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Incisor and profile alterations in extraction cases treated with standard Edgewise and pre-adjusted appliances: A controlled before-and-after study

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ABSTRACT

Background: Even though treatment of Class II malocclusion with premolar extractions and incisor retraction might affect incisor inclination and soft tissue profile, the effects of bracket prescription on this have not been thoroughly assessed.

Methods: Fifty patients (mean age: 13.6 years; 34% male) receiving extraction-based treatment with either standard Edgewise or pre-adjusted appliances were included. Between-group differences in the incisor inclination assessed with lateral cephalograms were analyzed statistically with linear/logistic regression at 5%.

Results: Treatment-induced changes included retroclination of the upper/lower incisors (−3.0° and −2.0°, respectively), retraction of the upper/lower incisors (−3.4 mm and −1.5 mm, respectively), retraction of the upper/lower lip (−2.1 mm and −2.0 mm, respectively), and enlargement of the nasolabial angle (+1.6°). Analysis of the data adjusting for confounders indicated that the pre-adjusted group, after treatment, had larger inclination of the upper or lower incisors (+3.2° and +4.5°, respectively), more prominent upper incisors relative to the facial plane (+1.3 mm), and smaller interincisal angle (−7.3 or −7.7°). Post-treatment upper incisor inclination fell within the cephalometric norm significantly more in the pre-adjusted than in the standard Edgewise group (odds ratio 4.3; 95% confidence interval 1.1–16.6). No differences were found in lower incisor prominence, upper/lower lip prominence, or nasolabial angle.

Conclusions: Pre-adjusted appliances were associated with increased inclination of the upper and lower incisors, with more prominent upper incisors, and with more acute interincisal angle after retraction compared with standard Edgewise appliances. However, such differences did not translate in greater retraction of the upper/lower lips and greater nasolabial angle.

1. Introduction

The effectiveness of orthodontic treatment with fixed appliances in establishing a well-balanced occlusion has been well documented over the past century. In past years, clinical research has focused on objectively measured treatment outcome quality [1] and its association with long-term outcomes. For example, finishing orthodontic treatment to an ideal occlusal standard, as proposed by the American Board of Orthodontists (ABO) [2], seems to be associated with a more balanced activation of anterior tempo-

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ralis muscle and improved patient-reported chewing ability compared with worse finished occlusions [3]. In addition, long-term changes in the occlusion of orthodontically treated patients seem to be more favorable in terms of improved settling and reduced tendency for anterior crowding relapse [4] as the finishing quality of orthodontic treatment increases [5]. Such evidence highlights the importance that well-finished postorthodontic occlusion plays and the care with which orthodontists should strive to achieve optimal results.

Orthodontic treatment of malocclusion with skeletal components, large overjet, or moderate to severe arch length discrepancy often includes extraction of permanent teeth, which are usually the first or second premolars. Extraction-based orthodontic treatment has been shown to be associated with better outcomes and improved long-term stability compared with nonextraction treatment of borderline cases [1,6]. At the same time, extraction of premolars and orthodontic retraction of the anterior teeth might affect the patient's soft tissue profile [7] in a manner dependent on the retraction amount [8] and especially if uncontrolled tipping is used. In such cases, one might need to apply additional torque to the retracted incisors to restore their ideal position within the alveolar bone, improve esthetics, enable proper articulation with the lower teeth, and facilitate adequate soft tissue support. However, torque application on upper incisors might prove to be a lengthy [9] and complicated task from the side of biomechanics of fixed appliances [10,11].

The orthodontic fixed appliance has become an integral part of modern orthodontic treatment since its introduction by E.H. Angle and the development of the pre-adjusted appliance by L. F. Andrews [12]. In the original concept of Andrews, the ideal fixed appliances would provide an advantage during many treatment phases, including postextraction incisor retraction, because the pre-adjusted bracket slot would minimize losses in tooth inclination/torque due to uncontrolled tipping. Various prescriptions for orthodontic appliances have been introduced in the past decades, but existing evidence on their comparative performance still remains limited [13]. A previous comparative study indicated that both standard Edgewise and pre-adjusted appliances were compatible with similar finishing quality according to the ABO tool, even though pre-adjusted appliances were associated with reduced treatment duration [14]. However, no evidence currently exists about the incisor inclination post retraction, which might also contribute to the establishment of a harmonious and stable long-term dentition [15–17].

Therefore, the aim of the present study was to assess the incisor inclination after extraction-based orthodontic treatment with either standard Edgewise or pre-adjusted fixed appliances. The following is the primary research question: "Is there any difference in inclination of the upper incisors after retraction with pre-adjusted appliances compared with standard Edgewise appliances?"

2. Materials and methods

2.1. Protocol, registration, and ethical approval

This controlled before-and-after study (retrospective collection of data from patients treated/measured prospectively) is based on an a priori protocol registered in ISRCTN (ID 13048456) and openly available in Open Science Framework (https://osf.io/e3j5f/). Ethical approval was sought and acquired from University of Zurich (BASEC-Nr.: 2018-00631) and University of Oslo (Regional Committees for Medical and Health Research Ethics; Ref. no.: 2017/1885). This paper is based on the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [18].

2.2. Sample

This controlled before-and-after study includes patients having comprehensive fixed appliance treatment with extraction of at least two upper premolars in two university clinics (Zurich and Oslo). Informed consent was acquired from all patients or their parents before treatment. Included patients in this study complied with the following patient eligibility criteria: (1) any age, sex, ethnicity, race, or Angle's molar classification; (2) full complement of teeth excluding the third molars; (3) no prior orthodontic therapy; (4) no dentofacial deformities and clefts; and (5) complete pre- and post-treatment data. In addition, they fulfilled the following treatment-related inclusion criteria: (1) comprehensive treatment with labial fixed appliances in both arches; (2) bilateral extraction of upper first or second premolars (with/without extraction of lower premolars); (3) retraction during treatment of the upper incisors as seen through superimposition of lateral cephalograms on the nasal line; (4) no temporary anchorage devices; (5) no orthognathic surgery; (6) no dental trauma; and (7) no impacted canines. Patients from the two university clinics were selected randomly from the archives of patients treated by postgraduate orthodontic residents in the past 10 years under the direct supervision of university faculty and presented in the orthodontic specialization boards of each country. Patients from one clinic (University of Zurich) were treated with standard Edgewise appliances (Mini Twin Diamond; Ormco, Orange, CA) and patients from the other clinic (University of Oslo) were treated with pre-adjusted appliances (MBT Victory; 3M Unitek, Monrovia, CA), both systems were conventionally ligated ones and with an 0.018 x 0.028 -inch slot. The university clinic in Oslo uses solely pre-adjusted appliances, whereas the university clinic in Zurich uses standard Edgewise appliances for almost 95% of each postgraduate's cases and only a handful selected cases are treated with pre-adjusted appliances (none included in this study). Treatment mechanics (including torque application) were left to the discretion of the clinical instructors supervising treatment in the two clinics, but space closure mostly included closing loops for the standard Edgewise group and sliding mechanics for the pre-adjusted group, both on slot-filling rectangular wires.

This study is based on patient records (pretreatment age, sex, extraction plan, treatment duration), dental cast measurements (overjet and overbite), and radiographic measurements from lateral cephalograms. Lateral cephalograms were taken in natural head position and analyzed using a modified Bell-Proffit-White analysis. From each patient's documentation or dental casts, the following pretreatment data were extracted: age, sex, overjet, overbite, and the following cephalometric angles: SNA, SNB, ANB, Wits, and SN-ML (for explanation see Supplement 1). In addition, treatment duration and the primary/secondary outcomes were extracted before (T1) and after treatment (T2). Finally, it was noted if four or fewer (two or three) premolars were extracted for orthodontic treatment and what was the malocclusion according to Angle's molar classification.

2.3. Sample size calculation

A priori sample size calculation for the primary outcome of upper incisor inclination was included in the preregistered protocol and was based on a previous study [19] with 1) control mean of 104.06°, 2) standard deviation (SD) of 5.65° assumed common between groups, 3) a clinically meaningful difference in inclination of 5° compared with that of the control mean, 4) use of an independent-samples Student's *t*-test, 5) alpha of 5%, and 6) beta of 20%. With these baseline data and assumptions, a needed sample

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Table 1
Demographics of included patients

Variable	Category	Standard Edgewise	Pre-adjusted	*P*
Sex, n (%)	Female	18 (72)	15 (60)	0.37*
	Male	7 (28)	10 (40)	
Age (y)	Mean (SD)	14.4 (2.5)	12.8 (1.0)	0.004†
Molar relationship, n (%)	Class I	14 (56)	16 (64)	0.29*
	Class II	5 (20)	7 (28)	
	Class III	6 (24)	2 (8)	
Extracted premolars, n (%)	4	23 (92)	18 (72)	0.07*
	2–3	2 (8)	7 (28)	
Treatment duration (mo)	Mean (SD)	27.8 (5.9)	27.0 (4.8)	0.62†

SD, standard deviation.
* χ^2 test.
† *t* test for independent samples.

of 22 patients per group (to a total of 44 patients) was calculated, which was increased to 25 patients per group (total of 50 patients) to allow for adjusted-for-confounding regression analyses.

2.4. Outcomes

The primary outcome of this study was the upper incisor inclination, as measured relative to the nasal line (1s-NL). Secondary outcomes included 1) upper incisor inclination relative to the cranial base (1s-SN), 2) lower incisor inclination relative to the mandibular plane (1i-ML), 3) upper incisor position relative to the facial plane (1s-NPg), 4) lower incisor position relative to the facial plane (1i-NPg), 5) interincisal angle (1s-1i), 6) upper lip distance from esthetic line (UL-E line), 7) lower lip distance from the esthetic line (LL-E line), and 8) nasolabial angle. All measured cephalometric variables are explained in Supplement 1. All outcomes were assessed in terms of average across all patients within each group. In addition, the primary (upper incisor inclination) and two other selected outcomes (lower incisor inclination and interincisal angle) were also assessed as the proportion of patients having "acceptable" incisor inclination. This was arbitrarily judged to be the case if a patient's incisor inclination fell within the variable's cephalometric norm [20] ± half an SD (110 ± 6° for 1s-NL, 94 ± 7° for 1i-ML, and 130 ± 6° for 1s-1i). Before the study, the two authors (SNP, CC) had completed the necessary calibration process with 40 random cases not included in this study. Data were acquired in a blind manner by having all patient identifiers blocked out by a third person from all radiographs and patient files.

2.5. Statistical analysis

Normality was checked through visual graph inspection and formally with the Shapiro-Wilk test. Descriptive statistics included means and SDs for continuous and absolute/relative frequencies for categorical variables. Differences between groups in baseline characteristics or follow-up measurements were assessed with Student's *t* tests for independent-samples or χ^2 test. Crude linear regression modeling or logistic regression modeling was used to assess the effect of appliance on the primary or secondary outcomes with its 95% confidence intervals (CIs) using the post-treatment inclination as response and the pretreatment inclination as covariate. Adjusted analyses controlling for confounders were done using the change-in-estimate method to select potential confounders with a minimum of 10% change set as cutoff [21]. A sample of 20 patients was randomly chosen and measured by two authors (SNP, CC), and another random sample of 20 patients was remeasured by one author (CC) after 2 weeks for repeatability. Repeatability and agreement of the measurements were assessed with the concordance correlation coefficient [22] and the Bland-Altman method [23]. Alpha was set at a two-sided 5%, but efforts were made to use more recent statistical guidelines on interpretation of statistical tests without overly relying on a $P < 0.05$ as a sole measure of association [24]. All analyses were done in Stata SE 14.2 (StataCorp., College Station, TX), and the data set was openly provided [25].

3. Results

This study included 50 patients treated either with pre-adjusted (n = 25) or with standard Edgewise appliances (n = 25), with no statistically significant differences in demographics between groups, except for age (Table 1), where standard Edgewise patients were slightly older than pre-adjusted patients (14.4 and 12.8 years, respectively). Among the 50 included patients 17 (34%) were male and 41 patients (82%) were treated with extraction of four premolars with an average duration of 27.4 months. Orthodontically, patients at baseline had mean overjet of 4.6 mm, overbite of 2.7 mm, and neutral jaw relationship both sagittally (average SNA 80.6°, SNB 77.2°, ANB 3.3°, Wits −0.5 mm) and vertically (average SN-ML of 35.3°) (Table 2). Compared with the standard Edgewise group, the pre-adjusted group had slightly more retrognathic mandibles (SNB of 76.2° and 78.3°, respectively) and more vertical configurations (SN-ML of 37.1° and 33.5°, respectively).

The observed treatment-related effects were summarized on average as upper incisor retroclination (−3.0°), lower incisor retroclination (−2.0°), enlargement of the interincisal angle (+5.6°), upper incisor retraction (−3.4 mm), lower incisor retraction (−1.5 mm), upper lip retraction (−2.1 mm), lower lip retraction (−2.0 mm), and enlargement of the nasolabial angle (+1.6°). Descriptive statistics (Table 3) indicated that treatment effects on the position of the upper or lower incisors (1s-NPg and 1i-NPg) and the interincisal angle (1s-1i) might differ between the two groups (*P* values of 0.07, 0.09, and 0.002, respectively).

As far as the primary outcome is concerned, after adjusting for confounders (Supplement 2a) the observed data indicate that upper incisors in the pre-adjusted group are more proclined after treatment than the standard Edgewise group (average differences of +3.1 or 3.2°; $P = 0.04$; Table 4). Looking at the secondary outcomes, the data were compatible with the pre-adjusted group having post space closure with 1) an increased upper incisor inclination also taking the cranial base as reference (+3.3°; 95% CI 0.3–6.3°; $P = 0.03$; Table 4), 2) increased lower incisor inclination (+4.5°; 95% CI 2.0–7.0°; $P = 0.001$; Table 4), 3) more anterior upper incisor position (+1.3 mm; 95% CI 0.1–2.4 mm; $P = 0.03$; Table 4), and 4) more acute interincisal angle (with average differences of either −7.3° or −7.7° being most compatible with the data; $P < 0.001$; Table 5). Analyses of the data indicated that no differences

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Table 2
Baseline dental/skeletal characteristics of included patients, given as mean (SD)

Variable	Standard Edgewise (n = 25)	Pre-adjusted (n = 25)	P*
Overjet (mm)	4.3 (1.7)	4.9 (2.7)	0.36
Overbite (mm)	3.2 (1.5)	2.2 (2.8)	0.11
SNA (°)	81.0 (5.0)	80.1 (4.4)	0.51
SNB (°)	78.3 (3.1)	76.2 (3.5)	0.04
ANB (°)	2.8 (2.8)	3.9 (2.9)	0.16
Wits (mm)	−1.3 (2.2)	0.2 (3.3)	0.08
SN-ML (°)	33.5 (5.9)	37.1 (6.6)	0.04
1s-SN (°)	107.3 (7.9)	105.5 (9.5)	0.47
1s-NL (°)	113.4 (8.0)	112.1 (8.2)	0.56
1i-ML (°)	95.1 (5.5)	94.2 (6.9)	0.64
1s-NPg (mm)	9.5 (2.8)	9.9 (5.5)	0.73
1i-NPg (mm)	4.8 (3.1)	4.9 (4.6)	0.95
1s-1i (°)	124.2 (9.1)	123.1 (14.3)	0.76
UL-E line (mm)	−1.2 (2.5)	−1.0 (2.9)	0.81
LL-E line (mm)	1.2 (2.4)	1.1 (3.6)	0.87
Nasolabial angle (°)	104.2 (11.4)	107.0 (9.9)	0.36

ANB, A point, nasion, B point; LL-E, lower lip distance from the esthetic line; ML, mandibular plane; NL, nasal line; NPg, facial plane; SD, standard deviation; SN, sella nasion; SNA, sella nasion point A; SNB, sella nasion point B; UL-E, upper lip distance from the esthetic line; 1s-1i, interincisal angle.
* *t* test for independent samples.

Table 3
Baseline dental/skeletal characteristics of included patients (n = 25 in each group), given as mean (SD)

Variable	Group	T1 Mean (SD)	T2 Mean (SD)	T2-T1 Mean (SD)	T2-T1 % Mean	P*
1s-SN (°)	Standard Edgewise	107.3 (7.9)	102.5 (5.3)	−4.8 (8.3)	−4.1	0.33
	Pre-adjusted	105.5 (9.5)	103.9 (6.4)	−1.6 (10.9)	−0.7	
1s-NL (°)	Standard Edgewise	113.4 (8.0)	108.7 (5.1)	−4.7 (8.3)	−3.8	0.18
	Pre-adjusted	112.1 (8.2)	110.8 (5.7)	−1.3 (10.4)	−0.6	
1i-ML (°)	Standard Edgewise	95.1 (5.5)	91.9 (6.7)	−3.2 (5.3)	−3.3	0.16
	Pre-adjusted	94.2 (6.9)	93.4 (8.5)	−0.8 (6.0)	−0.8	
1s-NPg (mm)	Standard Edgewise	9.5 (2.8)	5.6 (2.7)	−3.9 (1.9)	−42.9	**0.07**
	Pre-adjusted	9.9 (5.5)	6.9 (3.7)	−3.0 (3.4)	−44.1	
1i-NPg (mm)	Standard Edgewise	4.8 (3.1)	2.9 (2.5)	−1.9 (1.6)	−1.6	**0.09**
	Pre-adjusted	4.9 (4.6)	3.8 (3.5)	−1.0 (2.6)	−2.3	
1s-1i (°)	Standard Edgewise	124.2 (9.1)	132.4 (6.2)	8.3 (10.2)	+7.2	**0.002**
	Pre-adjusted	123.1 (14.3)	126.0 (7.0)	2.9 (15.4)	+3.6	
UL-E line (mm)	Standard Edgewise	−1.2 (2.5)	−3.2 (2.5)	−2.0 (1.0)	+37.9	0.89
	Pre-adjusted	−1.0 (2.9)	−3.1 (3.0)	−2.1 (1.3)	−3152.4	
LL-E line (mm)	Standard Edgewise	1.2 (2.4)	−1.1 (2.6)	−2.3 (1.3)	−162.9	0.18
	Pre-adjusted	1.1 (3.6)	−0.7 (3.7)	−1.8 (1.6)	+142.1	
Nasolabial angle (°)	Standard Edgewise	104.2 (11.4)	106.0 (11.5)	1.8 (6.7)	+2.0	0.98
	Pre-adjusted	107.0 (9.9)	108.3 (10.6)	1.3 (8.1)	+1.4	

LL-E, lower lip distance from the esthetic line; ML, mandibular plane; NL, nasal line; NPg, facial plane; SD, standard deviation; SN, sella nasion; T1, before treatment with fixed appliances; T2, after treatment with fixed appliances; UL-E, upper lip distance from the esthetic line; 1s-1i, interincisal angle.
* From linear regression on the absolute post-treatment value as dependent variable, appliance group as independent variable, and pretreatment absolute value as covariate.

between the two groups were identified for the position of the lower incisors, profile of the upper or lower profile, and the nasolabial angle ($P > 0.05$; Table 5).

Finally, 52% (n = 13) of patients in the pre-adjusted and 28% (n = 7) in the standard Edgewise groups had acceptable inclination of the upper incisors according to the cephalometric norm (± half an SD). The respective results were 44% (n = 11) and 36% (n = 9) for the lower incisor inclinations or 36% (n = 9) and 48% (n = 12) for the interincisal angle. Taking into account also potential confounders (Table 2b), the data were compatible with increased odds of having acceptably inclined indicated upper incisors with pre-adjusted appliances (Table 6) compared with standard Edgewise appliances (odds ratio 4.3; 95% CI 1.1–16.6; $P = 0.04$). No hints for a possible difference for lower incisor inclination or interincisal angle were found ($P > 0.05$; Table 6).

Interexaminer agreement and repeatability for the primary outcome of upper incisor inclination was almost perfect with a concordance correlation coefficient of 0.95 (95% CI 0.93–0.97) and a Bland-Altman average difference of 0.01° (95% limits of agreement = −4.48 to 4.49°). Intraexaminer agreement and repeatability were somewhat worse with a concordance correlation coefficient of 0.91 (95% CI 0.87–0.94) and a Bland-Altman average difference of −0.09° (95% limits of agreement = −6.28 to 6.09°). Similar almost perfect agreement was seen for the secondary outcomes of lower incisor inclination and interincisal angle (Supplement 3).

4. Discussion

The current study assessed the incisor inclination of 50 patients treated with incisor retraction after premolar extractions and either pre-adjusted or standard Edgewise fixed orthodontic appliances. The main finding of this study was that pre-adjusted appliances were associated with greater upper incisor inclination post-treatment than standard Edgewise appliances (with a difference of

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Table 4
Unadjusted (crude) and adjusted for confounders linear regression modeling for the effect of appliance type on the primary and secondary outcomes

Adjusting for	1s-SN (°)		1s-NL (°)		1i-ML (°)		1s-NPg (mm)		1i-NPg (mm)	
	b (95% CI)	*P*	b (95% CI)	*P*	b (95% CI)	*P*	b (95% CI)	*P*	b (95% CI)	*P*
Nothing (crude)	1.63 (−1.71 to 4.97)	0.33	2.10 (−1.00 to 5.21)	0.18	2.28 (−0.92 to 5.47)	0.16	**1.10 (−0.07 to 2.28)**	**0.07**	0.85 (−0.12 to 1.81)	0.09
Sex	1.37 (−1.96 to 4.70)	0.41	-	-	-	-	-	-	-	-
Age at T1	1.24 (−2.44 to 4.92)	0.50	2.44 (−0.98 to 5.85)	0.16	**3.16 (−0.32 to 6.64)**	**0.07**	0.89 (−0.39 to 2.18)	0.17	0.60 (−0.46 to 1.66)	0.26
Tx duration	1.81 (−1.44 to 5.06)	0.27	-	-	-	-	-	-	-	-
Molar relationship at T1	-	-	-	-	2.64 (−0.59 to 5.87)	0.11	1.21 (0.02 to 2.39)	0.05	0.97 (0.01 to 1.93)	0.05
4-PM extraction	-	-	-	-	1.34 (−1.82 to 4.51)	0.40	–	–	0.66 (−0.34 to 1.66)	0.19
SNA at T1	1.97 (−1.26 to 5.19)	0.23	-	-	-	-	**1.26 (0.14 to 2.39)**	**0.03**	0.95 (0.01 to 1.89)	0.04
SNB at T1	**3.30 (0.26 to 6.34)**	**0.03**	**3.24 (0.17 to 6.31)**	**0.04**	-	-	**1.31 (0.09 to 2.54)**	**0.04**	-	-
ANB at T1	-	-	-	-	2.70 (−0.63 to 6.03)	0.11	0.77 (−0.35 to 1.88)	0.17	0.51 (−0.41 to 1.42)	0.27
Wits at T1	2.67 (−0.57 to 5.90)	0.10	**2.99 (−0.07 to 6.05)**	**0.06**	1.74 (−1.66 to 5.14)	0.31	-	-	0.65 (−0.33 to 1.63)	0.19
SNML at T1	2.56 (−0.86 to 5.98)	0.14	**2.89 (−0.32 to 6.09)**	**0.08**	**4.49 (1.98 to 6.99)**	**0.001**	-	-	-	-
Overjet at T1	2.15 (−1.17 to 5.47)	0.20	**2.62 (−0.45 to 5.69)**	**0.09**	-	-	1.25 (0.11 to 2.39)	0.03	-	-
Overbite at T1	**2.86 (−0.39 to 6.10)**	**0.08**	**3.11 (0.04 to 6.19)**	**0.04**	**3.66 (0.91 to 6.40)**	**0.01**	-	-	-	-
1s-NPg1 at T1	1.82 (−1.54 to 5.18)	0.28	2.39 (−0.66 to 5.44)	0.12	**2.51 (0.03 to 5.00)**	**0.04**	-	-	-	-
Δ1s-NPg T2-T1	1.03 (−2.07 to 4.12)	0.51	1.26 (−1.37 to 3.89)	0.34	0.96 (−1.46 to 3.38)	0.43	-	-	-	-
1i-NPg1 at T1	-	-	-	-	-	-	-	-	-	-
Δ1i-NPg T2-T1	-	-	-	-			-	-	-	-

Effect estimates are given using standard Edgewise appliances as reference and pre-adjusted appliances as experimental.
ANB, A point, nasion, B point; b, unstandardized regression coefficient; CI, confidence interval; LL-E, lower lip distance from the esthetic line; ML, mandibular plane; NL, nasal line; NPg, facial plane; PM, premolar; SD, standard deviation; SN, sella nasion; SNA, sella nasion point A; SNB, sella nasion point B; T1, before treatment; T2, after debond; Tx, treatment; UL-E, upper lip distance from the esthetic line; 1s-1i, interincisal angle.

Table 5
Unadjusted (crude) and adjusted for confounders linear regression modeling for the effect of appliance type on the primary and secondary outcomes

Adjusting for	1s-1i (°)		UL-E line		LL-E line		Nasolabial angle (°)	
	b (95% CI)	*P*	b (95% CI)	*P*	b (95% CI)	*P*	b (95% CI)	*P*
Nothing (crude)	**−6.33 (−10.12 to −2.54)**	**0.002**	−0.05 (−0.73 to 0.63)	0.89	0.55 (−0.27 to 1.38)	0.18	0.05 (−4.07 to 4.16)	0.98
Sex	-	-	−0.02 (−0.71 to 0.67)	0.96	0.49 (−0.34 to 1.32)	0.24	0.44 (−3.53 to 4.42)	0.82
Age at T1	-	-	0.18 (−0.57 to 0.92)	0.64	-	-	−0.45 (−4.98 to 4.08)	0.84
Tx duration	-	-	−0.09 (−0.76 to 0.59)	0.80	-	-	−0.12 (−4.27 to 4.03)	0.96
Molar relationship at T1	-	-	-	-	0.73 (−0.06 to 1.52)	0.07	−0.31 (−4.54 to 3.91)	0.88
4-PM extraction	-	-	0.04 (−0.68 to 0.75)	0.92	-	-	0.82 (−3.33 to 4.97)	0.69
SNA at T1	-	-	−0.10 (−0.78 to 0.58)	0.77	-	-	0.15 (−4.02 to 4.33)	0.94
SNB at T1	**−7.10 (−11.04 to −3.16)**	**0.001**	−0.17 (−0.88 to 0.54)	0.64	-	-	0.20 (−4.14 to 4.54)	0.93
ANB at T1	-	-	0.01 (−0.69 to 0.71)	0.98	0.40 (−0.44 to 1.23)	0.34	−0.15 (−4.36 to 4.06)	0.94
Wits at T1	-	-	0.05 (−0.65 to 0.75	0.89	-	-	−0.59 (−4.79 to 3.61)	0.78
SNML at T1	**−7.27 (−11.17 to −3.37)**	**<0.001**	−0.25 (−0.94 to 0.45)	0.48	0.36 (−0.52 to 1.24)	0.41	1.12 (−3.13 to 5.38)	0.60
Overjet at T1	-	-	-	-	-	-	0.18 (−4.02 to 4.38)	0.93
Overbite at T1	**−7.68 (−11.22 to −4.13)**	**<0.001**	−0.22 (−0.89 to 0.44)	0.50	0.46 (−0.39 to 1.32)	0.28	0.05 (−4.25 to 4.35)	0.98
1s-NPg1 at T1	-	-	-	-	-	-	0.15 (−4.00 to 4.31)	0.94
Δ1s-NPg T2-T1	**−4.59 (−8.06 to −1.12)**	**0.01**	−0.15 (−0.83 to 0.53)	0.65	0.42 (−0.39 to 1.24)	0.30	−0.25 (−4.39 to 3.89)	0.90
1i-NPg1 at T1	-	-	-	-	-	-	0.07 (−4.07 to 4.22)	0.97
Δ1i-NPg T2-T1	-	-	−0.10 (−0.80 to 0.60)	0.77	0.42 (−0.41 to 1.24)	0.32	−0.40 (−4.54 to 3.75)	0.85

Effect estimates are given using standard Edgewise appliances as reference and pre-adjusted appliances as experimental (continued).
ANB, A point, nasion, B point; b, unstandardized regression coefficient; CI, confidence interval; LL-E, lower lip distance from the esthetic line; ML, mandibular plane; NL, nasal line; NPg, facial plane; PM, premolar; SD, standard deviation; SN, sella nasion; SNA, sella nasion point A; SNB, sella nasion point B; T1, before treatment; T2, after debond; Tx, treatment; UL-E, upper lip distance from the esthetic line; 1s-1i, interincisal angle.

+3.2° or +3.1° being most probable according to the data; Table 4). This might indicate that sliding mechanics along bracket slots that incorporate a prescription might be more effective in retaining at least part of the incisor inclination than commonly used standard Edgewise mechanics like space closure loops. It might be expected that orthodontic extractions and the consequent incisor retraction, even with the use of torquing auxiliaries, results in retroclination of the upper incisors, which is dependent on the premolar being extracted and the amount of retraction [26]. The greater inclination of the pre-adjusted group in this study was actually due to the appliance having minimal effect on average on the pretreatment incisor inclination (–0.6%), whereas the standard Edgewise group showed loss of inclination (−3.8%; Table 3). This might be explained by the McLaughlin-Bennett-Trevisi (MBT) prescription of the pre-adjusted appliance used in the University of Oslo and the integrated +17° torque for the upper central incisors that might be retained by a slot-filling wire during retraction. On the contrary, a retrospective study on premolar extraction cases did not agree with the present

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Table 6
Unadjusted (crude) and adjusted for confounders logistic regression modeling for the effect of appliance type on the correct incisor inclination after treatment

Adjusting for	1s-NL (°)		1i-ML (°)		1s-1i (°)	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Nothing (crude)	2.79 (0.86–9.01)	0.09	1.40 (0.45–4.35)	0.56	0.61 (0.20–1.89)	0.39
Sex	-	-	1.28 (0.40–4.09)	0.68	0.54 (0.17–1.75)	0.31
Age at T1	4.26 (1.09–16.63)	0.04	1.30 (0.38–4.50)	0.68	0.43 (0.12–1.53)	0.19
Tx duration	-	-	-	-	-	-
Molar relationship at T1	3.16 (0.93–10.76)	0.07	-	-	0.67 (0.21–2.13)	0.50
4-PM extraction	-	-	-	-	0.65 (0.20–2.08)	0.46
SNA at T1	-	-	1.60 (0.49–5.23)	0.44	-	-
SNB at T1	2.27 (0.67–7.72)	0.19	2.05 (0.59–7.15)	0.26	0.55 (0.17–1.81)	0.32
ANB at T1	3.49 (0.99–12.34)	0.05	1.30 (0.41–4.16)	0.66	-	-
Wits at T1	3.27 (0.95–11.26)	0.06	1.45 (0.45–4.68)	0.54	-	-
SNML at T1	2.29 (0.68–7.76)	0.18	1.65 (0.50–5.50)	0.41	0.56 (0.17–1.85)	0.35
Overjet at T1	-	-	1.53 (0.48–4.87)	0.48	-	-
Overbite at T1	2.48 (0.75–8.27)	0.14	1.30 (0.40–4.19)	0.66	0.54 (0.17–1.77)	0.31
1s-NPg1 at T1	-	-	-	-	-	-
Δ1s-NPg T2-T1	-	-	-	-	-	-
1i-NPg1 at T1	-	-	-	-	-	-
Δ1i-NPg T2-T1	-	-	1.64 (0.50–5.38)	0.41	-	-
Acceptable inclination at T1	-	-	-	-	-	-

Effect estimates are given using standard Edgewise appliances as reference and pre-adjusted appliances as experimental.
ANB, A point, nasion, B point; b, unstandardized regression coefficient; CI, confidence interval; ML, mandibular plane; NL, nasal line; NPg, facial plane; OR, odds ratio; PM, premolar; SN, sella nasion; SNA, sella nasion point A; SNB, sella nasion point B; T1, before treatment; T2, after debond; Tx, treatment; 1s-1i, interincisal angle.

study and found no significant difference in inclination of the upper and lower incisors or interincisal angle between pre-adjusted and standard Edgewise appliances [27].

This reduced retroclination of the upper incisors with pre-adjusted appliances was accompanied with reduced retraction of the tip of the upper incisors compared with the standard Edgewise appliances (with a difference of +1.3 mm being most probable; Table 4). As all patients were treated to fully closed spaces and to similar finishing quality according to the ABO tool [14], this indicates that the upper incisor tip in the standard Edgewise group was more posterior due to the incisors standing steeper post-treatment.

The data of the present study supported the notion that patients in the pre-adjusted groups more often had upper incisors acceptably proclined (according to the cephalometric norm) compared with the standard Edgewise group (odds ratio 4.3; Table 6). This agrees with a previous study having some overlap of patients with the current study [14], which indicated that both appliances lead to similar finishing quality in terms of the ABO's objective grading tool. Small differences existed between appliances in some ABO criteria and standard Edgewise appliances fared worse in the ABO's "overjet" criterion than pre-adjusted appliances (5.4 vs. 3.9 penalty points, respectively), which might be influenced by the post-treatment inclination of the upper incisors. However, such differences were in any case small, which indicates that the clinician's experience might play a greater role for the final outcome of treatment than the prescription of the fixed appliance. This is corroborated by another study comparing pre-adjusted Roth appliances with standard Edgewise appliances in terms of ideal tooth relationships [28]. That study indicated that Roth appliances were associated with better outcomes for some angulation and inclination outcomes compared with standard Edgewise appliances, but other outcomes were heavily dependent on the practitioner, with some producing better results with standard Edgewise and other with pre-adjusted appliances.

Considerable inclination differences were further found, with patients in the pre-adjusted group having higher lower incisor inclination (+4.5°) and more acute interincisal angle post-treatment (−7.3° to −7.7°) compared with the standard Edgewise group. The increased lower incisor inclination was similarly due to different retroclination during treatment in the pre-adjusted and standard Edgewise groups (−0.8% and −3.3%, respectively) and differential opening of the interincisal angle (+3.6% and +7.2%, respectively). However, it also must be noted that the lower incisors were on average less retracted in this study than the upper incisors (−1.5 mm vs. −3.4 mm, respectively), which might account for different effects in the inclination of these teeth.

Overall, even though differential effects were found for incisor position and inclination between the two appliances, this was not the case for the prominence of the lips or the nasolabial angle. Therefore, some small differences in tooth positioning might be of little clinical relevance to the patient from an esthetic standpoint.

This controlled before-and-after study presents several strengths, which include its preregistered protocol [29] and the transparent provision of its dataset [30]. The a priori sample size estimation contributes to this study being adequately powered to identify any clinically important effects on upper incisor inclination, whereas blind outcomes assessment reduces the risk for bias. However, limitations also exist for the present study, like its retrospective nature for data collection, which is associated with inflated effects compared with randomized clinical trials [31]. Furthermore, as not all treating orthodontists were equally proficient and used both standard Edgewise and pre-adjusted appliances, it was not possible to administer both appliances in a single clinic to better account for individual proficiency variation. In addition, retraction mechanics were not predetermined and were left to the discretion of the clinical instructors overseeing treatment in each university clinic. The possibility that proficiency bias might exist cannot be ruled out, even though all patients were treated under the direct supervision of long-term clinical instructors with decades of experience. Lip prominence was checked with the E line as reference, which might be affected by the growth changes of the nose [32], although patients were of relatively similar age and had similar treatment duration of slightly more than 2 years. Finally, important adverse effects like root resorption, vestibular/palatal gingival recessions, tooth elongation, and anchorage loss were not assessed in this study, even though these are often

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taken into consideration during clinical decision-making regarding implemented appliances and techniques.

5. Conclusions

Within the limitations of the present controlled before-and-after study, it can be concluded that extraction treatment with pre-adjusted appliances might be associated with increased inclination of the upper and lower incisors, with more prominent upper incisor position, and with more acute interincisal angle than standard Edgewise appliances. However, such differences might not have a meaningful impact on lip prominence or nasolabial angle.

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Author contributions

Spyridon Papageorgiou: conceptualization, methodology, software, investigation, writing-original draft preparation. Chiara Cassina: Investigation, validation, writing-reviewing, and editing. Vaska Vandevska-Radunovic: conceptualization, methodology, data curation, supervision, writing-reviewing, and editing. Theodore Eliades: conceptualization, methodology, data curation, supervision, writing-reviewing, and editing.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ejwf.2021.04.001.

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