Original Article

A Retrospective Study of Factors Contributing to Anchorage Loss in Upper Premolar Extraction Cases

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Abstract

Background: Anchorage control is one of the components in the treatment of extraction cases. However, what determines more or less anchorage loss is still an unanswered question. **Aim:** The purpose of this study was to investigate the most important factors contributing to the anchorage loss of maxillary first molars in premolar extraction cases. **Materials and Methods:** The study included 726 upper premolar extraction cases, including 214 male patients and 512 female patients, and the mean age was 14.4 ± 4.5 years old (range: 9-45). Factors including physiological characteristics, treatment mechanics, and cephalometric variables were collected and their influences on the angulation changes of maxillary first molars were analyzed. **Results:** The mean angulation change of maxillary first molar after treatment was 2.81°(mesial tipping). The change of UM/PP showed a statistically significant difference in different sex (male 3.84° ± 5.26° vs female 2.38° ± 5.10°), age (adult -0.05° ± 4.73° vs teenager 3.46° ± 5.07°), and molar relationship (Class II 3.28° ± 5.15° vs Class I 2.36° ± 5.19°). There are six variables accounted in the regression analysis (R = 0.608, R^2 = 37.0%). Among them, the pre-treatment molar tipping (Standardized Coefficients: -0.65) and the pre-treatment incisor/molar height ratio (Standardized Coefficients: -0.27) were the most important factors influencing anchorage loss during treatment. **Conclusion:** Compared with treatment-related factors, the patient's physiological characteristics play a more important role in anchorage loss. The pre-treatment angulation of the maxillary first molar is the most influential factor in changes to maxillary molar angulation, which are often predisposing anchorage loss.

Keywords: *Anchorage loss, incisor/molar height ratio, maxillary first molars, regression, tip*

Introduction

It is not uncommon to treat orthodontic patients with extractions, which requires thorough treatment planning and accurate diagnosis. Anchorage control is one of the key components in treatment planning, and it's imperative to choose proper mechanics to prevent molars from unfavorable mesialization. For decades, orthodontists have been designing a variety of intraoral and extraoral appliances to preserve anchorage, such as the Nance palatal arch,[1] lower lingual arch,[2] transpalatal arch,[3] headgear,[4] Temporary anchorage devices (TADs),[5-7] etc.

For certain cases, anchorage loss due to excessive molar mesialization is undesirable, especially when space is needed for the retraction of incisors. In addition, mesial tipping often accompanies mesialization,[8,9] and tipping can occupy extraction space and may even change the occlusal plane, which in turn can negatively affect

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treatment outcome and stability. To counteract these negative side effects, treatment frequently necessitates distal tipping through distal bends to the archwire, such as with the classic edgewise technique,[10,11] Begg technique,[12] and Tweed technique.

Another challenge is the diverse treatment responses to the same treatment technique.[13] Maxillary first molars remain relatively stable in some patients, while, in other patients, they mesialize and tip forward rapidly. Orthodontists have attempted to differentiate patients who are prone to anchorage loss from those who are not with little success. Even though research have shown different types of appliances or treatment mechanics that are capable of reinforcing anchorage, few studies have identified the physiological characteristics of patients to predict anchorage loss.[14,15] Consequently, it is not clear what elements really contribute to anchorage loss.

In this retrospective cross-sectional study, angular changes of the maxillary first molar were studied in patients with maxillary premolar extraction cases in Class I or Class II malocclusion that require moderate or strict anchorage control. By studying the maxillary molar tipping, we hope to identify physiological characteristics that can help predict anchorage loss during orthodontic treatment.

Material and Methods

The sample was collected from patients who finished their treatment during 1997-2005 at the Orthodontic Department of Peking University School and Hospital of Stomatology. The inclusion criteria include 1. Angle Class I or Class II patients; 2. Extraction of two maxillary premolars; 3. Completion of treatment with a fixed appliance; 4. Complete treatment records; 5. Presence of maxillary first molars pre- and post-treatment; and, 6. Cephalometric X-rays taken by the same machine. The exclusion criteria include 1. Retreatment cases; 2. Non-fixed appliances; and, 3. Surgical patients.

The sample consisted of 726 cases (214 male and 512 female) with a mean age of 14.4 years old (Range 9-45 years old). There were 135 adult patients and 591 adolescents, and 48.6% of them had Class II malocclusion (353). The following were analyzed for each patient case: physiological characteristics, type of malocclusion, treatment mechanics, duration of leveling and alignment, and total treatment time.

The dataset was measured and collected by five calibrated orthodontic PhD students, including treatment records and cephalograms. The variables involved in this study include:

1. Variables regarding treatment records:
    a. Physiological variables: age, sex, angle classification, deep overbite, deep overjet, open bite, scissor bite, and the amount of maxillary crowding.
    b. Treatment mechanics: usage of bite plate, occlusal splint, pendulum appliance, transpalatal arch, Nance appliance, headgear, and maxillary expansion.
2. Variables from cephalograms: All cephalograms were taken at the Department of Radiology, Peking University School, and Hospital of Stomatology. After scanning and uploading the cephalograms onto the computer, three orthodontic PhD students digitized the cephalograms using software and retrieved cephalometric measurements
3. The dependent variable of this study is the angular change of the maxillary first molars relative to the palatal plane. The vertical tooth axis of the first molar is defined as the line connecting the mesial buccal cusp and the mesial buccal apex of the first molar. UM/PP is defined as the angle formed by the molar axis and palatal plane [Figure 1]. The cephalometric measurements include pre-treatment (1), post-treatment (2), and changes during treatment (12). UM/PP-12 is the abbreviation of the independent variable. Figure 2 shows the landmarks, and Table 1 lists the cephalometric measurements and the corresponding definition.

Statistical analysis

The whole dataset was analyzed via SPSS v16.0 (SPSS, Chicago, IL, USA). The significance level was set at $P < 0.05$. The normality was tested by the Q-Q diagram and showed the normal distribution. Independent T-test and stepwise linear regression were used. Multiple regression analysis was performed to study the relationship between molar tipping and other variables.

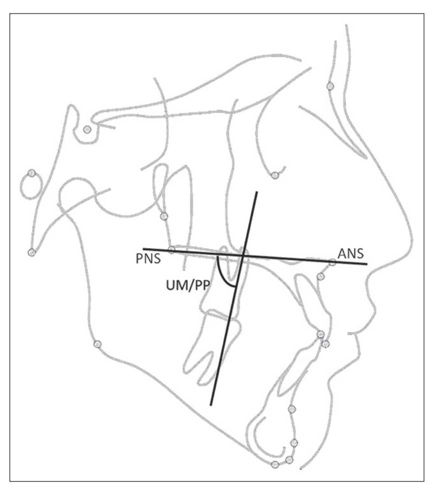

Figure 1: UM/PP is defined as the angle formed by the upper first molar axis and palatal plane

Results

1. UM/PP-12 and patients' physiological characteristics

The mean maxillary first molar tipping was 2.81° of mesial tipping (all positive angulations signify mesial movement) for the Class I and Class II patients. The outcomes of the t-test regarding the change of UM/PP and physiological characteristics show statistically significant differences

Table 1: Cephalometric measurements and the corresponding definition

Variables	Name	Definition
UM/PP（°）	Maxillary molar tipping	The angle formed by the molar axis and palatal plane
SNA（°）	SNA	The angle formed by Sella – Nasion and Nasion – A-point
SNB（°）	SNB	The angle formed by Sella – Nasion and Nasion – B-point
ANB（°）	ANB	The subtraction of SNB from SNA
MP/SN（°）	Mandibular plane	The angle formed by Sella – Nasion and mandibular plane
UI/PP（°）	Maxillary incisal tipping	The angle formed by incisal axis (incisal edge to incisal apex) and palatal plane
UIE-PP（mm）	Maxillary incisor to PP	The vertical distance between the edge of maxillary incisors and palatal plane
UMC-PP（mm）	Maxillary molar to PP	The vertical distance between the mesial buccal cusp of maxillary molars and palatal plane
UIE-PP/UMC-PP	Incisor/molar height ratio	The ratio of the vertical position of incisor to that of molar

Table 2: The relation of the change of maxillary molar angulation and physiological characteristics and treatment mechanics

Independent variables	Group	Sample size	UM/PP-1		UM/PP-2		UM/PP-12		
			Mean	SD	Mean	SD	Mean	SD	*P*
Sex	male	214	78.80	5.88	82.65	4.83	3.84	5.26	0.000**
	female	512	79.69	5.67	82.07	5.43	2.38	5.10	
Age	adolescent	591	78.38	5.20	81.84	5.11	3.46	5.07	0.000**
	adult	135	84.01	5.75	83.97	5.58	-0.05	4.73	
Deep overjet	no	234	80.93	5.81	83.73	5.06	2.80	5.37	0.983
	yes	492	78.72	5.57	81.53	5.22	2.81	5.11	
Deep overbite	no	230	80.64	5.67	83.05	5.07	2.41	4.97	0.159
	yes	496	78.87	5.69	81.86	5.31	2.99	5.28	
Open bite	no	710	79.43	5.76	82.24	5.29	2.82	5.21	0.765
	yes	16	79.69	5.21	82.12	4.04	2.42	4.20	
Maxillary crowding	no	129	79.88	6.21	81.89	5.63	2.01	5.19	0.053
	yes	597	79.33	5.64	82.31	5.18	2.98	5.18	
Scissors bite	no	655	79.41	5.77	82.21	5.31	2.80	5.25	0.889
	yes	71	79.61	5.48	82.51	4.82	2.89	4.59	
Molar relationship	I	373	81.06	5.50	83.42	4.92	2.36	5.19	0.018*
	II	353	77.71	5.49	80.99	5.33	3.28	5.15	
Bonding of second molars	no	586	79.25	5.52	82.13	5.28	2.88	5.14	0.436
	yes	140	80.18	6.57	82.68	5.20	2.50	5.41	
Bite plate	no	689	79.41	5.74	82.23	5.25	2.81	5.20	0.916
	yes	37	79.74	5.85	82.46	5.56	2.72	5.10	
Occlusal splint	no	714	79.45	5.75	82.25	5.27	2.80	5.22	0.903
	yes	12	78.47	5.03	81.46	5.32	2.99	3.19	
Pendulum appliance	no	723	79.45	5.75	82.26	5.25	2.81	5.18	0.61
	yes	3	76.01	3.43	77.29	8.90	1.28	7.54	
TPA	no	619	79.44	5.76	82.39	5.26	2.95	5.28	0.072
	yes	107	79.38	5.65	81.36	5.22	1.97	4.56	
Nance appliance	no	659	79.49	5.77	82.23	5.26	2.73	5.20	0.226
	yes	67	78.83	5.50	82.37	5.35	3.54	5.10	
Headgear	no	515	79.57	5.84	82.44	5.33	2.87	5.10	0.617
	yes	211	79.09	5.49	81.74	5.08	2.66	5.42	
Maxillary expansion	no	713	79.37	5.72	82.19	5.24	2.82	5.19	0.578
	yes	13	82.77	6.19	84.78	6.09	2.01	5.17	

UM/PP-1 :pre-treatment maxillary molar tipping; UM/PP-2 :post-treatment maxillary molar tipping ; UM/PP-12:the change of maxillary molar tipping; *: $P<0.05$; **: $P<0.01$

for sex (male 3.84° vs female 2.38°), age (adult -0.05° vs adolescent 3.46°), and molar relationship (Class II 3.28° vs Class I 2.36°) [Table 2]. Among the physiological characteristics, male adolescents with Class II malocclusion exhibited more mesial tipping of the maxillary molars. However, molar tipping on adult patients is close to 0°, indicating the molars of adult patients underwent bodily movement or minimum anchorage loss.

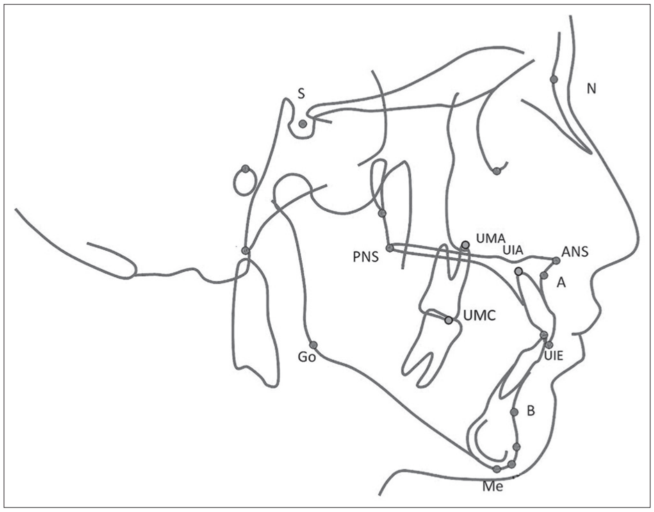

Figure 2: Landmark location. S: Sella; N: Nasion; A: A-point; B: B-point; ANS: Anterior Nasal Spine; PNS: Posterior Nasal Spine; UMA: Mesial buccal apex of the upper first molar; UMC: Mesial buccal cusp of the upper first molar; UIA: Apex of the upper middle incisor; UIE: Edge of the upper middle incisor; Me: Menton; Go: Gonion

Table 3: Cephalometric and time-related variables

Variables	Mean	Standard deviation
ANB-1 (°)	5.25	2.16
SNA-1 (°)	82.37	3.34
SNB-1 (°)	77.16	3.51
MP/SN-1 (°)	38.18	5.86
UI/PP-1 (°)	120.17	7.57
UIE-PP-1 (mm)	31.83	2.83
UM/PP-1 (°)	79.43	5.74
UMC-PP-1 (mm)	24.93	2.72
UIE-PP/UMC-PP-1 (ratio)	1.28	0.10
Time in NiTi wire (month)	8.85	4.77
Total treatment time（month）	30.07	10.00

2. UM/PP-12 and treatment mechanics [Table 2]

Treatment mechanics did not have any statistically significant effect on the maxillary molar tipping.

3. Stepwise multiple regression analysis

To better evaluate the effect of different variables in relation to maxillary molar tipping, we performed regression analysis between UM/PP-12 and the statistically significant variables in Table 2 as well as additional independent variables listed in Table 3.

There were six variables accounted in the regression analysis ($R = 0.608$, $R^2 = 37.0\%$, $R^2adj = 36.3\%$). Among them, the pre-treatment molar tipping (UM/PP-1, Standardized Coefficients = -0.65) was the greatest contributing factor, followed by the pre-treatment incisor/molar height ratio (UIE-PP/UMC-PP-1, Standardized Coefficients = -0.27) [Table 4].

Discussion

One of the key components of orthodontic treatment is anchorage control. In studies, many focused on linear changes during anchorage control but not tipping of the molars.[16,17] During orthodontic treatment, crown movement surpasses root movement in speed and extent, which can signify the initiation of anchorage loss. Molar tipping almost always accompanies mesialization; in other words, mesial tipping is closely related to anchorage loss. Thus, orthodontists should consider the physiologically tipping of molars while developing a treatment plan and its mechanics. This cross-sectional study analyzed physiological factors and mechanical factors that might trigger anchorage loss in Class I or Class II patients who underwent extraction and required anchorage control. A few characteristics have been found attributable to anchorage loss, and more attention should be given to these patients with these characteristics when anchorage control is needed.

Age is an important role in the anchorage loss of the upper first molar. According to this study, adolescents exhibited 3.46° mesial tipping of the maxillary first molar while adults 0.05° distal tipping. The difference between age and the amount of tipping showed

Table 4: The outcome of stepwise multiple regression analysis

	Unstandardized coefficients B	Std. Error	Standardized Coefficients Beta	*t*	*P*
(Constant)	78.98	5.53		14.29	0.000
UM/PP-1	-0.59	0.04	-0.65	-16.60	0.000
UIE-PP/UMC-PP-1	-13.42	2.11	-0.27	-6.36	0.000
UMC-PP-1	-0.35	0.08	-0.19	-4.65	0.000
Sex	-1.46	0.35	-0.13	-4.15	0.000
ANB-1	-0.29	0.08	-0.12	-3.55	0.000
Angle classification	-0.72	0.34	-0.07	-2.09	0.037

statistical significance. The results agree with the finding in Xu's study,[13] which showed younger adolescents had significantly more molar mesial displacement than older adolescents (mean difference, 1.3 mm). Mckinney[14] also found similar results that showed adolescents are more prone to anchorage loss than adults. This finding is reasonable because the maxillary first molar tends to significantly tip forward during growth. Iseri and Solow[18] noticed that the maxillary first molar would continuously erupt inferiorly and anteriorly before 25 years old while continuing at a slower speed after 25 years old. Tsourakis and Johnston[15] found a compensatory growth pattern of the maxillary molars in response to greater and longer mandibular growth, which revealed a close relationship between the movement of maxillary molar and mandibular growth. Zhang[19] studied the longitudinal eruptive and post-eruptive tooth movements using oblique and lateral cephalograms with implants. They found that continuous mesial tipping of the maxillary molars happened from 8.5 to 16 years of age, averaging 8.2° ± 5.5° for the first molars and 18.3° ± 8.5° for the second molars. Therefore, we inferred that the anchorage loss before adulthood might be due to two factors: (1) the application of force during space closure and (2) the growth and development of maxillary teeth in a downward and forward direction.

In this study, sex is obviously another factor contributing to maxillary molar tipping during orthodontic treatment. Male patients tend to undergo more mesial tipping than female patients, which is in agreement with preview studies.[13,14] We believe this phenomenon is attributable to the delayed growth peak in males. Female patients are on average two years ahead in physical maturity compared to their male counterparts and end their growth peak earlier.

According to this study, the maxillary first molar tipped forward greater in Class II patients, indicating Class II patients are predisposed to anchorage loss. Our previous cross-sectional study[20] found that patients with Class II malocclusion had the most distally tipped Upper molar (UMs). Kim[21] stated a well-compensated Class II patient tended to exhibit the most distal tipping of the maxillary first molars. For Class II patients, the distally-tipped maxillary molars would be leveled and aligned initially with a light wire, causing unfavorable anchorage loss and reducing extraction space. Mckinney[14] mentioned the undesirable anchorage loss with the straight-wire brackets, which should be considered iatrogenic and unnecessary.

In order to stop the upper first molar from tipping forward, orthodontists resort to auxiliary appliances (Nance appliance, Transpalatal Arch (TPA), and headgear, etc.). Our results showed that different types of auxiliary appliances used in this study had no statistically significant effect on the angular change of maxillary first molar. One explanation could be that extraoral appliances are not used at all times (e.g., fixed appliances are on 24 hours/day while headgear is worn 8-12 hours/day).

To compare various factors in regards to the amount of maxillary molar tipping, stepwise multiple regression analysis was performed. The most contributing factor was the pre-treatment angulation of the maxillary first molars. Since the pre-treatment status of molars is determined completely by individual malocclusion and physiological characteristics, its role is strikingly more important than the traditionally-believed forces from space closure or other mechanics. The negative standardized coefficients suggested that greater the distal tipping of pre-treatment maxillary first molars, greater the mesial tipping that would occur during orthodontic treatment.

In this report, the second most contributing factor was the incisor/molar height ratio (the ratio of the vertical position of incisor to that of molar relative to the palatal plane). The negative standardized coefficients indicated the smaller the pre-treatment UIE-PP/UMC-PP-1, the greater the mesial tipping of the maxillary first molars. The different relative heights of the brackets' position resulted in different deformities of the wires. The incisor/molar height ratio is rarely mentioned and considered in other studies, but it could be an important indicator of anchorage loss.

The present study is not without some limitations. The sample had more female and adolescent patients, and in most of the cases, the extracted teeth were upper first premolars, which might bring systematic bias into the study.

Generally, this study is a supplement to the traditionally-believed concept that anchorage loss is only from the mechanics used during space closure. This study showed that anchorage loss tends to occur in specific groups of patients with the following characteristics: adolescent age, male sex, and Class II malocclusion. Although the Straight Wire Appliance is renowned for its convenience, it is worth considering how to avoid iatrogenic maxillary molar tipping caused by the insertion of a NiTi wire in the buccal tube of maxillary molars with greater distal tipping initially.

Conclusion

1. Compared with treatment-related factors, the patient's own physiological characteristics play a

more important role in molar anchorage loss in premolar extraction patients. The pre-treatment angulation of the maxillary first molar is the most contributing factor of the anchorage loss: the greater the pre-treatment distal tipping, the greater the mesial tipping during treatment.

2. In Class I and Class II extraction patients, maxillary molar anchorage loss tends to occur in the specific groups of patients: adolescent age, male gender, and Angle's Class II occlusion.

Ethics approval and consent to participate

The present study was approved by the Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB: 201626016). Informed consent was obtained from all subjects. All methods in the study were carried out in accordance with the Helsinki guidelines.

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Conflicts of interest

There are no conflicts of interest.

References

1. Stivaros N, Lowe C, Dandy N, Doherty B, Mandall NA. A randomized clinical trial to compare the Goshgarian and Nance palatal arch. Eur J Orthod 2010;32:171-6.
2. Chen CY, Hsu KC, Marghalani AA, Dhar V, Coll JA. Systematic review and meta-analysis of passive lower lingual arch for resolving mandibular incisor crowding and effects on arch dimension. Pediatr Dent 2019;41:9-22.
3. Diar-Bakirly S, Feres MF, Saltaji H, Flores-Mir C, El-Bialy T. Effectiveness of the transpalatal arch in controlling orthodontic anchorage in maxillary premolar extraction cases: A systematic review and meta-analysis Angle Orthod 2017;87:147-58.
4. Zervas ED, Galang-Boquiren MT, Obrez A, Costa Viana MG, Oppermann N, Sanchez F, *et al*. Change in the vertical dimension of Class II Division 1 patients after use of cervical or high-pull headgear. Am J Orthod Dentofacial Orthop 2016;150:771-81.
5. Antoszewska-Smith J, Sarul M, Łyczek J, Konopka T, Kawala B. Effectiveness of orthodontic miniscrew implants in anchorage reinforcement during en-masse retraction: A systematic review and meta-analysis. Am J Orthod Dentofacial Orthop 2017;151:440-55.
6. Melsen B, Dalstra M. L'ancrage squelettique au passé, présent et futur [Skeletal anchorage in the past, today and tomorrow]. Orthod Fr 2017;88:35-44.
7. Xu Y, Xie J. Comparison of the effects of mini-implant and traditional anchorage on patients with maxillary dentoalveolar protrusion. Angle Orthod 2017;87:320-7.
8. Monga N, Kharbanda OP, Samrit V. Quantitative and qualitative assessment of anchorage loss during en-masse retraction with indirectly loaded miniscrews in patients with bimaxillary protrusion. Am J Orthod Dentofacial Orthop 2016;150:274-82.
9. Dai FF, Xu TM, Shu G. Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: First premolar extraction treatment with Invisalign. Angle Orthod 2019;89:679-87.
10. Klontz HA. Tweed-Merrifield sequential directional force treatment. Semin Orthod 1996;2:254-67.
11. Vaden JL. The Tweed-Merrifield philosophy. Semin Orthod 1996;2:237-40.
12. Willmot DR. The anchorage bend in the Begg technique. Br J Orthod 1983;10:128-33.
13. Xu TM, Zhang X, Oh HS, Boyd RL, Korn EL, Baumrind S. Randomized clinical trial comparing control of maxillary anchorage with 2 retraction techniques. Am J Orthod Dentofacial Orthop 2010;138:544.e1-9.
14. McKinney JR, Harris EF. Influence of patient age and sex on orthodontic treatment: evaluations of Begg lightwire, standard edgewise, and straightwire techniques. Am J Orthod Dentofacial Orthop 2001;120:530-41.
15. Tsourakis AK, Johnston LE Jr. Class II malocclusion: The aftermath of A "Perfect Storm". Semin Orthod 2014;20:59–73.
16. Barthélemi S, Desoutter A, Souaré F, Cuisinier F. Effectiveness of anchorage with temporary anchorage devices during anterior maxillary tooth retraction: A randomized clinical trial. Korean J Orthod 2019;49:279-85.
17. Yassir YA, McIntyre GT, El-Angbawi AM, Bearn DR. Does anchorage loss differ with 0.018-inch and 0.022-inch slot bracket systems? Angle Orthod 2019;89:605-10.
18. Iseri H, Solow B. Continued eruption of maxillary incisors and first molars in girls from 9 to 25 years, studied by the implant method. Eur J Orthod 1996;18:245-56.
19. Zhang X, Baumrind S, Chen G, Chen H, Liang Y, Xu T. Longitudinal eruptive and posteruptive tooth movements, studied on oblique and lateral cephalograms with implants. Am J Orthod Dentofacial Orthop 2018;153:673-84.
20. Su H, Han B, Li S, Na B, Ma W, Xu TM. Compensation trends of the angulation of first molars: Retrospective study of 1403 malocclusion cases. Int J Oral Sci 2014;6:175-81.
21. Kim YE, Nanda RS, Sinha PK. Transition of molar relationships in different skeletal growth patterns. Am J Orthod Dentofacial Orthop 2002;121:280-90.