Original Article

pISSN 2234-7518 • eISSN 2005-372X
https://doi.org/10.4041/kjod.2020.50.1.26

THE KOREAN JOURNAL of ORTHODONTICS

Comparison of inclination and vertical changes between single-wire and double-wire retraction techniques in lingual orthodontics

Bui Quang Hung
Mihee Hong
Wonjae Yu
Hee-Moon Kyung

Department of Orthodontics, School of Dentistry, Kyungpook National University, Daegu, Korea

Objective: The Heat Induction Typodont System (HITS), used in some recent studies, has a distinct advantage over previous tooth movement simulation methods. This study aimed to compare inclination and vertical changes between the single-wire and double-wire techniques during *en masse* retraction with different lengths of lever arms in lingual orthodontics using an upgraded version of the HITS. **Methods:** Duet lingual brackets, which have two main slots, were used in this study. Forty samples were divided into four groups according to the length of the lever arm (3-mm or 6-mm hook) and the retraction wire (single-wire or double-wire). Four millimeters of *en masse* retraction was performed using lingual appliances. Thereafter, 3-dimensional–scanned images of the typodont were analyzed to measure inclination and vertical changes of the anterior teeth. **Results:** Incisor inclination presented more changes in the single-wire groups than in the double-wire groups. However, canine inclination did not differ between these groups. Regarding vertical changes, only the lateral incisors in the single-wire groups presented significantly larger values than did those in the double-wire groups. Combining the effect of hook lengths, among the four groups, the single-wire group with the 3-mm hook had the highest value, while the double-wire group with the 6-mm hook showed the least decrease in crown inclination and extrusion. **Conclusions:** The double-wire technique with an extended lever arm provided advantages over the single-wire technique with the same lever arm length in preventing torque loss and extrusion of the anterior teeth during *en masse* retraction in lingual orthodontics.
[Korean J Orthod 2020;50(1):26-32]

Key words: *En masse* retraction, Lingual, Heat Induction Typodont, Tooth movement

Received March 28, 2019; Revised October 7, 2019; Accepted October 11, 2019.

Corresponding author: Hee-Moon Kyung.
Professor, Department of Orthodontics, School of Dentistry, Kyungpook National University, 2177 Dalgubeol-daero, Jung-gu, Daegu 41940, Korea.
Tel +82-53-600-7372 e-mail hmkyung@knu.ac.kr

How to cite this article: Hung BQ, Hong M, Yu W, Kyung HM. Comparison of inclination and vertical changes between single-wire and double-wire retraction techniques in lingual orthodontics. Korean J Orthod 2020;50:26-32.

INTRODUCTION

Achieving appropriate anterior torque after incisor retraction is an essential treatment goal for clinicians. Conventional methods for maintaining anterior torque include direct application of moment/force to the lingual brackets and lever-arm extension.[1] Loss of control of anterior segment torque could more easily occur with lingual techniques than with conventional labial techniques.[2] Moreover, compared with the labial approach, the lingual approach enables the use of a longer hook on the lingual side because of the width and depth of the palate.[3] However, using a longer hook may cause irritation to the patient's tongue.

Lingual brackets with two main slots, such as Fujita's Duet brackets,[4] were developed to overcome this drawback. The new design allows for the engagement of an auxiliary wire into six anterior brackets in the course of *en masse* retraction and enables the use of shorter lever arms.[1] Although these approaches seem useful for torque control, few studies have reported findings in support of this idea.

Orthodontic treatment requires a long time, usually more than 2 years.[5] Furthermore, when conducting clinical research in orthodontics, limiting the differences between experimental and control groups to a single factor can be quite challenging.[6] For education and research purposes, many methods of simulating orthodontic movements have been developed, but each method has its own shortcomings. The finite element method has been used in numerous previous orthodontic studies. However, most of these studies only evaluated the initial tooth movement.[7] In the conventional typodont, which is widely used in dental education, heat is derived from an outside source; therefore, the wax surrounding the root apexes is the last to soften. This differs from the clinical situation, wherein bone resorption occurs around the tooth and the outer bone remains intact. To overcome these limitations, the Calorific machine system has been developed, but this system has a complicated design and requires wires to connect the tooth to the machine.[8] The Heat Induction Typodont System (HITS), which has been used in some recent studies,[9,10] has a distinct advantage over other tooth movement simulation methods. Our study used an upgraded version of the HITS machine with design modifications to improve energy efficiency.

Therefore, the purpose of this study was to compare inclination and vertical changes between single-wire and double-wire techniques during *en masse* retraction with different lengths of lever arms in lingual orthodontics using an upgraded version of the HITS.

MATERIALS AND METHODS

Heat Induction Typodont System simulation

A maxillary typodont with the first premolars extracted was prepared for the *in vitro* simulation study (Figure 1A). All anterior teeth were manufactured using aluminum for ensuring heat conductivity and light weight to prevent unwanted movement due to gravity. In contrast, resin was used for the posterior teeth. A typodont wax block (CALWAX, La Mirada, CA, USA) was used to form the alveolar bone.

The prepared typodont was placed in the HITS (Dentos, Daegu, Korea) (Figure 1B). The machine provided a rapid alternating magnetic-field environment, creating eddy currents inside the aluminum teeth. Eddy currents are circulating flows of electrons within the body of the conductor. The resistance of the teeth converted this

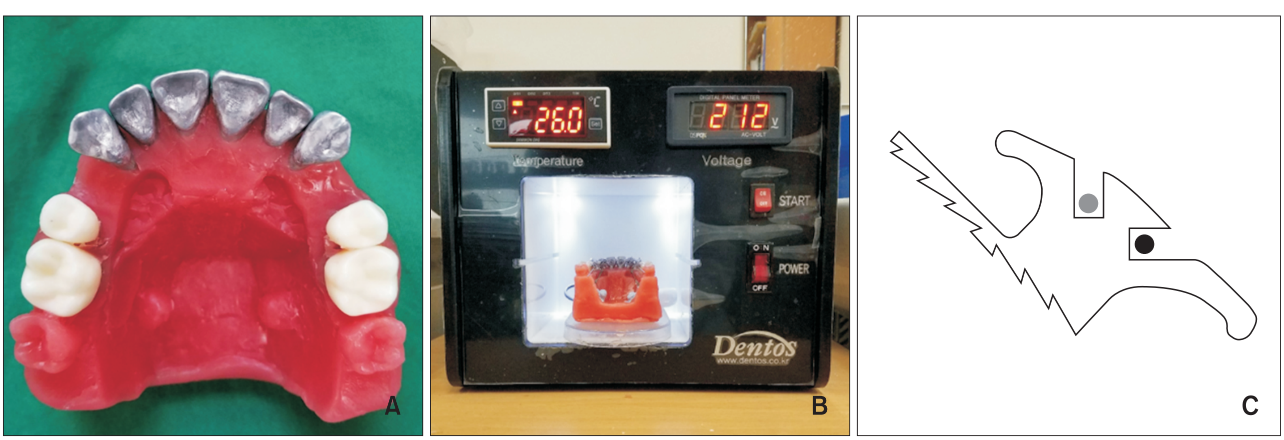

Figure 1. A, The maxillary typodont is composed of anterior metal teeth and posterior resin teeth, and the first premolars were extracted. **B**, The typodont is placed in the Heat Induction Typodont System machine. **C**, A Duet bracket has two main slots, one occlusal slot (grey circle) and one lingual slot (black circle).

https://doi.org/10.4041/kjod.2020.50.1.26

electrical energy into heat, which finally softened the wax surrounding the teeth, resulting in tooth movement due to the designed force. Meanwhile, the posterior resin teeth were not supposed to be moved in order for them to be used as the superimposition reference. Our study utilized an upgraded version of the HITS machine with design modifications to improve the energy efficiency for increasing the speed of heating the metal teeth.

Duet lingual brackets (Dentos), which have two main slots: one occlusal and one lingual, were used in this study (Figure 1C). Bracket positioning was determined using the Lingual Plain Wire Mushroom Bracket Positioner (Dentos).[11] Pattern Resin (GC Corporation, Tokyo, Japan) was used to manufacture an individual tray for each bracket on a setup model.[12] A silicone impression (Vertex™ Castasil 21; Vertex Dental, Zeist, The Netherlands) was obtained to guarantee the reproducibility of the procedure, thereby enabling every initial typodont to be identical.

Forty samples were equally divided into four groups according to the length of the lever arm and the retraction technique. Groups 1 and 2 used a single wire with 3-mm and 6-mm hook lengths, respectively. Groups 3 and 4 used double wires with 3-mm and 6-mm hook lengths, respectively. For the single-wire technique, a 0.016 × 0.022-inch (in) stainless steel archwire (U2 size; Dentos) was engaged in all lingual slots. For the double-wire technique, an additional segmented 0.018 × 0.018-in stainless steel archwire was engaged into the occlusal slot of the six anterior teeth brackets (Figure 2). Four-millimeter *en masse* retraction, which was controlled by a resin stop, was performed through the force vector from the microimplant position between the first and second molars to two different vertical levels of the anterior retraction hooks by using an 8-mm-long NiTi coil spring (Dentos), thereby applying a force of 150 g per side.[13]

During space closure, the temperature of the six maxillary anterior aluminum teeth was maintained at approximately 51–53°C. Approximately 15 minutes was required to reach the target temperature and another 10 minutes to complete space closure. The entire procedure was repeated 10 times for each group.

Measurement

After applying an anti-reflection coating (DMAX, Daegu, Korea), the typodont was scanned using a 3Shape R1000 scanner (3Shape A/S, Copenhagen, Denmark) and stored as standard tessellation language files. The files were imported into Blender (Blender Foundation, Amsterdam, The Netherlands), an open-source 3-dimensional computer graphics software, for analysis.

The scanned images of each typodont before (T1) and after retraction (T2) were superimposed using posterior segments, which maintained their position during space closure. At T1, the plane that passed through the central incisors' edges and the right and left lingual cusp tips of the first molar was defined as the original occlusal plane. Images on the superimposition and data for inclination and vertical position changes were analyzed (Figure 3). The former was defined as the difference between T1 and T2 inclination angle formed by the long axis of the tooth and the original occlusal plane, and the latter was the perpendicular distance of the tips of the teeth between T1 and T2, referenced to the original occlusal plane.

Statistical analysis

The Kruskal–Wallis test and Dunn's *post-hoc* test were used for comparisons among the four groups. The Mann–Whitney *U* test was used to evaluate the effect of

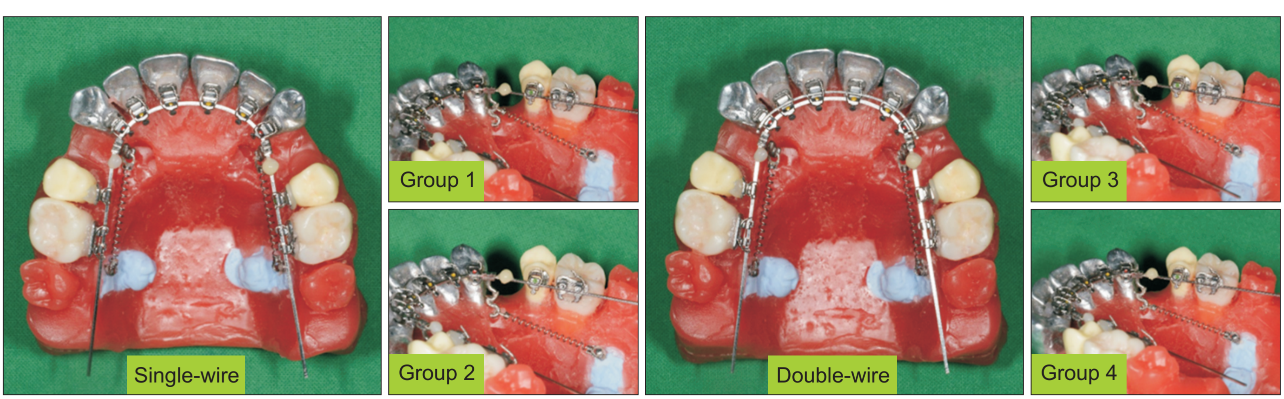

Figure 2. Illustrations of the four groups used in this study. In the double wire groups, an auxiliary wire is placed only in the six anterior brackets.
Group 1, Single wire with a 3-mm hook; Group 2, single wire with a 6-mm hook; Group 3, double wire with a 3-mm hook; Group 4, double wire with a 6-mm hook.

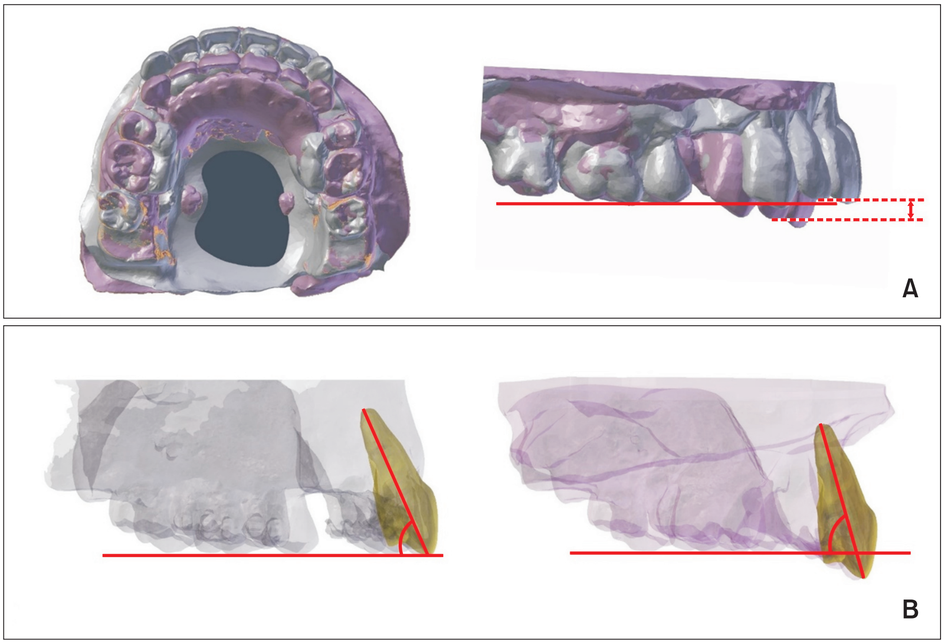

Figure 3. A, Measurement of vertical position changes by the perpendicular distance of the tip of the teeth between T1 and T2, referenced to the original occlusal plane. **B**, Measurement of inclination changes by the difference between T1 and T2 inclination angle formed by the long axis of the tooth and the original occlusal plane.
T1, Before incisor retraction (gray); T2, after 4-mm space closure (purple).

Table 1. Comparison of labiolingual inclination and the vertical position at T1 within each tooth type

T1	Group 1 (n = 10)	Group 2 (n = 10)	Group 3 (n = 10)	Group 4 (n = 10)	Total (n = 40)	Kruskal-Wallis (*p*-value)
Labiolingual inclination (°)						
Central incisor	56.27 ± 0.17	56.18 ± 0.25	56.08 ± 0.26	56.20 ± 0.18	56.18 ± 0.22	0.369
Lateral incisor	56.46 ± 0.43	56.30 ± 0.43	56.46 ± 0.35	56.42 ± 0.39	56.41 ± 0.39	0.686
Canine	59.11 ± 0.24	59.14 ± 0.26	59.16 ± 0.18	59.18 ± 0.25	59.15 ± 0.23	0.959
Vertical position (mm)						
Central incisor	−0.47 ± 0.08	−0.48 ± 0.09	−0.52 ± 0.11	−0.53 ± 0.11	−0.50 ± 0.10	0.536
Lateral incisor	−1.48 ± 0.09	−1.51 ± 0.07	−1.48 ± 0.09	−1.51 ± 0.09	−1.50 ± 0.08	0.648
Canine	−0.16 ± 0.11	−0.21 ± 0.15	−0.21 ± 0.13	−0.17 ± 0.11	−0.19 ± 0.12	0.418

Values are presented as mean ± standard deviation. The Kruskal-Wallis test was used for statistical analysis. A negative value of the vertical position indicates that the tooth is located superior to the original occlusal plane.
T1, Before incisor retraction; Group 1, single wire with a 3-mm short retraction hook; Group 2, single wire with a 6-mm long retraction hook; Group 3, double wire with a 3-mm short hook; and Group 4, double wire with a 6-mm long hook.

the retraction wire and the lengths of the lever arms. All statistical analyses were conducted using IBM SPSS Statistics for Windows, ver. 20.0 (IBM Corp., Armonk, NY, USA), and the level of significance for all the tests was set at $p < 0.05$. For reliability tests, 10 samples were extracted randomly, and the same investigator remeasured the values after a 2-week interval. No statistically significant differences were observed in intraexaminer error, as determined by the paired *t*-tests ($p > 0.05$). Dahlberg's formula was used to test for random errors; the average error level was 0.02 mm (error range, 0.01–0.03 mm) in linear measurements, and the average error level was 0.04° (error range, 0.02–0.06°) in angular measurements.

RESULTS

No significant difference was observed between the four groups in crown inclination and vertical position at T1 ($p > 0.05$) as shown in Table 1.

After 4-mm retraction, in the 40 samples, the mean value of inclination changes was 18.16 ± 1.46° for the central incisors, 14.92 ± 1.59° for the lateral incisors, and 9.82 ± 0.78° for the canines. The corresponding mean vertical position changes were 3.40 ± 0.45 mm, 2.39 ± 0.39 mm, and 1.35 ± 0.14 mm, respectively.

The analyses of the effect of the retraction wire and the lengths of the lever arms are shown in Table 2. The effect of hook length on inclination was significant in

 https://doi.org/10.4041/kjod.2020.50.1.26

Table 2. Effect of retraction wire and hook length

ΔT1–T2	Short-hook groups (n = 20)	Long-hook groups (n = 20)	*p*-value	Single-wire groups (n = 20)	Double-wire groups (n = 20)	*p*-value
Labiolingual inclination (°)						
Central incisor	19.10 ± 1.02	17.23 ± 1.23	< 0.001***	18.78 ± 1.22	17.55 ± 1.45	0.009**
Lateral incisor	15.64 ± 1.24	14.19 ± 1.60	0.005**	16.03 ± 1.09	13.81 ± 1.20	< 0.001***
Canine	10.36 ± 0.48	9.27 ± 0.63	< 0.001***	9.80 ± 0.80	9.83 ± 0.78	0.871
Vertical position (mm)						
Central incisor	3.69 ± 0.30	3.11 ± 0.39	< 0.001***	3.47 ± 0.48	3.33 ± 0.42	0.387
Lateral incisor	2.63 ± 0.34	2.14 ± 0.28	< 0.001***	2.55 ± 0.41	2.22 ± 0.31	0.007**
Canine	1.40 ± 0.14	1.31 ± 0.13	0.051	1.37 ± 0.16	1.34 ± 0.12	0.685

Values are presented as mean ± standard deviation.
T1, Before incisor retraction; T2, after 4-mm space closure.
The Mann–Whitney *U* test was used for statistical analysis (**$p < 0.01$; ***$p < 0.001$).

Table 3. Multiple comparisons of inclination and vertical position changes among the four groups

ΔT1–T2	Group 1 (n = 10)	Group 2 (n = 10)	Group 3 (n = 10)	Group 4 (n = 10)	Total (n = 40)	Kruskal–Wallis (*p*-value)	Multiple comparision
Labiolingual inclination (°)							
Central incisor	19.69 ± 0.54	17.87 ± 1.01	18.51 ± 1.07	16.59 ± 1.11	18.16 ± 1.46	< 0.001***	1-2, 1-4, 3-4
Lateral incisor	16.64 ± 0.65	15.42 ± 1.12	14.65 ± 0.81	12.97 ± 0.89	14.92 ± 1.59	< 0.001***	1-3, 1-4, 2-4
Canine	10.42 ± 0.41	9.18 ± 0.59	10.30 ± 0.56	9.36 ± 0.70	9.82 ± 0.78	< 0.001***	1-4, 3-4, 1-2, 2-3
Vertical position (mm)							
Central incisor	3.80 ± 0.22	3.14 ± 0.45	3.58 ± 0.35	3.08 ± 0.32	3.40 ± 0.45	< 0.001***	1-2, 1-4
Lateral incisor	2.83 ± 0.30	2.26 ± 0.29	2.42 ± 0.23	2.02 ± 0.23	2.39 ± 0.39	< 0.001***	1-2, 1-4
Canine	1.44 ± 0.13	1.29 ± 0.16	1.37 ± 0.14	1.32 ± 0.10	1.35 ± 0.14	0.126	-

Values are presented as mean ± standard deviation. Positive value of the vertical position indicates that the tooth is extruded passing the original occlusal plane and *vice versa*.
T1, Before incisor retraction; T2, after 4-mm space closure; Group 1, single wire with a 3-mm short retraction hook; Group 2, single wire with a 6-mm long retraction hook; Group 3, double wire with a 3-mm short hook; and Group 4, double wire with a 6-mm long hook.
The Kruskal–Wallis test and Dunn's *post hoc* test were used for statistical analysis (***$p < 0.001$).

all tooth types ($p < 0.01$). However, between the single-wire and double-wire groups, significant differences were observed in the inclination of the central and lateral incisors ($p < 0.01$), but no significant difference was observed in the inclination of the canines. Hook length had a significant effect on vertical position changes of the central and lateral incisors ($p < 0.001$). However, between the single-wire and double-wire groups, vertical position change was significantly different in only the lateral incisors ($p < 0.01$), and no significant difference was observed in the central incisors and canines.

Multiple comparisons among groups (Table 3) revealed that Group 1 had the highest value, while Group 4 had the least amount of decrease in crown inclination and vertical position changes. Between Groups 2 and 3, no significant difference was observed in inclination changes of the central and lateral incisors. However, Group 2 showed significantly less inclination changes in the canines.

DISCUSSION

This study compared the inclination and vertical changes in anterior teeth after 4-mm *en masse* retraction between the single-wire and double-wire techniques with different hook lengths.

Compared to the single-wire technique, the double-wire technique provided better anterior torque control in the central and lateral incisors and less extrusion in the lateral incisors. This result suggested that during *en masse* retraction, using the double-wire technique is helpful in preventing side effects in the anterior teeth.

In edgewise appliances, torque is controlled by a couple force moment, which could be generated when a rectangular wire engages into a rectangular bracket.[14] Interbracket spans were shorter on the lingual side than on the labial side, and this resulted in increased difficulty in developing adequate force moment for rotation and torque control.[7,15] In the two-slot bracket system, two couple force moments may be generated in both the lingual and occlusal slots to provide better control of tooth movement. However, our result suggested that the double-wire technique could not guarantee full control of tooth movement. A more cautious approach should be adopted in clinical situations, wherein the inclination of the canines or extrusion of the central incisors are important factors.

Two different hook lengths were used in this study: 3 mm and 6 mm. According to a previous study,[16] both the 3-mm and 6-mm hook lengths provide a force vector under the central resistance of the six anterior teeth. With that kind of directional force, torque loss and extrusion should be higher in the short-hook group than in the long-hook group. Among the four groups, Groups 2 and 3 had different hook lengths but showed similar effects of torque control on the incisors. Our result suggested that instead of extending the hook length, using double wires with short hook lengths may yield a similar pattern of tooth displacement. Kim et al.,[17] in a finite element analysis study, found that in order to prevent torque loss during *en masse* retraction using the single-wire technique, the length of the hook should be at least 15–20 mm. With lingual appliances, using a long hook is possible because of the width and depth of the palate, and a case report showed good lingual treatment outcome after *en masse* retraction using a single wire with that hook length.[3] However, lever arms longer than 15 mm are subject to elastic deformation; thus, they may induce anterior transverse bowing and may diminish the translational effects on the incisors.[17] With the double-wire technique, Lim and Hong[1] reported one successful case, wherein the inclination of the incisors was well maintained after space closure using a shorter hook length.

Some previous studies have used a prototype of this HITS for research purposes.[9,10] Our study used an upgraded version of the HITS machine with design modifications to improve energy efficiency. The metal teeth could be heated faster, and hence, less time was required to reach the desired temperature. In previous studies,[8,10] sticky wax was used to manufacture the typodont, and the required temperature for the experiment was considerably high, ranging from approximately 60°C to 65°C. Since most orthodontic appliances are manufactured from metal, they would also be heated during the experiment and their physical characteristics may change. In our study, the melting point of the wax was approximately 51–53°C. In the HITS, the anterior metal teeth should be heated up to 51–53°C to melt the surrounding wax for enabling tooth movement. However, the rest of the experimental apparatus, such as the wax body, brackets, wires, and posterior resin teeth, were not heated up to that temperature. During the experiment, the temperature of the wire was measured as being below 35°C. Our results suggested that conventional typodont wax is an acceptable material to simulate tooth movement in the HITS.

Finite element analysis has been recommended as a useful tool that has been used in many previous orthodontic studies. However, most of these studies were limited to the evaluation of initial tooth movement, and designing a dynamic simulation with a long distance of movement was quite challenging in these studies.[7] Nevertheless, the HITS machine used in this study could simulate a 4-mm retraction.

However, owing to the tapered structure of the model teeth, the amount of metal required to cover the cervical region was higher than that required for the apical area, which increased the difficulty of facilitating lingual root torque rather than crown tipping because of the uneven distribution of heat conducted by the HITS machine to the model teeth. The current version of the HITS cannot mimic the periodontal tissue and attachment apparatus. In the future, new wax materials and further improvements in experimental design may provide better orthodontic movement simulation.

CONCLUSION

This typodont study showed that the double-wire technique with extended lever arms provided advantages over the single-wire technique with the same lever arm length in preventing torque loss and extrusion of the anterior teeth during *en masse* retraction in lingual orthodontics.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Lim SM, Hong RK. The Tandem Archwire technique in lingual orthodontics. J Clin Orthod 2013;47:232-40; quiz 267.
2. Lombardo L, Scuzzo G, Arreghini A, Gorgun O, Ortan YO, Siciliani G. 3D FEM comparison of lingual and labial orthodontics in en masse retraction. Prog Orthod 2014;15:38.

3. Hong RK, Heo JM, Ha YK. Lever-arm and mini-implant system for anterior torque control during retraction in lingual orthodontic treatment. Angle Orthod 2005;75:129-41.
4. Hong RK, Sohn HW. Update on the Fujita lingual bracket. J Clin Orthod 1999;33:136-42.
5. Beckwith FR, Ackerman RJ Jr, Cobb CM, Tira DE. An evaluation of factors affecting duration of orthodontic treatment. Am J Orthod Dentofacial Orthop 1999;115:439-47.
6. Meikle MC. Guest editorial: what do prospective randomized clinical trials tell us about the treatment of class II malocclusions? A personal viewpoint. Eur J Orthod 2005;27:105-14.
7. Liang W, Rong Q, Lin J, Xu B. Torque control of the maxillary incisors in lingual and labial orthodontics: a 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2009;135:316-22.
8. Rhee JN, Chun YS, Row J. A comparison between friction and frictionless mechanics with a new typodont simulation system. Am J Orthod Dentofacial Orthop 2001;119:292-9.
9. Kyung HM, Kim JY, Kyung IK. Heat Induction Typodont System® (HITS) for simulating orthodontic tooth movement. Clin J Korean Assoc Orthod 2013;3:177-9.
10. Kim JY, Yu WJ, Koteswaracc PNK, Kyung HM. Effects of bracket slot size during en-masse retraction of the six maxillary anterior teeth using an induction-heating typodont simulation system. Korean J Orthod 2017;47:158-66.
11. Kyung HM, Park HS, Bae SM, Sung JH, Kim IB. The lingual plain-wire system with micro-implant anchorage. J Clin Orthod 2004;38:388-95.
12. Kim T, Bae G, Cho J. New indirect bonding method for lingual orthodontics. J Clin Orthod 2000;34:348-50.
13. Lee JS, Park H, Kyung HM. Micro-implant anchorage for lingual treatment of a skeletal class II malocclusion. J Clin Orthod 2001;35:643-7.
14. Isaacson RJ, Lindauer SJ, Rubenstein LK. Moments with the edgewise appliance: incisor torque control. Am J Orthod Dentofacial Orthop 1993;103:428-38.
15. Sifakakis I, Pandis N, Makou M, Eliades T, Katsaros C, Bourauel C. A comparative assessment of torque generated by lingual and conventional brackets. Eur J Orthod 2013;35:375-80.
16. Jang HJ, Roh WJ, Joo BH, Park KH, Kim SJ, Park YG. Locating the center of resistance of maxillary anterior teeth retracted by Double J Retractor with palatal miniscrews. Angle Orthod 2010;80:1023-8.
17. Kim KH, Lee KJ, Cha JY, Park YC. Finite element analysis of effectiveness of lever arm in lingual sliding mechanics. Korean J Orthod 2011;41:324-36.

 https://doi.org/10.4041/kjod.2020.50.1.26