External apical root resorption in patients treated with conventional and self-ligating brackets

Nikolaos Pandis, a Maria Nasika, b Argy Polychronopoulou, c and Theodore Eliades d
Corfu, Athens, and Thessaloniki, Greece

Introduction: Our aim was to comparatively investigate the amount of external apical root resorption (EARR) between conventional and passive self-ligating brackets. Methods: Ninety-six patients were selected from a pool of patients satisfying the following inclusion criteria: no evidence of resorption on pretreatment panoramic radiographs; no contributing history of trauma; no dilacerations of lateral incisor roots, maxillary anodontia, and impacted canines; complete root formation at the start of treatment; intact and caries-free maxillary incisors; and no endodontically treated incisors. Patients received treatment with either a passive self-ligating bracket system or a conventional edgewise appliance, both with a 0.022-in slot. EARR of the maxillary incisors was evaluated on panoramic radiographs, taken before and after orthodontic treatment measured in millimeters. Distortion of measurements caused by panoramic radiographs was investigated by using a calibrated periodontal probe attached to the lateral incisor, and the extent of magnification was estimated to be 14%. Statistical comparisons of EARR between appliance type, age, sex, extraction treatment, and duration of treatment were investigated with univariate and multivariate regression modeling. Results: Overall, no difference was found in the amount of EARR between appliance systems. Age, sex, and extraction treatment were not reliable predictors of EARR, but a positive association between EARR and duration of treatment was observed. Conclusions: No difference should be expected for root resorption between conventional and passive self-ligating brackets. (Am J Orthod Dentofacial Orthop 2008;134:646-51)
tested the hypothesis that an active self-ligating bracket with an active clip might induce more EARR; their findings, however, did not confirm that hypothesis.

The introduction of passive self-ligating systems, with no active spring and alignment performed by wires engaged in a passive tube, with more play, jiggling, and less friction, raises again the question of their effect on EARR. In the orthodontic literature, no studies have explored the effect on EARR of passive self-ligating systems.

The hypothesis we tested was that the differences in the mode of wire ligation between conventional and passive self-ligating brackets affect the rate of root resorption. Our purpose was to comparatively assess the incidence of EARR in patients treated with the Damon self-ligating system and conventional straight-wire appliances.

**MATERIAL AND METHODS**

Ninety-six patients (29 boys and 67 girls; average age, 13.2 years) were included in this cohort investigation. Their selection from a larger pool of 147 patients was based on the following inclusion criteria: no evidence of resorption on the pretreatment panoramic radiograph; no severely dilacerated maxillary incisor roots, anodontia, and impacted canines; complete root formation at the start of treatment for all teeth; intact and caries-free maxillary incisors; and no endodontic treatment. The demographics of these subjects are listed in Table 1.

Complete records were obtained including panoramic radiographs before and after treatment from the same radiographic machine (Orthophos 10, Sirona, Bensheim, Germany) and by the same operator (N.P.).

The patients were divided into 2 equal groups: 1 group was bonded with an 0.022-in slot, Roth prescription, conventional edgewise appliance (Microarch, GAC, Bohemia, NY), and the other received a passive self-ligating appliance of the same slot size (Damon2,Ormco, Glendora, Calif). All stages of treatment were performed by the same clinician who has received training in both appliance systems.

The archwire sequence for the conventional group in most cases included 0.016-in and 0.020-in copper-nickel-titanium (Ormco) ligated with elastomeric ligatures and finished with 0.019/0.025-in stainless steel ligated with elastics. In the self-ligating group, the archwire sequence involved a 0.014-in, a 0.016/0.025-in (when applicable) copper-nickel-titanium Damon (Ormco), and a 0.019/0.025-in stainless steel for finishing. A small variation in the medium stages of treatment in archwire sequence was due to the mechanotherapeutic scheme suggested by the relevant guidelines accompanying the Damon2 bracket manual.

To evaluate EARR, panoramic radiographs were used, and the root lengths of the 4 maxillary incisors were compared before and after treatment. All measurements were performed by the same clinician (N.P.) with a 3-times magnifying glass and a fine-tip digital caliper with accuracy up to .01 mm (Mitutoyo Digital ND12-6C, Mitutoyo, Kanagawa, Japan) interfaced with an Excel spreadsheet (Microsoft, Redmond, Wash).

Assessment of the magnification of the maxillary incisors in panoramic radiographs was performed by inclusion of a graded tip of a periodontal probe in the panoramic radiographs. The metal tip was temporarily bonded between the maxillary central incisors from the

| Table 1. Demographic and clinical characteristics of the study sample by wire system |
|-----------------|-----------------|-----------------|-----------------|------------|
| **Characteristics** | **Total (n = 96)** (mean ± SD or %) | **Conventional (n = 48)** (mean ± SD or %) | **Self-ligating (n = 48)** (mean ± SD or %) | **P value** |
| Demographic | | | | |
| Age (y) | 13.21 ± 1.64 | 13.14 ± 1.73 | 13.29 ± 1.57 | NS* |
| Sex | | | | |
| Female | 67 (69.79%) | 36 (75.00%) | 31 (64.58%) | NS |
| Male | 29 (30.21%) | 12 (25.00%) | 17 (35.42%) | |
| Clinical | | | | |
| Extraction | | | | |
| No | 81 (84.38%) | 42 (87.50%) | 39 (81.25%) | NS |
| Yes | 15 (15.63%) | 6 (12.50%) | 9 (18.75%) | |
| Treatment duration (mo) | 26.43 ± 6.29 | 25.97 ± 6.65 | 26.89 ± 5.94 | NS* |

Row comparisons between conventional and self-ligating bracket.

*Nonsignificant from t test.

†Nonsignificant from chi-square test.
incisal edge and upward. The comparisons of the actual with the radiographic length of the probe tip showed an average magnification of 14%. This practically means, for an average root resorption of 1.5 mm, the magnification is less than 0.2 mm.

Furthermore, to assess intraexaminer reliability, 10 panoramic radiographs were randomly retraced from the records, and the lengths of the 4 maxillary incisors were remeasured. The ICC for all pairs of measurements indicated excellent agreement (ICC ≥0.95).

Statistical analysis

Demographic and clinical characteristics were investigated with conventional descriptive statistics. Comparisons between the 2 appliance systems were conducted with the t or chi-square test depending on the characteristic. The null hypothesis of the study was that EARR is independent of bracket system, and the alternative hypothesis was that EARR is related to the appliance used. Assessments of the predictive value of extractions, treatment duration, sex, and age were also performed.

Wilcoxon signed rank tests were conducted to examine possible EARR differences among the incisors. Data were further analyzed with simple and multiple regressions to determine the independent characteristics that were predictors of EARR. Specifically, quantile (median) regression modeling was used to predict changes in median EARR due to the non-Gaussian distribution of the EARR measurement. Factors of possible importance for EARR change, such as appliance system, treatment duration, extraction, sex, and age, were investigated separately and with a multiple regression model, and nonsignificant variables were deleted by backward elimination (deletion criteria 𝑃 >0.10). All statistical analyses were performed with the STATA statistical package (version 8.0, StataCorp, Houston, Tex).

RESULTS

Table I shows the distribution of demographic and clinical variables in the 2 appliance groups. The distribution of sex, age, extractions, and treatment duration was the same between the 2 appliance groups.

In Table II, the EARR on the maxillary incisors is shown. Overall, EARR of the 4 maxillary incisors showed a median of 1.05 mm (5th-95th percentile: 0.18-3.06 mm); the maxillary central and lateral incisors showed similar EARR. The negative sign in a value in Table II indicates a root length increase that can be attributed to completion of root development in some younger patients.

Univariate analysis showed that EARR increased as treatment duration increased, as indicated in Table III. Multivariate regression showed the model best fitting the data. Treatment duration independent of appliance type was a significant predictor of EARR, with an average increase of 0.03 mm per month, whereas the variable “appliance” showed a borderline association with EARR. Specifically, self-ligating brackets induced increased EARR relative to conventional appliances with an average of 0.37 mm after accounting for treatment duration effects (Table III).

DISCUSSION

We attempted to comparatively investigate the degree of EARR on maxillary incisors of patients treated with either a conventional or a passive self-ligating bracket system. In general, extraoral x-rays are considered less accurate than periapical radiographs in studying the extent of EARR. However, Katona questioned the validity of the periapical films in accurately depict-
Root resorption can be underestimated because of the inherent deficiency of panoramic x-rays to show EARR in a facial direction. Several recent studies explored this factor by evaluating the 3-dimensional morphology of roots after force application by using advanced instrumentation.\cite{48-50}

These results, albeit with the foregoing limitation, support previous findings reporting mild EARR that is slightly more evident on the lateral incisors. Additionally, sex and patient age at the start of treatment among adolescents were not found to affect EARR, whereas treatment duration had a positive association with the amount of EARR. The latter has been attributed to persistent bone turnover associated with extended tooth movement.

Concerning the type of appliance, no statistically significant difference was found between conventional and passive self-ligating systems, although a trend indicating more EARR for the self-ligating system was evident, but it did not reach significance ($P > 0.05$). However, in the general biomedical literature, significance levels slightly higher than the conventional 0.05 might receive critical importance depending on the severity of the health hazard imposed on the sample.\cite{51-53} Thus, although our results should not give rise to statements on the relative capacity of specific appliance type to cause resorption, more research is needed before a definitive conclusion can be drawn on this subject.

The only relevant study in the literature comparing conventional and self-ligating brackets was by Blake et al,\cite{23} who found no difference in the amount of root resorption. Interestingly, the use of light and constant forces has been linked with higher EARR prevalence. Specifically, Weiland\cite{29} demonstrated that the mode of persistent activation of nickel-titanium wires, deriving

### Table III. Coefficients derived from regression modeling ($\beta$) and $P$ values for EARR (mm) as dependent variable by using univariate and multivariate models

<table>
<thead>
<tr>
<th>Predictor variables</th>
<th>Category or increment</th>
<th>Univariate model</th>
<th>Multivariate model*</th>
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<tr>
<td></td>
<td></td>
<td>$\beta$</td>
<td>SE</td>
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<td>Appliance</td>
<td>Conventional baseline</td>
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<tr>
<td></td>
<td>Self-ligating</td>
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<tr>
<td>Treatment duration</td>
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</tr>
<tr>
<td></td>
<td>Yes baseline</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>Sex</td>
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<tr>
<td></td>
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</tr>
<tr>
<td>Age</td>
<td>1 year</td>
<td>0.34</td>
<td>0.31</td>
</tr>
</tbody>
</table>

NS, Nonsignificant.

*Final multivariate model resulting by backward elimination of nonsignificant predictors (deletion criterion $P > 0.10$).
from their considerably increased work range relative to their stainless steel counterparts, might be related to increased EARR. In this context, it could be postulated that the temporal characteristics of the force application to teeth might be more important in modulating EARR than force magnitude per se. However, further investigations are necessary to elucidate the differences in EARR accompanying the use of brackets with different ligation modes.

Our investigation was limited to the assessment of EARR on the maxillary incisors. Although these teeth show a higher prevalence of EARR, conclusions on EARR involvement in orthodontic tooth movement with different appliances would require examination of the entire dentition.

CONCLUSIONS

The following conclusions can be drawn from this clinical investigation.

1. Sex and age of adolescent patients are not related to the extent of EARR.
2. EARR appears to be related to treatment duration.
3. No difference in root resorption is expected between Damon2 self-ligating and conventional edgewise brackets with respect to root resorption in spite of a trend shown for 1 type of appliances (0.06). Validation of this finding requires further long-term investigation.

REFERENCES

53. Cohen J. The earth is round (p <0.05). Am Psychol 1994;47:997-1003.