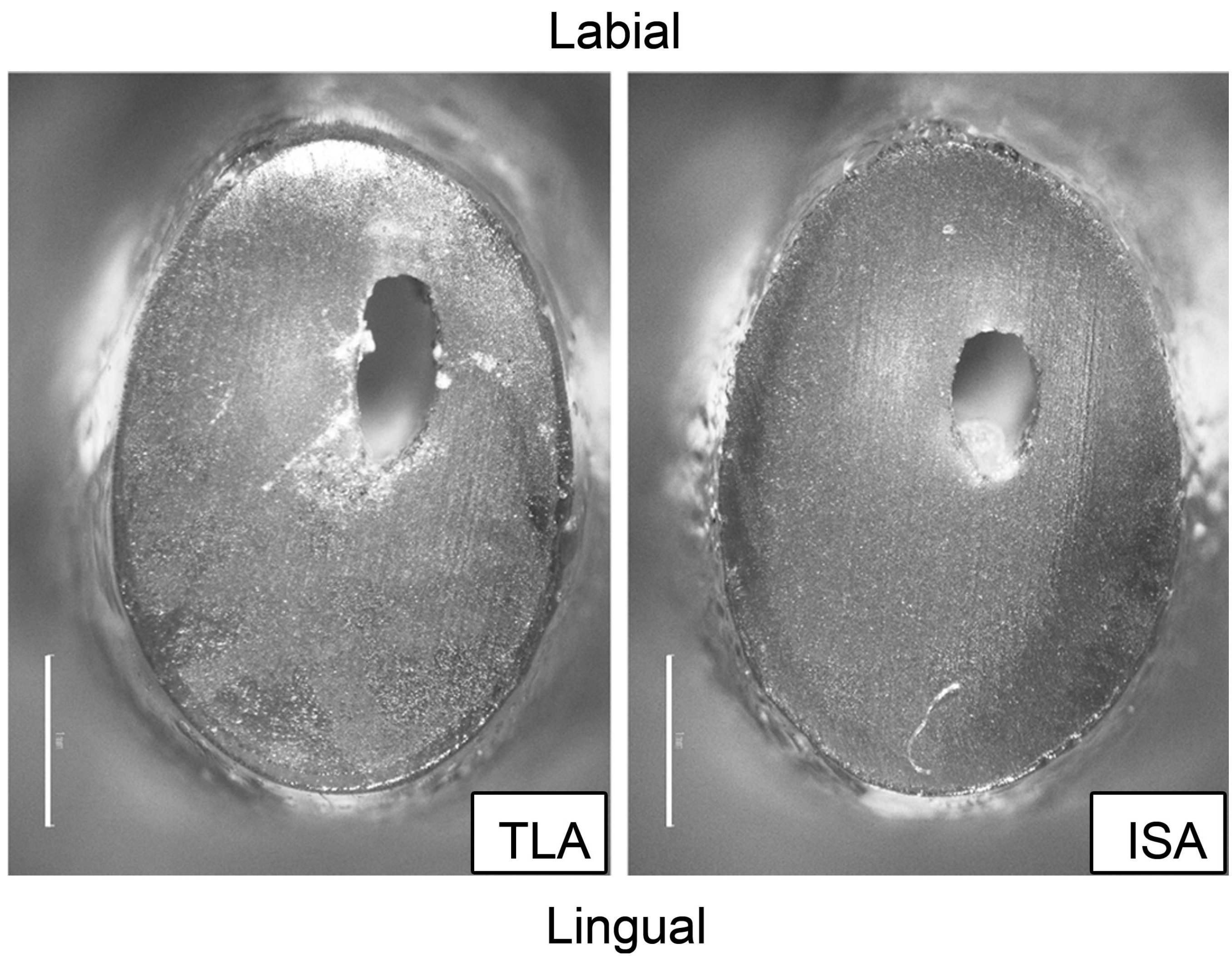

Figure 4.

Typical cross-sectional images for the TLA group and the ISA group. Left, TLA; right, ISA. The vertical scale bar represents a length of 1 mm.

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Table 1

Root canal area after preparation and distance of transportation for both groups.

	Preparation area ($mm^2 \pm SD$)	Distance of transportation ($mm \pm SD$)
TLA	65.5 ± 7.1^{b}	0.7 ± 0.1^{B}
ISA	51.8 ± 6.9^{a}	0.4 ± 0.1^{A}

Different superscript letters indicate statistically significant differences between groups ($p < 0.05$)