Abstract: This study investigated differences in periodontal health variables between buccally impacted maxillary canines (BIMC) and palatally impacted maxillary canines (PIMC) after surgical-orthodontic treatment with open technique. Nineteen patients were enrolled: 10 with unilateral BIMC (5 men, 5 women; mean age 18.50 ± 1.96 years) and 9 with unilateral PIMC (4 men, 5 women; mean age 19.44 ± 2.40 years). Probing depth and keratinized tissue were recorded 12 months after surgical-orthodontic treatment, and the differences between the 2 sides were analyzed as primary outcomes. In addition, data for BIMC and PIMC were directly compared. In the BIMC group, probing depths were significantly higher for lateral incisors than for the untreated side (P = 0.044), and keratinized tissue values were significantly lower for canines than for the untreated side (P = 0.006). No significant differences were observed in the PIMC group. In BIMC, surgical-orthodontic treatment with open technique resulted in loss of periodontal keratinized tissue in the treated tooth and periodontal attachment loss in adjacent lateral incisors. However, the periodontal status of PIMC was not affected by surgical-orthodontic treatment with open technique.

Keywords: impacted teeth; canine; periodontal attachment; keratinized tissue; orthodontic appliances; orthodontic movement.

Introduction

Maxillary canine impaction is a common clinical condition in dentistry (frequency 0.2-2.8%) (1). About 4% of patients referred to orthodontists are affected by this condition, and the ratio is 4:1 for palatally vs buccally impacted canines (2-5).

Transverse maxillary deficiency is associated with maxillary canine impaction (6-8); thus, early interceptive orthodontic treatment with rapid maxillary expansion is effective in increasing the eruption rate of displaced maxillary canines (9-11). In the absence of such treatment, maxillary canine impaction requires comprehensive orthodontic-surgical treatment, including surgical exposure of the canine crown and orthodontic traction to bring the impacted canine into occlusion (12-14).

Existing evidence (15-17) is unclear regarding periodontal outcomes after surgical exposure and subsequent orthodontic alignment of displaced canines—some studies reported periodontal problems, included loss of alveolar bone height, increased pocket probing depths, and loss of attached gingivae or found only a limited periodontal effect (17). The effects of open and closed technique on ultimate periodontal status has been extensively investigated (5,18). Although studies are less critical of periodontal outcomes for closed technique, a systematic review noted that the results were similar to those for open technique and found no evidence favoring
open or closed technique (19,20).

At the authors’ knowledge, no previous study has compared post-treatment periodontal status between buccally impacted maxillary canines (BIMC) and palatally impacted maxillary canines (PIMC). This prospective observational study investigated differences in periodontal health parameters between BIMC and PIMC after surgical-orthodontic treatment with open technique and compared the findings with those from contralateral physiologically erupted canines. The primary study outcomes were differences in probing depth (PD) and keratinized tissue (KT) between BIMC and PIMC and their respective contralateral normally erupted canine. The secondary outcomes were the differences in PD and KT values between BIMC and PIMC.

**Materials and Methods**

**Subjects**

In this prospective observational clinical study, 10 patients with unilateral BIMC (5 men, 5 women; mean age 18.50 ± 1.96 years) and 9 patients with unilateral PIMC (4 men, 5 women; mean age 19.44 ± 2.40 years) were enrolled after a thorough clinical examination and radiographic assessment. All patients were enrolled after providing written informed consent. The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of the University of L’Aquila (Document No. DR206/2013).

Unilateral impaction was first evaluated by clinical examination when a permanent maxillary canine was absent in the dental arch after the expected eruption time and a physiologically erupted contralateral canine was present. The deciduous canine might still be present on the impaction side of the maxillary dental arch. A diagnosis of impaction was confirmed by conventional panoramic X-rays and lateral cephalograms. In some cases, cone-beam computed tomography was used to determine the location (buccal or palatal) of the impacted canine.

Additional inclusion criteria were presence of a normally erupted and correctly positioned contralateral canine, complete permanent dentition, submucosal impaction of the impacted canine, absence of periodontal disease, good level of oral hygiene, and absence of periodontal inflammation, which was defined as plaque index (PI) and bleeding on probing values of 0 and the absence of clinical signs of gingival inflammation, gingival recession, and tooth mobility.

**Surgical-orthodontic procedure**

The patients underwent standardized combined surgical-orthodontic treatment with open technique after initial orthodontic treatment to achieve sufficient space for the impacted canine. In the BIMC and PIMC groups, an apically repositioned full-thickness mucoperiosteal flap and operculectomy were respectively used to expose the impacted canine.

To begin traction, a button was placed at the crown level in the exposed and most accessible surface of the tooth and tied with elastic thread. To avoid damage to the periodontal tissue and the canine, the elastic thread was replaced approximately every 15 days to ensure slow, constant traction. The follicular envelope, if present, was removed down to the cementoenamel junction because of the possibility it might prevent bone healing and retention of the periodontal ligament to the tooth. In both cases, the canine was moved into alignment above the mucosa by applying orthodontic traction with an elastic thread. All surgical and orthodontic treatments were conducted by the same expert operator (S.M.).

**Periodontal evaluation**

Periodontal measurements were recorded by using a World Health Organization periodontal probe, 12 months after the end of orthodontic treatment and removal of the orthodontic appliance. Two periodontal variables were recorded and analyzed in treated and normally erupted canines. PD was recorded as the mean at 6 sites (mesiobuccal, midbuccal, distobuccal, mesiopalatal, midpalatal, and distopalatal) on each of the treated and control canines. PD was also recorded at sites adjacent to upper lateral incisors (distal site) and first bicuspids (mesial site). KT was measured from the gingival margin to the mucogingival junction, at the medial position of the buccal aspect of the crown. KT was also recorded for upper lateral incisors and first bicuspids. All periodontal measurements were made by the same expert operator (D.M.), who was blinded to the study goals and to the presence of an orthodontically erupted canine.

**Statistical analysis**

The primary outcomes of this study were the differences in PD and KT between BIMC and PIMC and their respective contralateral normally erupted canine. Because of the small sample size, the Mann-Whitney U test was used to compare differences between the 2 sides. The secondary outcomes were the differences in PD and KT values between BIMC and PIMC, which were also analyzed with the Mann-Whitney U test. Statistical significance was defined as a P value of less than 0.05. Post hoc power analysis was performed for the primary outcome.
A total of 19 patients with unilateral maxillary canine impaction were successfully treated. PD and KT periodontal values were recorded, analyzed with descriptive statistics, and expressed as means and standard deviations. The mean time for orthodontic eruption was 5.5 ± 1.4 months in the BIMC group and 5.7 ± 1.1 months in the PIMC group.

**PD** (Table 1)
In general, mean PD was higher in both treatment groups than in their respective control groups. The difference was statistically significant only for the lateral incisor in the BIMC group (BIMC 3.15 mm, BIMCc 2.40 mm; $P = 0.044$). Furthermore, the difference in mean PD between BIMC and PIMC was statistically significant for lateral incisors ($P = 0.012$).

**KT** (Table 2)
Mean KT was generally lower in both treatment groups than in their respective control groups. This difference was statistically significant only for the canine in the BIMC group (BIMC 3.15 mm, BIMCc 3.35 mm; $P = 0.006$). In addition, the difference in mean KT between BIMC and PIMC was statistically significant for canines ($P = 0.021$).

**Results**
Statistical power
The post hoc power calculation for the primary analysis showed a sample power of 76-96%.

**Discussion**
Previous studies (15,17) have yielded conflicting findings regarding periodontal outcomes after surgical exposure and subsequent orthodontic alignment of submucosal impacted canines; some reported periodontal problems such as loss of alveolar bone height, increased pocket PDs, and loss of attached gingivae or found that treatment had a limited periodontal effect (17). In the present study, the periodontal outcome after orthodontic eruption was significantly worse in the BIMC group than in physiologically erupted contralateral canines. The BIMC group had a 1 mm lower mean KT, and the adjacent lateral incisors had a 0.75 mm higher PD. This result is not consistent with the results of a recent literature review, which found no significant differences between BIMC and untreated canines (5,21). However, that report conceded that data are limited on periodontal outcomes for BIMC after surgical-orthodontic treatment.

Analysis of periodontal variables in the PIMC group showed no differences between treated canines and the contralateral untreated control group. A previous study (17) reported a significant difference of 0.2-0.6 mm in periodontal attachment between operated and unoperated PIMC, but the difference was considered clinically

### Table 1 Results of analysis of pocket depth

<table>
<thead>
<tr>
<th></th>
<th>Treated Mean (mm)</th>
<th>SD</th>
<th>Control Mean (mm)</th>
<th>SD</th>
<th>Difference</th>
<th>Mann-Whitney $U$ Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIMC</td>
<td>Canine 2.75</td>
<td>0.54</td>
<td>2.40</td>
<td>0.52</td>
<td>0.35</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Lateral incisor* 3.15</td>
<td>0.94</td>
<td>2.40</td>
<td>0.66</td>
<td>0.75</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>First premolar 2.40</td>
<td>0.66</td>
<td>2.30</td>
<td>0.48</td>
<td>0.10</td>
<td>n.s.</td>
</tr>
<tr>
<td>PIMC</td>
<td>Canine 2.33</td>
<td>0.50</td>
<td>2.11</td>
<td>0.33</td>
<td>0.22</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Lateral incisor* 2.22</td>
<td>0.44</td>
<td>2.39</td>
<td>0.60</td>
<td>−0.17</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>First premolar 2.00</td>
<td>0.00</td>
<td>2.11</td>
<td>0.22</td>
<td>−0.11</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

*: Statistical significance after comparison of BIMC and PIMC; BIMC: Buccally impacted maxillary canines; PIMC: Palatally impacted maxillary canines; SD: Standard deviation; n.s.: not significant.

### Table 2 Results of analysis of keratinized tissue

<table>
<thead>
<tr>
<th></th>
<th>Treated Mean (mm)</th>
<th>SD</th>
<th>Control Mean (mm)</th>
<th>SD</th>
<th>Difference</th>
<th>Mann-Whitney $U$ Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIMC</td>
<td>Canine* 3.25</td>
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<td>3.35</td>
<td>0.47</td>
<td>−1.00</td>
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<td></td>
<td>Lateral incisor 3.50</td>
<td>0.47</td>
<td>3.75</td>
<td>0.49</td>
<td>−0.25</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>First premolar 1.75</td>
<td>0.59</td>
<td>2.00</td>
<td>0.47</td>
<td>−0.25</td>
<td>n.s.</td>
</tr>
<tr>
<td>PIMC</td>
<td>Canine* 3.22</td>
<td>0.75</td>
<td>3.56</td>
<td>0.39</td>
<td>−0.33</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>Lateral incisor 3.61</td>
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<td>3.83</td>
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<td>−0.22</td>
<td>n.s.</td>
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<td>1.94</td>
<td>0.46</td>
<td>0.06</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

*: Statistical significance after comparison of BIMC and PIMC; BIMC: Buccally impacted maxillary canines; PIMC: Palatally impacted maxillary canines; SD: Standard deviation; n.s.: not significant.
irrelevant.

With respect to the present primary outcomes, direct comparison of the 2 treatment groups showed that BIMC had a significantly worse post-treatment KT, about 0.9 mm less than that of PIMC. Moreover, the BIMC adjacent lateral incisor at the distal site had a 0.9 mm significantly greater PD than that of the PIMC adjacent lateral incisor. Thus, BIMC appear to be associated with worse periodontal outcomes.

To our knowledge, only one previous study (22) examined the effects of the type of canine impaction on post-treatment PD and KT outcomes. That report found no significant differences in PD, but a significantly higher KT (by about 0.5 mm) in PIMC as compared with BIMC. These results are consistent with our findings, which suggest that a treated BIMC has about 1 mm less KT than its contralateral tooth and that the PD of the adjacent lateral incisor will increase by about 0.75 mm.

This study is limited by its small sample size; thus, future studies with bigger samples should be encouraged. Nevertheless, the post hoc power analysis of the primary outcome of the study yielded excellent results. A second limitation of this study is that only open technique was evaluated.

The present results indicate that clinicians should be aware that when BIMC are surgically exposed with open technique and erupted with orthodontic traction, they will likely lose about 1 mm of KT, as compared to physiological eruption. Moreover, the adjacent lateral incisor will develop an attachment loss of about 0.75 mm. This information is useful for determining periodontal prognosis after orthodontic treatment of BIMC. In contrast, PIMC periodontal outcomes appear to be unchanged by surgical-orthodontic treatment with open technique.

Conflict of interest
The authors declare no conflict of interest. This study received no external funding.

References
palatally impacted canines. Angle Orthod 64, 257-264.