



Effect of Adhesive Systems and Bevel on Enamel Margin Integrity in Primary and Permanent Teeth

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Abstract: ***Purpose:** This study compared the effectiveness of self-etch and total-etch adhesive systems in bonding to the beveled and nonbeveled margins of primary and permanent teeth. **Methods:** This in vitro, factorial-designed study allowed evaluation of 3 factors: (1) tooth type; (2) presence of a bevel; and (3) adhesive type. Two preparations, each including a beveled and nonbeveled margin, were completed on buccal surfaces of 60 extracted molars (30 primary and 30 permanent). Preparations were randomly assigned to self-etch or a total-etch adhesive system and restored with resin composite. After thermocycling, teeth were stained with silver nitrate, sectioned, and measured for microleakage. Statistical analysis used a repeated measures analysis of variance. **Results:** Beveled margins had less microleakage than nonbeveled margins for primary and permanent teeth ($P < .001$). Total-etch had less microleakage than self-etch adhesives on primary (53% less, $P < .001$) and on permanent teeth (22% less, $P = .01$). Self-etch had considerably more microleakage when enamel margins were not beveled. Comparably less microleakage, however, was found for total-etch and self-etch in restorations with beveled margins. **Conclusions:** Total-etch adhesive and beveled margins resulted in the least microleakage. Margin beveling has a greater effect in minimizing microleakage than the type of adhesive used. (Pediatr Dent 2008;30:134-40) Received April 4, 2007 / Last Revision August 7, 2007 / Revision Accepted August 14, 2007.*

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The integrity and durability of the interface between enamel and restorative material is of fundamental importance in dentistry. The acid etch bonding of composite resin to enamel has proven to be an effective method to enhance the enamel-restoration interface by increasing its strength and decreasing leakage.^{1,2} Nonetheless, bonded interfaces are not yet perfect and confidence in their long-term durability is not complete. Therefore, dentistry continues to seek improved restoration margins. The use of dental adhesives and the beveling of enamel are 2 methods suggested for improving marginal integrity and durability when using composite resin restorative materials. Equivocal results have been reported with the newer self-etching adhesives,³⁻¹⁰ and little work has been reported on the use of either adhesives or beveled margins on primary tooth enamel.^{11,12}

Dental adhesives. Dental adhesives play an important role in the longevity of composite restorations. Good adhesive bonding at the enamel-composite interface helps prevent microleakage,

which has been associated with the influx of bacteria, recurrent decay, and postoperative sensitivity.^{3,13} New dental adhesives are continuously being developed, and the newer self-etch adhesives are marketed as being less technique sensitive, less time consuming, and as effective as the older total-etch adhesives. Studies evaluating microleakage of self-etch adhesives, however, have shown inconclusive results on permanent enamel, and few studies have evaluated their effectiveness on primary enamel.^{11,12}

Total-etch adhesives can be classified as having 3 separate components (acid etch, primer, and adhesive) or 2 components (acid etch plus a combined primer and adhesive). Phosphoric acid (H_3PO_4) is used to etch the preparation, remove the smear layer, and create a porous and decalcified surface for the interlocking resin tags. Once the preparation surface is etched, the acid is rinsed off, the preparation is gently dried, and a primer is applied. The primer has 2 functional properties: 1) the hydrophilic component has an affinity for the tooth surface; and 2) the hydrophobic component has an affinity for resin. The adhesive is applied to the primed surface. It copolymerizes with the primer and bonds to the tooth surface.^{13,14} The prepared surface has increased surface area, which then polymerizes and bonds with the composite restoration. The application of total-etch systems is relatively technique sensitive and requires good isolation of the field. Studies evaluating the performance, bond strength, and microleakage of total-etch systems have shown good results.¹⁵⁻²⁰ Thus, the total etch systems are considered the gold standard today for bonded restorations.

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Self-etch adhesives can be classified as having 2 components (a combined etch and primer, and an adhesive) or they may be classified as a 1-component system (a combined “all-in-one” etch, primer, and adhesive).

The self-etch all-in-one adhesives require no rinsing step and were developed to reduce application time and technique sensitivity. The methacrylated phosphoric esters function as an etching agent, so that separate acid etching of the preparation surface is not required.^{3,21} As the self-etch all-in-one adhesives etch the preparation surface, they infiltrate the exposed tooth structure with hydrophilic monomers, which then copolymerize with the subsequently placed composite restoration.^{5,22,23} Because both the etching and adhesive steps occur simultaneously, there should be no discrepancy between the depth of demineralization and the depth of resin infiltration, thus, in theory, decreasing gap formation and postoperative sensitivity.⁴

Manufacturers of self-etch adhesives claim that they are as effective as total-etch systems. Studies evaluating the microleakage of self-etch adhesives on permanent teeth, however, report inconclusive results. Several studies have found the prevention of microleakage by the total-etch adhesive to be significantly better than that of the self-etch adhesive.⁵⁻⁷ Several other studies have reported no significant difference in microleakage between total-etch and self-etch adhesives on permanent enamel.^{3,8-10,24}

Few studies have evaluated microleakage of the newer self-etch adhesives on primary enamel. The presence of a 20- to 100- μ m thick prismless or aprismatic zone at the surface of primary enamel has been reported. The reported frequency and distribution, however, has varied from 100% of primary teeth to 20% or fewer.²⁵⁻²⁷ Within the prismless zone, all the crystals are aligned parallel to each other and perpendicular to the surface.²⁶ The nature of this zone, however, may not be constant around any individual tooth. The prismless layer is generally more highly mineralized due to the parallel nature of the crystals and the lack of prism boundaries,²⁷ and some believe that longer acid etching time is required.²⁸ The difference in the enamel structure of primary teeth suggests that the results and conclusions of bonding experiments on permanent enamel should not be applied directly to primary enamel and that experimental testing should be carried out separately on primary teeth.

The few studies on primary enamel and adhesives have used either scanning electron microscopy or microleakage, and the comparisons with permanent enamel are inconsistent.^{11,12,29,30}

Marginal bevel. The placement of a bevel at the margin of composite preparations has frequently been recommended to improve the bonding surface and reduce microleakage.³¹ A bevel provides more prepared enamel surface area where exposed enamel rod ends are available for acid conditioning and subsequent bonding. The increased enamel surface area is important in the acid etching technique because greater resin tenacity is positively correlated with increased surface area.^{32,33} The resin-enamel bond has been found to be stronger with cut-and-etched

transverse cross-sections of enamel prisms than with longitudinal sections,^{34,35} and beveling is believed to expose more transverse cross-sections in permanent teeth. A bevel increases bonding to the enamel rod ends without overcontouring the restoration.³⁶ An additional benefit of beveling is that the bevel provides a greater marginal surface to compensate for polymerization shrinkage, which should help reduce microleakage.³⁷

Many studies have shown a significant decrease in microleakage with the placement of a marginal bevel in the composite preparations of permanent teeth.^{31,33,38-40} Several recent studies with new adhesive materials, however, show no significant difference in microleakage at beveled and nonbeveled margins.^{8,41,42} These studies suggest that a re-examination of the marginal preparation used with the newer adhesive materials would be beneficial. To date, no study has evaluated the combined effects of self-etch adhesive and margin beveling on primary enamel bonding.

The purpose of this *in vitro* study was to compare the effectiveness of bonding to beveled and nonbeveled margins of self-etch and total-etch adhesive systems in primary and permanent teeth. The integrity of the enamel-composite interface was evaluated by measuring microleakage at the margins of buccal surface restorations on primary and permanent molars.

Methods

Sixty freshly collected, extracted human molars (30 primary and 30 permanent) were used in the study. Primary molars were extracted for orthodontic purposes or due to carious lesions not affecting the tooth's buccal surface. Extracted noncarious permanent third molars were also used. The study was approved by the Institutional Review Board of the University of Minnesota, Minneapolis, Minn. Prior to entry into the study, soft tissue residue was removed from the teeth, and the teeth were stored in 0.2% sodium azide solution at room temperature.

Two restorations were prepared on each tooth's buccal surface and randomly assigned: 1 to total-etch (TE) adhesive (Adper Single Bond Plus, 3M ESPE, St. Paul, Minn) and 1 to self-etch (SE) adhesive (Adper Prompt L-Pop, 3M ESPE). Each tooth was then randomly assigned to have a bevel placed on either the mesial or the distal margin of the preparations. This method of randomization yielded 30 primary and 30 permanent teeth with 60 preparations in each tooth type.

Two vertically oriented, rectangular-shaped slot preparations were completed on the mesial and distal side of each tooth's buccal surface using a no. 330 carbide bur under copious water coolant. The mesial-distal width of the preparation was approximately 2 mm, with the occlusal-gingival height approximately 3 mm. The depth of the preparation was approximately 2 mm, measured by the length of the cutting blades of a no. 330 carbide bur. An approximately 1-mm bevel was placed with a no. 150L carbide bur on the randomly assigned mesial or distal margin of each preparation.

The preparations were restored using either the total-etch adhesive or a self-etch adhesive following the manufacturer's

instructions. For the preparations restored using the total-etch adhesive, phosphoric acid gel was applied for 15 seconds, rinsed with water for 10 seconds, and blotted dry. The total-etch adhesive was applied in 2 consecutive coats to the entire preparation, dried gently for 2 to 5 seconds, and light cured (Spectrum Curing Light, Dentsply Caulk, Milford, Del.) for 10 seconds. For the preparations restored using the self-etch adhesive, the adhesive material was used in accordance with the manufacturer's instructions. The self-etch adhesive was then applied to the entire preparation with a rubbing motion for 15 seconds and gently air dried before a second coat was applied. The adhesive was light cured for 10 seconds. All preparations were restored with resin composite (Filtek Supreme, 3M ESPE), light-cured for 40 seconds, and polished with Sof-Lex discs (3M ESPE) to remove any marginal composite flash. The teeth were then stored in distilled water at 21°C. Thermocycling began within 12 hours of restoration.

The thermocycling process consisted of 500 cycles alternating between a hot bath (55°C) and a cold bath (5°C) with a 30-second bath immersion time, after which the teeth were immersed in 50% AgNO₃ solution in the dark for 2 hours. Excess AgNO₃ solution was rinsed off with water. The teeth were then placed in developing solution under fluorescent light for 8 hours.

Each tooth was then sectioned horizontally under water coolant using a low-speed diamond wheel sectioning machine (model no. 650, South Bay Technology, Inc., San Clemente, Calif). After sectioning, each tooth yielded 4 samples, 2 total etch adhesive samples and 2 self-etch adhesive samples. Each sample contained a beveled and nonbeveled margin, resulting in 8 microleakage measurements per tooth.

Microleakage was measured by an operator who was blinded to the type of adhesive. The type of margin (beveled vs nonbeveled), however, was evident upon measurement of the image. The image of the enamel-composite interface at the cavity margin was captured at X90 magnification under a stereomicroscope and stored in a digital format. Microleakage, seen as a dark line at the enamel-composite interface (Figure 1), was measured in millimeters using Image-Pro Plus software (v. 4.5 for Windows, Media Cybernatics, Inc., Silver Spring, Md.). Two microleakage measurements were taken for each sample: 1 for the beveled margin and 1 for the nonbeveled margin. All questionable data and 12 random samples (24 measurements) were confirmed by 2 other examiners who were also blinded to the adhesive group.

The 60 teeth provided a total of 480 microleakage measurements (60 teeth x 2 restorations x 4 measurements per restoration). Five samples (2 from primary teeth and 3 from permanent teeth), however, were lost due to fracture during sectioning, and 3 measurements (1 on a primary tooth and 2 on permanent teeth) could not be made because the dye penetration primarily followed cracks and was not measurable at the restoration margin. Consequently, 467 measurements were completed in the study. Since 8 measurements were made from each tooth, measurements

on the 4 combinations of adhesive bonding type and margin preparation type were assumed to be correlated within each tooth. Thus, all 8 measurements tended to be higher or lower together, depending on characteristics specific to the tooth (eg, primary or permanent tooth type, enamel quality, patient age, etc). Therefore, the statistical analysis used a repeated-measures analysis of variance. The analysis used the MIXED procedure in the SAS system (v. 9, SAS Institute, Cary, NC), with the restricted likelihood method. Statistical significance was considered to be $P < .05$.

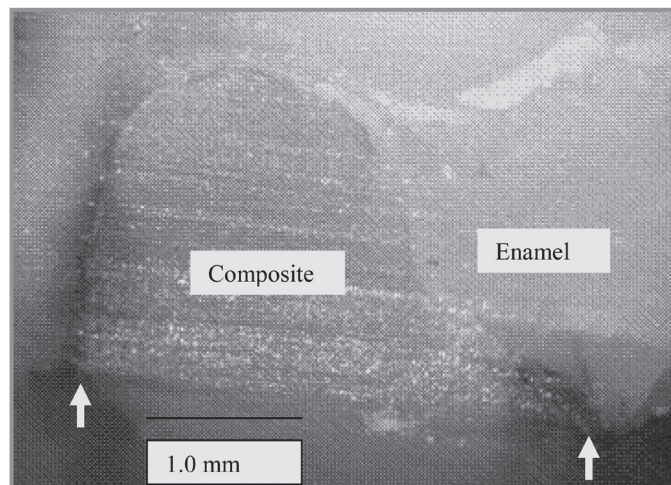


Figure 1. A representative sample showing microleakage at the beveled and nonbeveled margins of a restoration (beveled margin marked by white arrow on right and nonbeveled marked by white arrow on left).

Results

Mean microleakage measurements and 95% confidence intervals are shown in Figure 2.

Total-etch adhesive and beveled margins resulted in the least amount of microleakage for primary and permanent teeth. The total-etch adhesive had significantly less microleakage than the self-etch adhesive for primary teeth (53%, $P < .001$) and for permanent teeth (22%, $P = .01$). Beveled margins had significantly less microleakage than nonbeveled margins for primary (66%, $P < .001$) and permanent teeth (73%, $P < .001$). The results of the statistical analysis, simultaneously considering 3 experimental factors (adhesive, margin, and tooth type), are presented in the Table. The interaction of tooth type and adhesive type (Table) indicates that the extent of the difference:

1. between the microleakage in primary and permanent teeth depends on the adhesive type used; or, equivalently
2. in microleakage between total-etch and self-etch depends on the tooth type ($P < .001$).

Beveled margins allowed much less microleakage on average for primary and permanent teeth. The interaction of margin type and adhesive type (Table) indicates that either the:

1. effect of beveling on microleakage depends on the adhesive type used; or, equivalently

- 2. extent of the difference in microleakage between total-etch and self-etch depends on the margin type used ($P=.03$).

Total-etch and self-etch allowed similarly small microleakage values in restorations with beveled margins, while self-etch allowed considerably more microleakage in restorations with nonbeveled margins.

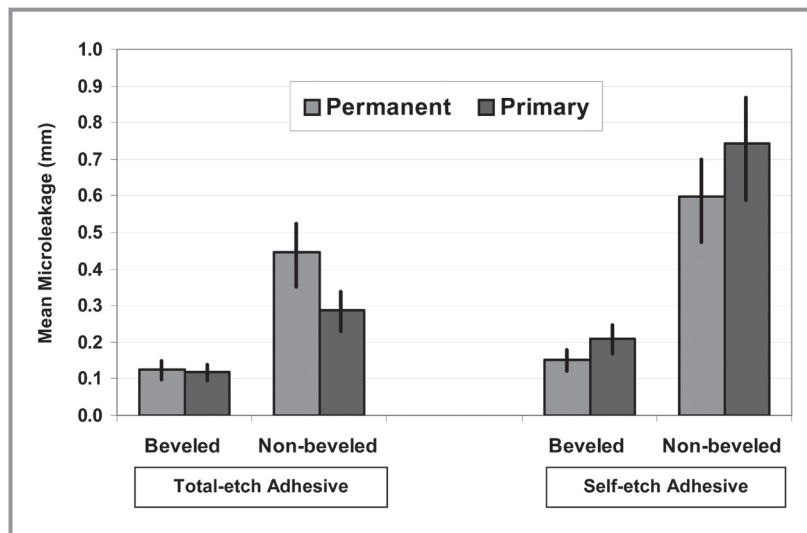


Figure 2. Mean microleakage measurements and 95% confidence intervals by adhesive and margin type. Vertical lines represent 95% confidence intervals.

Table. SIGNIFICANCE TESTS FROM THE ANALYSIS OF VARIANCE OF 3 VARIABLES		
Effect	F-statistic	P-value
Tooth type	0.49	.49
Adhesive type	60.89	<.001
Margin type	374.89	<.001
Tooth type by adhesive type interaction	16.57	<.001
Tooth type by margin type interaction	3.17	.08
Margin type by adhesive type interaction	4.80	.03
Tooth type by margin type by adhesive type interaction	1.86	.18

Discussion

Microleakage at the margin between dental restorative material and tooth structure can lead to recurrent decay, pulpal irritation and pathology, postoperative sensitivity, and staining. An in vitro measurement of microleakage is a surrogate for marginal integrity, allowing comparisons between restorative factors to see which factors decrease leakage and are, thus, better for marginal integrity. The present in vitro study compared the bonding effectiveness of a self-etch adhesive, Adper Prompt L-Pop, and a total-etch adhesive, Adper Single Bond Plus, using microleakage to evaluate the marginal integrity of restorations with and without margin bevels, in primary and permanent enamel.

Of the 3 factors tested (adhesive, margin, and tooth type), beveling had by far the most profound effect on marginal leakage. The presence of a marginal bevel significantly reduced microleakage in primary and permanent enamel (70% overall), regardless of the type of adhesive used ($P<.001$). These results agreed with many studies that reported a decrease in microleakage with the placement of a bevel.^{28,31,33,38-40,43}

Few studies have evaluated the effect of self-etch adhesives in restorations with a marginal bevel. Two of those studies differed from our findings. Ireland et al and Santini et al reported no significant difference in microleakage between beveled and nonbeveled margins in permanent enamel.^{8,41} Atash and Vanden Abbeele evaluated beveled margins in primary enamel. Their nonbeveled margin, however, was placed on the root surface in cementum.¹² In the context of other recent studies, our results suggest that further evaluation of marginal preparation with the new adhesives would be beneficial.

We found that the self-etch system was significantly less effective in preventing microleakage than the total-etch system in primary and permanent teeth, resulting in 65% more leakage overall. The total-etch adhesive allowed less microleakage than the self-etch adhesive on permanent enamel ($P=.01$); the self-etch adhesive resulted in 28% more leakage compared with total etch. These results are supported by many studies that reported less effective bonding properties with a self-etch system in permanent teeth.⁴⁻⁷ Some studies, however, reported similar enamel bonding ability for the 2 adhesive systems.^{3,8,9} Brackett et al found that self-etch adhesives actually allowed less microleakage than the total-etch systems, but their sample size was very small ($N=8$) and their results were not statistically significant.¹⁰

Due to differences in the enamel structure of primary and permanent teeth, conclusions regarding the use of dental materials on primary teeth should not be made from studies evaluating permanent teeth. The present study found significantly more microleakage for the self-etch adhesives than the total-etch adhesive on primary enamel ($P<.001$)—a 113% increase. Few studies have evaluated the microleakage of self-etch adhesives on primary enamel. Casagrande et al found no statistical difference between the 2 adhesive systems.¹¹ Their sample size was small ($N=11$), however, and the teeth were not subjected to any stresses. Also, their assessment of microleakage was relatively subjective, with scores assigned 0 to 3 based on dye penetration. Atash and Vanden Abbeele evaluated 8 different adhesives using dye penetration scoring and found that the self-etch, all-in-one adhesives presented with lower enamel microleakage scores than the other adhesives.¹² Our study used thermal stresses, but not mechanical

stresses, and showed greater microleakage in primary than permanent teeth when the self-etch adhesive was used, suggesting that the self-etch adhesive does not work as well on primary enamel.

Studies vary regarding adhesive etching ability.^{4,22,23,44} The adhesive's acidity may affect the initial enamel etch, thus influencing marginal integrity and bonding ability. Van Meerbeek et al classified self-etch adhesives as "strong," "intermediate," or "mild," depending on the pH.⁴⁵ Those having a pH <1, such as Adper Prompt L-Pop (pH=0.4), were considered strong acidity adhesives. Those with a pH of approximately 2, such as Clearfil SE Bond Plus (pH=2.0), were considered to be mild acidity adhesives. Van Meerbeek et al observed that the "strong" self-etch adhesives produced more effective enamel etching than the "mild" self-etch adhesives. Inoue et al found that the "strong" (pH<1.0) self-etch adhesives formed microtags, considered to be the primary mechanism for bonding to enamel, but no macrotags.⁴⁶ They also reported that the "moderate" and "mild" self-etch adhesives showed little effect at all on the enamel surface.

Most self-etch adhesives are composed of aqueous mixtures of acidic monomers with a pH higher than that of phosphoric acid etch gels.⁴⁷ The relatively higher pH results in shallow enamel demineralization compared to that of phosphoric acid.⁴ The effects of acidity on bonding ability are still inconclusive. Other studies report that the primer of self-etching adhesives is acidic enough to demineralize the smear layer and tooth structure.^{22,23} Prompt L-Pop has a 4:1 phosphoric acid ester to water ratio. Some believe that the water content helps improve its adhesive behavior and the lower pKa is sufficient to etch beyond the smear layer and form an authentic hybrid layer.⁴⁴

Hobson and McCabe observed that an ideal etch pattern was not essential for high bond strengths.⁴⁸ Perdigão et al evaluated bond strengths of self-etch adhesives with respect to pH values and conditioning times.⁴⁹ They found a significant correlation between the enamel conditioner's acidity and enamel bond strengths. The 2 adhesives with lower mean pH values were found to have the highest bond strengths. The bond strengths of the 2 adhesives with the highest pH values increased when the adhesive application time doubled. Pashley and Tay, and Ibarra et al found that "strong" and "intermediate" self-etch adhesives, those with lower pH values, could adequately seal enamel margins.^{50,51} The pH of the adhesive is most likely one of many contributing factors in the performance of self-etch adhesives, and effective bonding to enamel may require a different pH than effective bonding to dentin.

Our study had limitations associated with all in vitro research. Although the thermal stresses of the oral environment were simulated for the study, not all variables can be reproduced. Many factors not incorporated in the study may influence marginal integrity and adhesive bonding ability, including enamel rod orientation, mechanical stresses of function, pH of the oral cavity, bacteria, diet, salivary content and flow, and medications.

We attempted to evaluate the effectiveness of adhesive systems and marginal preparation on microleakage in primary and permanent enamel. Future studies should assess the microleakage of self-etch adhesives in relation to pH. The many types of self-etch adhesives available, differences in pH, limited number of studies, and inconclusive results of previous studies indicate that further investigation is needed to understand the effects of these many factors on the marginal integrity and durability of composite restorations.

Conclusions

Based on this study's results the following conclusions can be made:

1. Beveling the margins of all nonstress-bearing composite restorations reduces marginal microleakage in primary and permanent teeth.
2. Adper Single Bond Plus, a total-etch adhesive, prevents more microleakage than Adper Prompt L-Pop, the self-etch adhesive used in this study.
3. Margin beveling has a greater effect on minimizing microleakage than the type of adhesive used.

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Abstract of the Scientific Literature

Childhood obesity and skeletal maturation

The purpose of this study was to examine the potential relationship between increased body mass index (BMI) and accelerated skeletal maturation. Fishman's hand-wrist analysis was used to determine the skeletal ages of 107 children (44 boys and 63 girls), ages 9-16 years. The difference between chronologic age and dental skeletal age was analyzed against BMI, sex, and chronologic age. Subjects were separated into normal weight, overweight, and obese based on published BMI tables. The mean differences between chronologic and skeletal ages for normal weight, overweight, and obese subjects were 0.21 years, 0.44 years, and 1.00 years, respectively. These differences were not statistically significant, although there was a trend for obese subjects to have accelerated skeletal maturation, compared with the subjects from the other two groups. Skeletal age differences were found to decrease significantly with increasing age, and mean skeletal age did not differ significantly by sex.

Comments: As the US population drifts towards higher BMI, more studies will be needed to articulate the impact on the healthcare delivery system, even orthodontic care. If a larger study finds the trend identified here to be statistically significant, one can make the argument that children with higher BMI would need to have orthodontic evaluation and intervention earlier than children with a normal BMI. **RHH**

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Akridge M, Hilgers KK, Silveira AM, Scarfe W, Scheetz JP, Kinane DF. Childhood obesity and skeletal maturation assessed with Fishman's hand-wrist analysis. *Am J Orthod Dentofacial Orthop* 2007;132:185-90.

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