Introduction

The treatment of an impacted maxillary canine is not completed merely by its orthodontic alignment. Final periodontal health is a fundamental factor for evaluating the success of the treatment undertaken for impacted maxillary canines, especially those that are deeply impacted (1). Three factors may influence the post-treatment periodontal status of maxillary impacted canines after the surgical exposure: the impaction side, the surgical technique, the orthodontic movement/force traction (2, 3). The proper localization of the impacted tooth plays a crucial role in determining the feasibility of, as well as the proper access for, the surgical approach and the proper direction for the application of orthodontic forces (2-4). However, the initial vertical and horizontal position of the maxillary impacted canine may also affect post-treatment periodontal status after surgery with the closed-eruption technique, but data on this issue are unknown (5).

Two basic surgical methods for the exposure of an impacted canine are commonly used: the open and the closed techniques. The surgical approach should prevent soft-tissue recession and radicular bone loss on unerupted teeth with...
proper orthodontic, periodontic, and patient management. Following exposure, many canines are brought into alignment with minimal treatment, but there are others for which extensive treatment is needed. They may require rotation, uprighting and sometimes root torque. The difference in mechanotherapy needed for these movements could have ramifications with respect to the final periodontal status of the teeth concerned (6). Many studies investigated the periodontal status of impacted canines following surgical orthodontic treatments (4, 7-10). Most of them compares the periodontal effects between unilateral palatally impacted canines exposed with different surgical techniques with contralateral spontaneously erupted canines. Only Evren (4) evaluated the periodontal health of palatally impacted and buccal ectopic maxillary canines after completion of orthodontic treatment. No studies in literature are available with regard to the assessment of the periodontal status of the buccally impacted canine in an infraosseous position and with regard to the comparison between the periodontal health of palatally impacted canines and the buccally impacted canines recovered by the closed surgical technique at the end of overall orthodontic treatment. The aim of this retrospective study is to evaluate the periodontal status of palatally and buccally impacted canines that were exposed with closed technique, and to compare them with the contralateral canines that served as control teeth as well as to compare them with each other.

Methods

A total of 54 patients with an impacted maxillary canine were visited and treated at the Department of Orthodontics of the University of Rome “Tor Vergata” over a period of 5 years. Patients with unilateral palatally or buccally impaction of the maxillary permanent canine associated with normally erupted contralateral canine and with indication for a combined-surgical orthodontic treatment with closed eruption were enrolled in the study. The study was approved by the Ethical Committee of the University of Rome “Tor Vergata”, (R.S. 127/16). Informed consent was signed by the parents of all subjects. All subjects were divided into two groups: palatally impacted canines group (PICG) and buccally impacted canines group (BICG). The intraosseous palatal or buccal position of the upper permanent canine was evaluated on the basis of the CBCT (11). Cases showing submucosal impaction, need for extraction of first premolars and without indication for closed surgical technique were excluded from the study. A total of 39 patients met the entry criteria. Four subjects were excluded due to the lack of movement of the impacted canines (ankylosis). Seven subjects were excluded as did not agree to come to the recall appointment for the periodontal observation. This reduced the parent sample to a study sample of 28 subjects, 14 patients (8 females, 6 males) with unilateral palatally impacted canines (PIC) and 14 patients (7 females, 7 males) with unilateral buccally impacted canines (BIC), agreed to come to the recall appointments. Mean age of the patients at the beginning of the treatment was 13 years 5 months ± 1 year 4 months and 16 years 4 months ± 1 year 6 months at the end of the treatment. Mean treatment duration was found to be 2 years 10 months ± 1 year 3 months (3 years 2 months ± 1 year 8 months for palatal canines, 2 years 8 months ± 8 months for buccal canines). Mean recall observational period was 2 years 4 months ± 1 year 1 month after the end of active orthodontic treatment. Mean age of subjects who underwent the periodontal evaluation was 18 years 7 months ± 2 years. The treatment plan of both buccally and palatally impacted canines had been integrated into the overall orthodontic treatment scheme: recovery and management of the necessary eruption space, surgical exposure and attachments bonding, application of the anchorage device and forced traction, orthodontic finishing, post-treatment retention. In the PIC group the closed eruption technique without the tunnel was performed to expose the
palatally impacted canines. In the BIC group the closed eruption was employed too as the teeth were deeply impacted and higher than the mucogingival junction (12, 13). The extent of surgical exposure involved the removal of enough bone to allow for the complete curetting of the follicular sac of the unerupted tooth and was performed for all the treated cases (6).

In order to improve the anchorage during the traction of the impacted canine, after soft-tissue healing, the Quad-helix Canine System was placed and an elastic tie was stretched from the chain emerging from the surgically recovered canine to the eyelet of the device (14).

After the eruption of the canine, levelling and alignment proceeded with successively thicker archwires up to a .019 x .025 stainless steel archwire. According to the requests, the mechanotherapy necessitated rotation, uprighting and root torque movements to bring the canine into its place.

The surgical technique was performed by the same operator (CA) as well as the orthodontic treatment (MM) on all the patients.

In both groups, the controlateral normal erupted canine served as control. All patients were recalled for collection of the clinical data. The periodontal status of the canines was evaluated clinically. Six periodontal parameters were used. These were chosen from among the most commonly used periodontal parameters as to cover all dental and gingival landmarks. Many Authors used two, three, or five of them (5, 15).

Statistical analysis

Data of the impacted canines were compared with their controlateral controls. Descriptive statistics were calculated as mean ± SD for all the examined (metric) variables. To compare parametric data (probing pocket depth, width of keratinized tissue, and gingival thickness) the paired-samples t-test was applied; to compare nonparametric data (plaque index, gingival bleeding index, gingival recession) the Wilcoxon signed rank test was used. The Student t paired test was used for the comparison of the parametric data between palatally impacted and buccally impacted canines, and the Mann-Whitney U-test was used for the comparison of the nonparametric data. The difference was considered to be statistically significant when P<0.05 for all tests. All statistical tests were made using SPSS 12.0 software (SPSS Inc, Chicago, Ill). Reproducibility of the measurements was assessed by repeating the periodontal evaluation of 20 subjects 1 month after the first examination.
by 1 operator (CD). Correlation between these two sets of measurements was assessed with Pearson correlation analysis.

Results

Palatally impacted canines exhibited significant greater pocket depths on the mesiolingual site compared to their controlaterals ($P<0.05$) (Table 1). No statistically significant differences were found with regard to the probing pocket depths on the other sites and to the width of the keratinized tissue and gingival thickness, as well as to the plaque index, gingival bleeding index and gingival recession between the palatally impacted canines and their controlaterals (Table 2). Buccally impacted canines had significant increased width of the keratinized tissue compared to their contralaterals ($P<0.05$). No statistically significant differences were found with regard to the probing pocket depths, gingival thickness, as well as to the plaque index, gingival bleeding index and gingival recession between the buccally impacted canines and their controlaterals (Tables 3, 4).

Palatally impacted canines had significant greater pocket depths on the midbuccal site and on all the palatal sites when compared to the buccally impacted canines ($P<0.05$). No significant differences were found in the width of the keratinized tissue, the gingival thickness, the plaque index, the gingival bleeding index as well as in the gingival recession in the comparison between treated impacted palatally and buccally canines (Tables 5, 6).

Discussion

The purpose of the present observational study was to evaluate the periodontal status of recovered impacted palatal and buccal canines and to assess the possible existing differences between the two entities on the basis of the either palatal or buccal impaction side.

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**Table 1** - Comparison of the palatally impacted canines and their controlateral after orthodontic treatment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Palatally Impacted Canines (n=6)</th>
<th>Controlateral (n=6)</th>
<th>Difference</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>PPD DB</td>
<td>2.50</td>
<td>0.55</td>
<td>2.25</td>
<td>0.76</td>
</tr>
<tr>
<td>PPD MidB</td>
<td>1.25</td>
<td>0.42</td>
<td>1.08</td>
<td>0.49</td>
</tr>
<tr>
<td>PPD MB</td>
<td>2.67</td>
<td>0.82</td>
<td>2.67</td>
<td>0.52</td>
</tr>
<tr>
<td>PPD DL</td>
<td>2.50</td>
<td>0.55</td>
<td>2.33</td>
<td>0.52</td>
</tr>
<tr>
<td>PPD MidL</td>
<td>1.50</td>
<td>0.84</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>PPD ML</td>
<td>2.83</td>
<td>0.52</td>
<td>2.08</td>
<td>0.20</td>
</tr>
<tr>
<td>Width of Keratinized tissue (KT)</td>
<td>4.33</td>
<td>0.82</td>
<td>3.50</td>
<td>0.84</td>
</tr>
<tr>
<td>Gingival Thickness (GT)</td>
<td>0.58(a)</td>
<td>0.20</td>
<td>0.58(a)</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*Paired Sample t-test*

* $P < 0.05$

(a) The correlation and t cannot be computed because the standard error of the difference is 0.

SD indicates standard deviation.
### Table 2 - Comparison of the palatally impacted canines and their controlateral after orthodontic treatment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Palatally Impacted Canines (N=6)</th>
<th>Controlateral (N=6)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Plaque Index (PI)</td>
<td>0.67</td>
<td>0.52</td>
<td>0.67</td>
</tr>
<tr>
<td>Gingival bleeding Index (GBI)</td>
<td>0.33</td>
<td>0.52</td>
<td>0.50</td>
</tr>
<tr>
<td>Gingival Recession (GR)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Wilcoxon Signed Rank Test
* P < 0.05
SD indicates standard deviation

### Table 3 - Comparison of the buccally impacted canines and their controlateral after orthodontic treatment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Buccally Impacted Canines (n=9)</th>
<th>Controlateral (N=9)</th>
<th>Difference</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>PPD DB</td>
<td>1.89</td>
<td>0.60</td>
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<td>0.61</td>
</tr>
<tr>
<td>PPD MidB</td>
<td>0.67</td>
<td>0.43</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>PPD MB</td>
<td>2.28</td>
<td>0.83</td>
<td>1.83</td>
<td>1.06</td>
</tr>
<tr>
<td>PPD DL</td>
<td>1.44</td>
<td>0.73</td>
<td>1.39</td>
<td>0.99</td>
</tr>
<tr>
<td>PPD MidL</td>
<td>0.72</td>
<td>0.44</td>
<td>0.61</td>
<td>0.49</td>
</tr>
<tr>
<td>PPD ML</td>
<td>1.67</td>
<td>0.71</td>
<td>1.56</td>
<td>0.73</td>
</tr>
<tr>
<td>Width of Keratinized tissue (KT)</td>
<td>4.56</td>
<td>1.01</td>
<td>2.83</td>
<td>1.00</td>
</tr>
<tr>
<td>Gingival Thickness (GT)</td>
<td>0.58</td>
<td>0.26</td>
<td>0.67</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Paired Sample t-test
* P < 0.05
SD indicates standard deviation

### Table 4 - Comparison of the buccally impacted canines and their controlateral after orthodontic treatment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Buccally Impacted Canines (n=9)</th>
<th>Controlateral (n=9)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Plaque Index (PI)</td>
<td>0.22</td>
<td>0.44</td>
<td>0.22</td>
</tr>
<tr>
<td>Gingival Bleeding Index (GBI)</td>
<td>0.33</td>
<td>0.50</td>
<td>0.33</td>
</tr>
<tr>
<td>Gingival Recession (GR)</td>
<td>0.22</td>
<td>0.67</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Wilcoxon Signed Rank Test
* P < 0.05
SD indicates standard deviation
Twenty-eight patients with unilateral impacted canines were treated while the contralateral tooth was normally erupted. All cases enrolled in the study presented deep infraosseous canine impaction, diagnosed from cone beam CT. All subjects were observed after a mean period of 2 years 4 months ± 1 year 1 month following the removal of the orthodontic appliances. The treated palatal canines showed periodontal conditions similar to the contralateral canines with regard to the PPD on the buccal sites. On the lingual site the PPD of the impacted canines was similar to the contralateral teeth with the exception of the mesiolingual site (PPD ML). On this site the PPD was significantly greater (difference 0.75 mm). The KT was greater on the test side compared with the control side, while the plaque index and the gingival recession were similar in the test and control teeth, but not statistically significant.

The present results are in accordance with those of earlier studies reporting that the periodontal effects of aligning an ectopic tooth are more pronounced in certain sites around the tooth.
Woloshyn et al. (20), using a closed exposure, found deeper probing depths on the mesial and distal aspects of the teeth when compared with controlateral (control) teeth. Parkin et al. (21) found that the periodontal attachment level (periodontal probing depth + gingival recession) was 0.5 mm on the mesiopalatal and 0.6 mm on the distopalatal aspects of the operated canine with closed-eruption technique; however this difference was not statistically significant. The loss of marginal periodontal attachment on the mesiolingual surface of the canine found in the present study may be explained by reduced cleanliness in this area as the canines approach alignment in the arch. This explanation is further supported by the fact that no additional loss was observed on the distopalatal surface (20). Furthermore, the increased PPD on the mesiolingual site in the PIC group can be related to the orthodontic movements involving tipping of their crowns labially to reach the line of the dental arch and a proper alignment (6). Tipping movements, has been demonstrated, are associated with a lag in the movement of the gingiva in relation to the tooth. The tension from gingival fibers and lag of gingival tissues arising from this tooth movements could be a factor in the mechanism of inflammations for the patients in whom a surgical approach was performed (8). If the eyelet had been placed on the palatal aspect of the canine during surgery, the canine might also erupt in a rotated position. The process of derotating the canine could result in increased probing depth on the mesiolingual aspect (21).

In the present study on the previously palatal impacted canines no gingival recessions were registered. In a retrospective analysis consisting of 32 patients treated with surgical closed technique, Zasciurinskiene et al. (5) found that 6 on a total of 32 patients had gingival recession, although the mean values were small. However it was not clear at which site the recession was present, nor was the range of the recession quantified. The absence of gingival recessions at the periodontal evaluation in the present study might be ascribed to correct motivation of the patients to the implementation of a proper tooth brushing technique (16).

Comparison between buccally impacted canines and their controlateral showed no significant differences in probing pocket depths. The mean greatest pocket depth was found in mesiobuccal site of buccally impacted canines (2.28 ± 0.83 mm). This result is not statistically nor clinically relevant as a deep residual probing depth (> 4 mm) or increase in probing depth may prove an useful adjunct to probing attachment loss in the identification of progressive periodontitis sites (22). For buccally impacted canines, as for palatally impacted canines, also the tooth movement and position may play a significant role on the PPD. The extrusion movement or the lingual tipping needed to relocate the buccally impacted canine into the arch involves the tension of the marginal tissue with subsequently increased inflammation, typically seen in teeth undergoing fixed appliance therapy (8, 23).

The only statistically significant difference was found in width of keratinized tissue resulting increased in buccally impacted canines than in controlateral teeth (difference 1.73 mm). With regard to buccal canines, the literature is scarce since the prevalence of the buccal impactions is significantly lower than the palatal and many of the buccal canines which are considered impacted at an early age, improve their direction and finally erupt spontaneously (24).

Crescini et al. (16, 25) using a closed surgical technique with tunnel traction, at a follow-up of 3 years found no significant differences in keratinized tissue width between treated impacted and normally erupted canines, whereas Vermette et al. (13) detected in the closed eruption group narrower attached gingiva on the distal surface. But the findings of these studies cannot be compared with the results of the present study because they include both palatal and labial impaction (16, 25) or do not specify the incisor or canine impactions (13). The increased width of keratinized tissue found in our study could be expected as a closed approach has been performed, with the flap repositioned into its original place at the end of surgery (16).

With regard to the gingival thickness, plaque in-
In the present study palatally and buccally impacted canines have been compared each other. None previous study compared the periodontal status between the palatally and the buccally impacted canines surgically exposed with the closed-eruption technique. Greater probing pocket depth were found in palatally impacted canines than in buccally. Interestingly, the statistically significant difference emerged on the midbuccal site and on all the lingual sites of the palatally impacted canines. There is some evidence that the type of orthodontic movement needed to align the ectopic canine may be more important variables influencing long-term periodontal Health (26). The consequences on the periodontal status of palatally impacted canines are related to the more complex mechanotherapy needed for rotation, uprighting and sometimes root torque required to bring the canine into its place as well as to the deeper infraosseous position of impaction (6). In addition, these teeth are in a state of partial eruption for a longer period than buccally impacted canines, during which the surrounding gingival tissue is often constantly irritated by the sharp profile of an orthodontic bracket or ligature wire (7).

In this study no statistically significant differences emerged with regard to the width of the keratinized tissue and gingival thickness, plaque index, gingival bleeding index and gingival recession from the comparison between palatally and buccally impacted canines.

The results of the present study differed with those reported by Evren et al. (4), who reported higher level of plaque and gingival bleeding index, and reduced attached gingival width in buccally ectopic and not impacted canines when compared with palatally impacted canines. In our study the width of the keratinized tissue was increased in buccally impacted canines. These results are not in parallel with those demonstrated by Kohavi et al. (9) as the Authors reported attached gingival width was significantly reduced following the alignment of buccal ectopic maxillary canines. It should be also underlined that both Evren (4) and Kohavi (9) analyze the periodontal health of buccally ectopic canine not surgically exposed, but spontaneously erupted. It can be speculated that these differences can be related to the bone removal. As our study was retrospective it was not possible to evaluate the removed bone volume, that is considered one of the most important variables for the periodontal health.

The present study confirms results of already published literature on palatal canines, but adds some additional information on buccal impactions, especially regarding the increase in the width of keratinized gingiva of buccal canines exposed with a closed eruption technique.

There is a periodontal impact when an unilateral canine is exposed and aligned. This impact is small and unlikely to have clinical relevance at the timing of periodontal observation. Our positive findings could be explained by the mechanics and the efficient appliance design used to move the impacted canine into the arch following surgical exposure. The Quad-helix Canine System, made of rigid stainless steel wire, allows through its rigid buccal or palatal arms with spaced eyelet for the traction of the impacted canine, the progressive redirection of the orthodontic traction/force vector toward the center of the alveolar ridge, thus simulating a physiological eruption pattern and obtaining good periodontal status (14).

A possible limitation of this study is the small sample size, related to the difficulty for the recruitment of the impactions and, for all of them, for the closed surgical approach. Indeed, the canine impaction fluctuates between 0.92% and 5.2%, and the buccal impaction occurs less frequently than palatal impaction (2, 27).

Although the comparison between palatal and buccal canines is insignificant as these entities are different from the beginning, it can be spec-
ulated that the results emerged from this study suggests to the clinician a more careful management of the palatally impacted canines as in terms of orthodontic forces as of treatment duration.

**Conclusion**

From the periodontal evaluation performed on postpeak vertebral maturation subjects with previously impacted buccally and palatally impacted canines treated by closed eruption technique, emerged:

- After surgical-orthodontic treatment of palatally impacted canines, there were no significant differences in post-treatment periodontal status of the impacted canines and the controlateral canine.
- The palatal canines when compared to buccal canines, evidenced a greater probing pocket depth on the lingual sites than the buccal canines. Therefore, the overall consequences of the buccally impacted canine exposed with closed technique seem better than palatally impacted canines.
- The changes observed in the periodontal status of impacted canines, although statistically significant, did not reach clinical significance.

**References**


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