Original Article

Bidimensional techniques for stronger anterior torque control in extraction cases

A combined clinical and typodont study

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ABSTRACT

Objective: To investigate the capacity of bidimensional techniques for torque control of anterior teeth in extraction cases.

Materials and Methods: Two different bidimensional techniques were distinguished by nomenclature as bidimensional-slot (bDS) and bidimensional-wire (bDW), respectively. (1) In the clinical study, patients were randomly assigned to three groups (ie, bDS [n = 27], bDW [n = 24], and control [n = 25] groups). The major inclusion criterion was mild crowding in the upper arch, with the two upper first premolars (teeth 14 and 24) to be extracted. After space closure through standardized treatment, the torque of the upper central incisors (∠TQ _U1) was calculated using the angle formed by the base of the U1 bracket and the working archwire on cephalograms. (2) In the typodont study, a standardized setup of the upper dentition with teeth 14 and 24 extracted was established. The spaces were closed through water bath followed by elastics, using the bDW or the conventional (control) technique, respectively. In six replicate experiments, after space closure, the ∠TQ _U1 was measured on the standardized lateral photographs.

Results: (1) In the clinical study, after space closure, the ∠TQ_U1 was $9.4^\circ \pm 3.4^\circ$ (bDS), $8.3^\circ \pm 3.3^\circ$ (bDW), and $5.8^\circ \pm 2.9^\circ$ (control), respectively. The ∠TQ_U1 of bDS and bDW were both significantly ($P < .05$) larger than that of the control, but no statistical difference was found between them. (2) In the typodont study, after space closure, the ∠TQ_U1 of bDW ($8.5^\circ \pm 0.9^\circ$) was significantly ($P < .01$) larger than that of the control ($4.9^\circ \pm 1.0^\circ$).

Conclusion: The bDS and the bDW techniques may help enhance anterior torque control in extraction cases. (*Angle Orthod.* 2012;82:715–722.)

KEY WORDS: Torque control; Bidimensional; Slot size; Archwire size; Extraction

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INTRODUCTION

In orthodontic treatment, torque control is often required, particularly in the maxillary incisors, for an ideal interincisal angle, adequate incisor contact, and sagittal adjustment of the dentition in order to achieve an ideal occlusion.[1] Great efforts have been made to investigate torque expression in both conventional[2–5] and self-ligating[2,3,6,7] brackets, using the finite element method,[3,5] optical image correlation technique,[4] or some special apparatuses.[2,6,7] In the clinic, in addition to individual twisting of rectangular wire, numerous torturing auxiliaries,[8] such as Art spring and Warren spring, have been engaged for torque control. Nevertheless, most of these approaches involve additional wire bending or may cause discomfort to the patients, with unguaranteed effects.

The idea of a "bidimensional" approach was first put forward in the so-called "bimetric system,"[9] in which, 0.016-inch brackets are used on the anterior teeth (canine to canine), while 0.022-inch brackets are used on the posterior teeth. A 0.016 × 0.022-inch stainless steel (SS) archwire is engaged with a 90° twist made distal to the canines so as to "full-sizedly" fill the anterior section as "edgewise," while the buccal sections are filled as "ribbon." After that, a "bidimensional edgewise technique"[10] was proposed, in which non-preadjusted 0.022 × 0.028-inch brackets are used for all the teeth, and a 0.016 × 0.022-inch archwire is used with a 90° twist immediately distal to the lateral incisors, so as to form a 0.022 × 0.016-inch ribbon segment that fills the anterior brackets and two 0.016 × 0.022-inch edgewise segments that fit into the buccal brackets, with a clearance of 0.006 inch. This is actually a "bidimensional-wire" technique, in contrast to the currently labeled "bidimensional" approach,[11–13] which is in fact a "bidimensional-slot" technique. In the bidimensional-slot technique, the pretorqued 0.018-inch brackets are placed on the incisors, while the 0.022-inch brackets are placed on other teeth. When a 0.018 × 0.022-inch SS archwire is engaged, it "full-sizedly" fits into the anterior brackets, but leaves a clearance of 0.004 inch within the buccal brackets. In current orthodontics, clinical application of the bidimensional-slot technique has occasionally been reported,[14,15] but rarely has the bidimensional-wire technique been discussed.

The theories of the bidimensional approach—that the full-size engagement at the anterior segment can give the utmost play to the pretorque in these brackets, while the clearance at the buccal segments can facilitate the wire sliding in space closure—probably make sense.[16] However, the statements in favor of the bidimensional approach have almost all been empirical, and no substantial evidence supporting this approach is available to date, which is probably the major reason for its limited application. Therefore, this study was designed to investigate the capacity of the bidimensional approach for anterior torque control through a controlled clinical trial combined with typodont experiments.

MATERIALS AND METHODS

In this study, the two different bidimensional techniques were explicitly distinguished using nomenclature as the bidimensional-slot (bDS) and bidimensional-wire (bDW) techniques, respectively.

The Clinical Study

In the clinical study, three groups were assigned, including two experimental groups (bDS and bDW) and the control group (Figure 1).

Seventy-nine participants were enrolled at the beginning of the study; these participants were randomly (by drawing lots) assigned to the three groups as follows: 29 participants to bDS, 24 participants to bDW, and 26 participants to the control. Ethical approval for the study was sought from the bioethics committee of the university. The patients and their parents (as appropriate) were invited to take part in the study, and only those willing to provide written informed consent were accepted into the study.

The inclusion criteria for patient entry into the study were as follows: (1) no ongoing dental or periodontal problems; (2) no severe skeletal discrepancy (ie, no orthognathic surgery was required); and (3) the crowding in the upper arch was less than 2 mm on each side, while the two upper first premolars (teeth 14 and 24, each with an average size of 7 mm) were to be extracted, thereby leaving at least 5 mm of space on each side. As for the lower arch, either extraction (to be finished with Class I molar relationship) or nonextraction (to be finished with Class II molar relationship) was appropriate. The majority of the participants had either mild-to-median Class I bimaxillary protrusion or mild-to-median Class II division 1 relationship. MBT metal brackets (3M Company, St Paul, MN, USA) were used for all of the participants.

The treatment procedure was the same for the three groups, and involved, in brief, alignment, leveling, and space closure by sliding mechanism. All of the lower arches were treated with 0.022 × 0.028-inch brackets and 0.018 × 0.025-inch SS (ClassOne Orthodontics Carlsbad, CA, USA) as the working archwire. The three groups differed from each other in terms of the upper arch, as shown in Figure 1. The process of archwire formation in bDW is shown in Figure 2.

All of the treatment was rendered by doctoral postgraduates under instruction from the same supervisor. The operators had no idea about the specific aim or design of this study. In the phase of space closure, exaggerated curve of Spee (2–3 mm in depth) was used on the upper working archwire when appropriate, and interarch elastics or additional anchorage (such as headgear) was used if needed, while no additional twist of the archwire (except for the 90° twist in bDW) or any torquing auxiliaries were used. Lateral cephalograms were taken at the beginning of the treatment (C0) and when the upper spaces were completely closed (C1). The angle formed by the upper central incisors (U1) and the SN plane was measured on C0, referred to as $\angle$U1-SN (0).

Of note, the anterior torque control was evaluated using a novel indicator, "torque of U1." On the cephalogram (C1), the angle formed by the base of the U1 bracket and the working archwire was measured, and this angle was referred to as $\angle\alpha$ (Figure 3), and the "torque of U1" ($\angle$TQ _U1) was calculated as "$\angle TQ\_U1 = \angle\alpha - 90°$." The efficacy of torque control was defined as the ratio of $\angle$TQ _U1 to

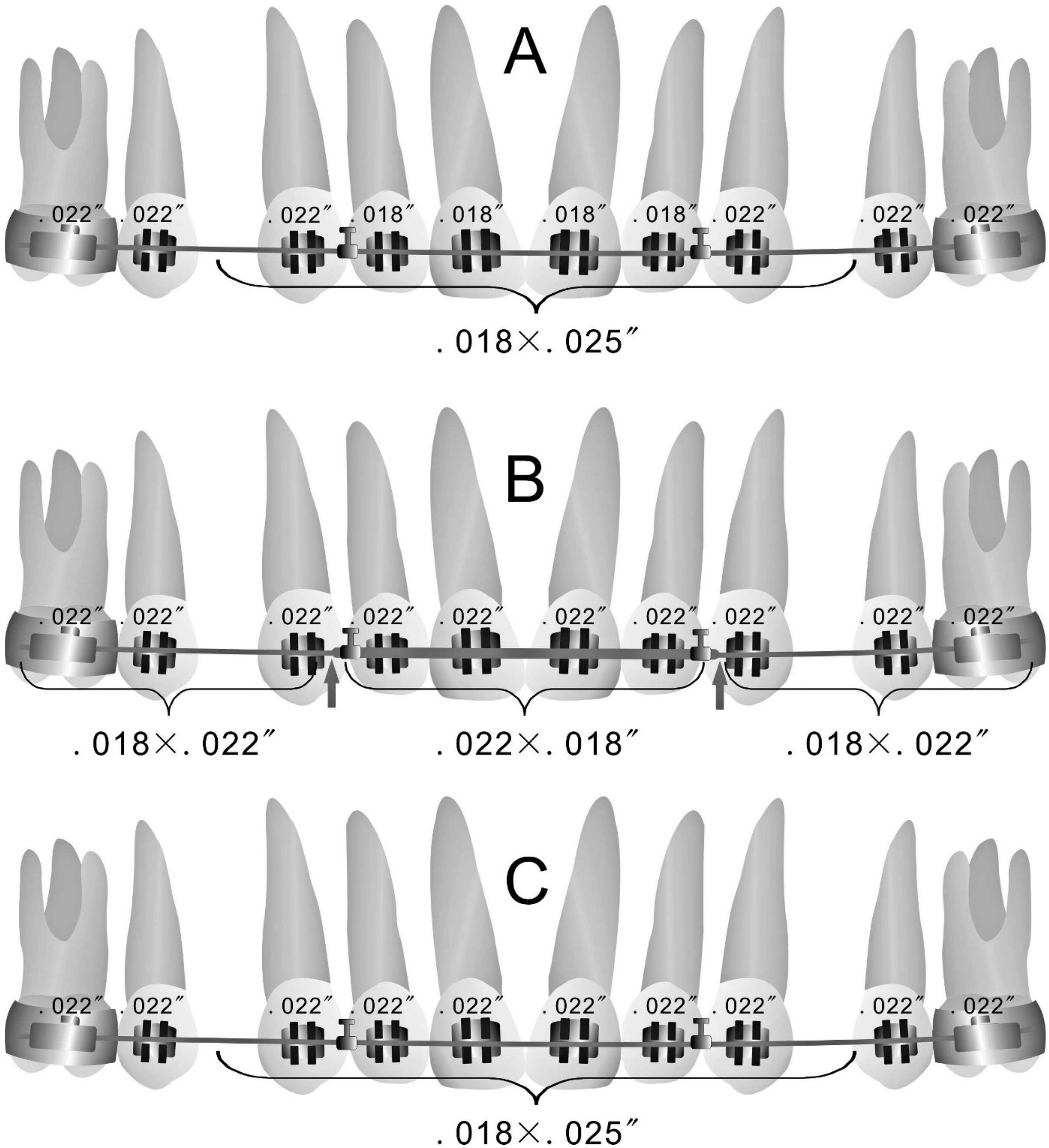

Figure 1. The three groups. (A) Bidimensional-slot (bDS): 0.018 × 0.025-inch brackets were used for the upper incisors, while 0.022 × 0.028-inch brackets were used for the other teeth; 0.018 × 0.025-inch stainless steel (SS) wire was used as the working archwire. (B) Bidimensional-wire (bDW): 0.022 × 0.028-inch brackets were used for all of the teeth; 0.022 × 0.018-inch SS, with a 90° twist mesial to the canine at the arrow, was used as the working archwire. (C) The control: 0.022 × 0.028-inch brackets were used for all of the teeth; 0.018 × 0.025-inch SS was used as the working archwire.

the pretorque of the MBT bracket for U1 (17°[17]). The reason for using the bracket base rather than the facial axis of clinical crown (FACC) for torque evaluation will be explained in the Discussion section. Three replicate measurements were done by the same operator using a cephalometric program Winceph 7.0 (Rise Corp., Miyaginoku, Japan); this investigator was unaware of the experimental design.

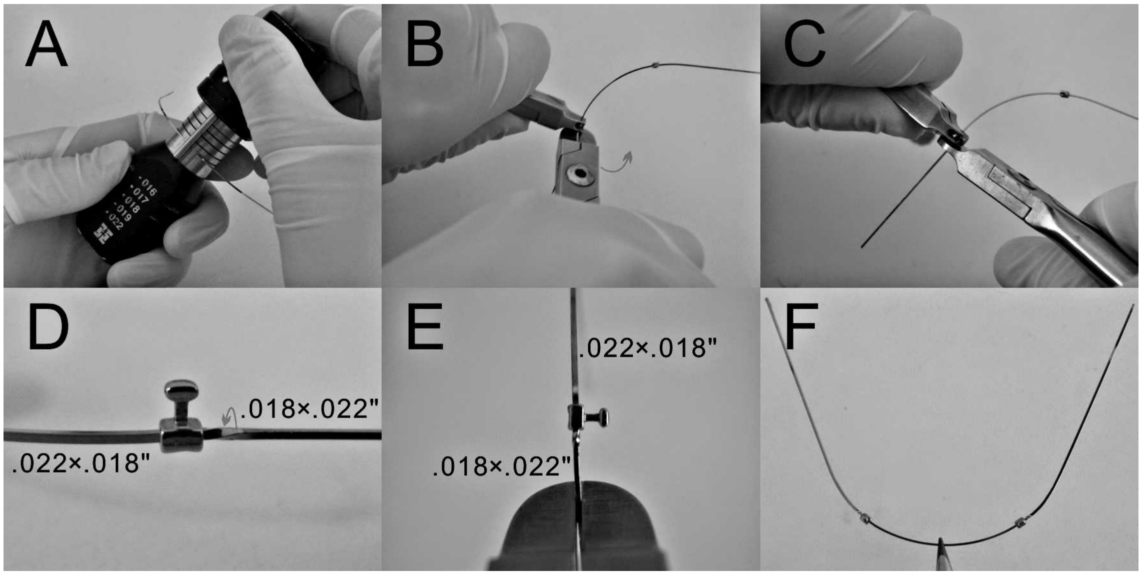

Figure 2. The forming of the bidimensional working archwire in bDW. (A) The anterior arc was formed in the 0.022-inch slot of a turret. (B, C) Hooks were crimped immediately distal to the lateral incisors; a 90° gingival-lingual twist of the archwire was made immediately distal to the hooks using a crimping plier and a torque bending plier. (D) The 0.022 × 0.018-inch anterior segment and the 0.018 × 0.022-inch buccal segments were formed. (E) Ensure that no unwanted torque was formed at the buccal segments. (F) The bidimensional working archwire was done.

The Typodont Study

To exclude the confounding factors in the clinical study, a typodont (Nissin, Kyoto, Japan) study was launched. The upper teeth (teeth 16 to 26) were seated in the wax, with teeth 14 and 24 "extracted," leaving a space of 5 mm on each side. The teeth were bonded with 0.022 × 0.028-inch MBT metal brackets (3M) at the standard height and were then aligned using 0.014-inch NiTi, 0.017 × 0.025-inch NiTi, and 0.0215 × 0.025-inch NiTi in sequence, with a water bath at 45°C for 30 minutes in each stage. When the dentition was completely aligned and leveled (Figure 4A), a vinyl polysiloxane impression (3M) (Figure 4B) was made to record the initial form of the dentition, which was then used for repositioning the teeth at the beginning of each repeated experiment (ie, to "reset" the dentition to a standardized status).

The spaces were closed using a sliding mechanism with the bDW and the conventional (control) techniques, respectively, and the experiments were done in six replications. To close the spaces, the typodont was placed in a water bath at 45°C for 10 minutes to soften the wax, and then out of the water the anterior teeth were retracted by pulling two elastics in the direction along the hook on the molar (Figure 4C). Each time the anterior teeth were retracted for about 1 mm, and after five cycles the spaces were completely closed (Figure 4D). Standardized lateral photographs were taken from the right and the left side of the dentition, before and after space closure, respectively (Figure 4E–H). Briefly, the focus of the camera was on the U1 bracket, and the shooting direction was perpendicular to the sagittal plane of the dentition. ∠TQ _U1 was measured on the photographs by one operator who was unaware of the experimental design. Three measurements were done for each value, and the mean value of the left and the right measurements was calculated.

Statistical Analysis

Intraclass correlation (ICC) coefficient (two-way mixed mode and average measure) was calculated to evaluate the reproducibility of the measurement of ∠TQ _U1. In the clinical study, one-sample *t*-test was used to compare the ∠U1-SN (0) in each group with the normal value of 105°,[18] and one-way analysis of variance was used to compare the ∠U1-SN (0) and ∠TQ _U1 among the three groups; this was followed by intergroup comparison using the Student-Newman-Keuls method. In the typodont study, an unpaired *t*-test was used to compare ∠TQ _U1 between the bDW and the control. The statistical analysis was done using SPSS 11.0 for Windows (SPSS, Chicago, IL, USA).

RESULTS

The Clinical Study

Three cases were excluded as a result of poor superposition (the gap over the width of a bracket)

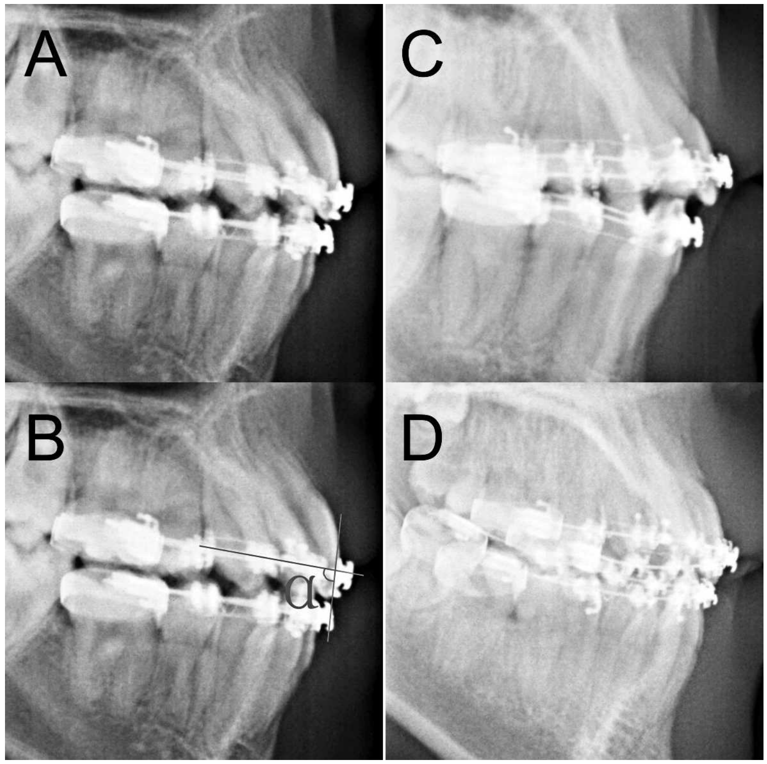

Figure 3. The measurement for torque of U1 (∠TQ _U1) on cephalograms after space closure. (A, B) Measurement of ∠α, which is formed by the base of the U1 bracket and the working archwire. The torque of U1 (∠TQ _U1) was calculated as "∠TQ _U1 = ∠α − 90°." (C) The two sides of the working archwire were not perfectly superimposed (ie, with a small gap, an auxiliary midline was drawn between them for measurement). (D) The two sides of the working archwire were poorly superimposed (ie, with a gap bigger than a bracket, the cephalogram was excluded).

between the two sides of the working archwire on C1 (Figure 3D), leaving 27 (7 male, 20 female, 15.6 ± 5.9 years of age) in bDS, 24 (6 male, 18 female, 16.2 ± 5.2 years of age) in bDW, and 25 (8 male, 17 female, 15.4 ± 6.3 years of age) in the control for analysis.

The ∠U1-SN (0) measured 112.4° ± 6.3° (bDS), 111.7° ± 6.6° (bDW), and 112.5° ± 6.1° (control), respectively; all values were significantly ($P < .01$) larger than the normal value. No significant difference was found among the three groups, indicating an equal baseline (Figure 5A).

ICC for measurement of ∠TQ_U1 was 0.97 (95% confidence interval [CI]: 0.93–0.99), indicating an excellent reproducibility (ICC > 0.75[19]). The

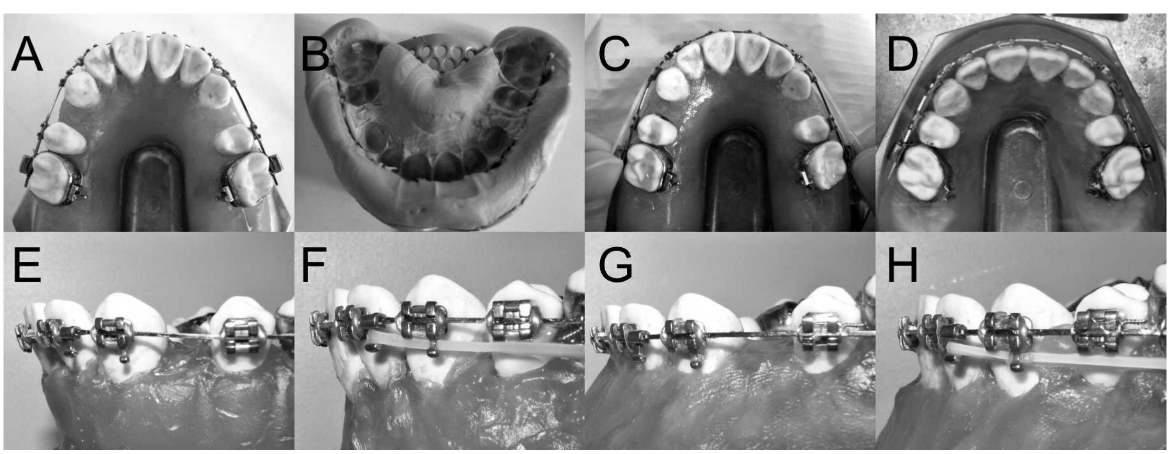

Figure 4. The typodont experiments. (A) The upper dentition with teeth 14 and 24 extracted was aligned and leveled. (B) The initial setup of the typodont was recorded using a vinyl polysiloxane impression, which helped reset the typodont before each repeated experiment. (C) The anterior teeth were retracted by pulling two elastics. (D) The spaces were closed. (E, F) In the bDW, the ∠TQ_U1 before (E) and after (F) space closure. (G, H) In the control, the ∠TQ_U1 before (G) and after (H) space closure.

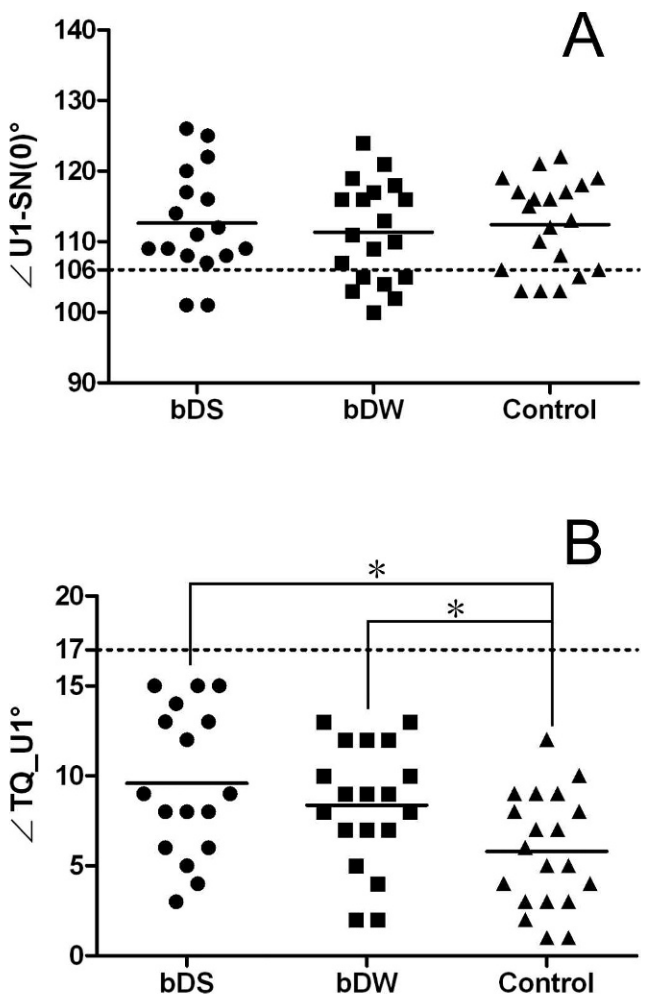

Figure 5. In the clinical study, (A) before treatment, the ∠U1-SN (0) values of the three groups were all significantly ($P < .01$) larger than the normal value. No significant difference was found between them. (B) After space closure, the ∠TQ_U1 was significantly ($P < .01$) different among the three groups. The ∠TQ_U1 values of bDS and bDW were both significantly larger than that of the control. However, no significant difference was found between bDS and bDW. Each point represents the mean value of three repeated measurements on the same cephalogram. n = 27 (bDS), n = 24 (bDW), and n = 25 (control); * $P < .05$.

∠TQ_U1 was 9.4° ± 3.4° (bDS), 8.3° ± 3.3° (bDW), and 5.8° ± 2.9° (control), respectively. The efficacy of torque control was 55% (bDS), 49% (bDW), and 34% (control), respectively. The ∠TQ_U1 was significantly ($P < .01$) different among the three groups. The ∠TQ_U1 values of bDS and bDW were both significantly ($P < .05$) larger than that of the control, but there was no significant difference between bDS and bDW (Figure 5B; Table 1).

The Typodont Study

ICC for measurement of ∠TQ_U1 was 0.95 (95% CI: 0.77–0.99), indicating an excellent reproducibility (ICC > 0.75[19]). Before space closure, there was no statistical difference between the ∠TQ_U1 of bDW

Table 1. In the Clinical Study, Student-Newman-Keuls (SNK) Following One-Way Analysis of Variance (ANOVA) Analyses for Intergroup Comparison of the ∠TQ _U1 Demonstrates that Subset 1 (the Control) Was Differentiated from Subset 2 (the Bidimensional-Slot [bDS] and the Bidimensional-Wire [bDW] Groups)

		Subset for $\alpha = .05$	
ANOVA	N	1	2
Control	25	5.8	—
bDS	27	—	9.4
bDW	24	—	8.3
Significance	—	1.0	0.2

(14.5° ± 0.9°) and that of the control (14.5° ± 0.6°), indicating an equal baseline (Figure 6A). After space closure, the ∠TQ_U1 of bDW (8.5° ± 0.9°) was significantly larger than that of the control (4.9° ± 1.0°) (Figure 6B). The efficacy of torque control was 50% (bDW) and 29% (control), respectively.

DISCUSSION

In current orthodontics, 0.022-inch preadjusted brackets have been commonly used. Labiolingual inclination or torque is now largely provided with accuracy by the pretorque in the brackets.[20] As a result of the rigidity of the wire, which fully matches with the 0.022-inch slot, however, most clinicians have to use undersized (0.019 × 0.025-inch or even smaller) SS as a working archwire.[21] This inevitably leads to lack of cohesive contact between the bracket and the archwire, known as torsional play or the engagement angle,[7,22] which can even be deteriorated by the fact that wires are most of the time undersized[23] while bracket slots are oversized.[24] In a 0.022-inch slot, the engagement angle for a 0.018 × 0.025-inch SS could be as high as 18°,[1] leaving the 17° pretorque for U1 in the MBT system[17] practically useless. On the other hand, a change of the archwire size from 0.018 × 0.025 inches to 0.019 × 0.025 inches will increase the torque moment by 125%,[3] and if a 0.021 × 0.025-inch SS is used in a 0.022-inch slot, the engagement angle might be only about 6°.[1] From this point of view, the bidimensional approach might be an advisable solution to the ineffective expression of pretorque due to the unmatched size of archwire and slot.

In the previous studies, the torque of U1 is usually evaluated using the angle formed by FACC and the occlusal plane. However, this evaluation can be affected by variables such as the facial contour of an individual tooth or the height of bracket placement.[25] In this study, we have deliberately used the angle formed by the bracket base and the working archwire for torque evaluation, which directly reflects the interaction between the wire and the slot, excluding other variables. When the pretorque in the MBT U1 bracket

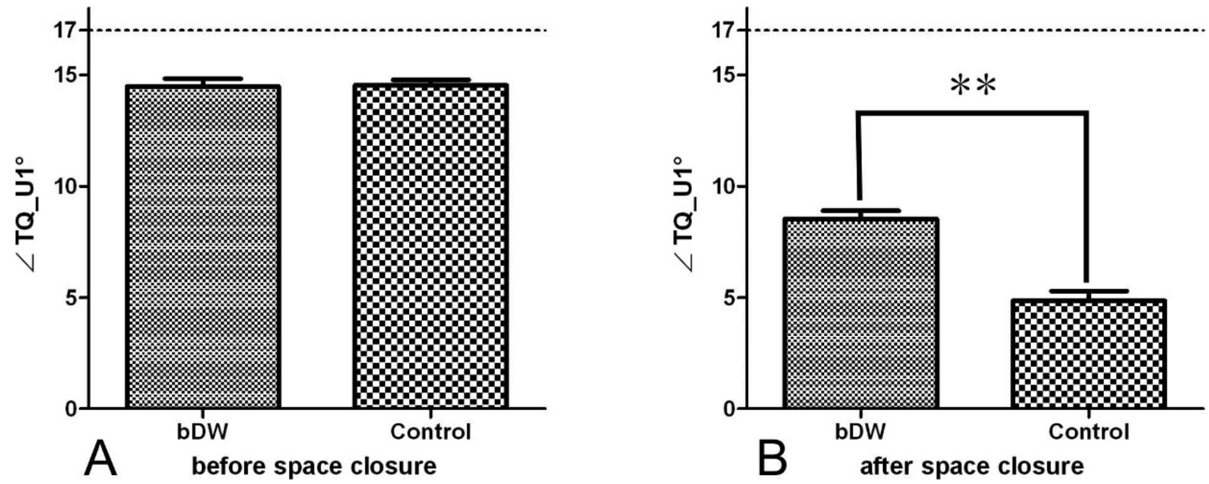

Figure 6. In the typodont study (A) before space closure, there was no statistical difference between the ∠TQ_U1 of bDW and the control. (B) After space closure, the ∠TQ_U1 of bDW was significantly larger than that of the control. The values are expressed as mean ± standard deviation (SD), n = 6; ** $P < .01$.

(17°) is 100% expressed, theoretically the torque measured using this method should be exactly 17°.

Combining the findings in the clinical and the typodont studies, it is strongly suggested that the bidimensional approach is more effective for anterior torque control than is the conventional approach. On the other hand, no significant difference was shown between the bDS and bDW techniques, indicating that they have similar capability for anterior torque control. As the bDW technique doesn't require purchase of additional 0.018-inch brackets and can be employed whenever needed, it might be more economical and more flexible than the bDS technique, and therefore it may deserve preference in the clinic setting. Nevertheless, as suggested by the authors, twisting of the wire should be done very carefully, especially with regard to the fact that the buccal segments must be twisted gingival-lingually rather than in the opposite direction, so that the wire can be mechanically more favorable for resisting the lingual crown torque of the incisors. In addition, it is also suggested that customized bidimensional wires be manufactured in the future.

In summary, the two bidimensional techniques were explicitly distinguished for the first time. They both have shown stronger torque control for U1 than does the conventional approach, either in the clinical or in the typodont study. However, it should be noted that the bidimensional approach just makes full use of the interaction between the rectangular wire and the pretorqued bracket, which is only one of the many factors that contribute to the control of buccolingual inclination of anterior teeth.

CONCLUSIONS

- The bidimensional approach offers stronger torque control for the anterior teeth than does the conventional method in extraction cases treated with preadjusted appliances.
- The bDS technique and the bDW technique offer similar capacity for anterior torque control.

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