TURKISH JOURNAL of ORTHODONTICS

DOI: 10.5152/TurkJOrthod.2022.21017

Original Article

Effects of Recent/Healed Post-Extraction Protocols on Incisor and Canine Alignment During Fixed Orthodontic Appliance Therapy

Adedayo Ayomide Olabintan[1], Olayinka Donald Otuyemi[2], Kikelomo Adebanke Kolawole[2]

[1]Department of Child Dental Health, Obafemi Awolowo University Teaching Hospitals Complex Ile-Ife, Nigeria
[2]Department of Child Dental Health, Obafemi Awolowo University Ile-Ife, Nigeria

Cite this article as: Ayomide Olabintan A, Donald Otuyemi O, Adebanke Kolawole K. Effects of recent/healed post-extraction protocols on incisor and canine alignment during fixed orthodontic appliance therapy. *Turk J Orthod.* 2022;35(2):84-93.

Main Points

- This study compared the rates of incisor and canine alignment in recent and healed extraction cases in order to determine which protocol would favor accelerated tooth movement.
- The rates of initial canine and incisor alignment were not significantly different between the recent and healed post-extraction protocols.
- The alignment rate was significantly faster in adolescents compared to adults.
- The alignment rate was not significantly different between both sexes or dental arches.

ABSTRACT

Objective: The purpose of this study was to determine the effects of recent/healed post-premolar extraction protocol, gender, age, and dental arch on incisor and canine alignment during fixed orthodontic appliance therapy.

Methods: The study sample consisted of 50 dental arches of patients undergoing fixed orthodontic appliance therapy. The arches were randomized into an equal number of recent and healed extraction groups. The orthodontic setup was instituted within 3-7 days and 5-6 weeks following first premolar teeth extractions in the recent and healed extraction groups, respectively.

Orthodontic tooth alignment was carried out using 0.016-inch NiTi wires for 16 weeks. Study casts were made at baseline, 4, 8, 12-, and 16-week follow-up treatment. Little's Irregularity Index was used to assess orthodontic tooth alignment.

Mann–Whitney *U* test was used to compare the alignment rates between groups, and multiple linear regression was used to predict the relationship of groups and sociodemographic factors to alignment rate. The statistical significance level was set at $P < .05$.

Results: The mean daily incisor and canine alignment rates in the recent and healed extraction cases were 0.13 mm and 0.11 mm, respectively ($P = .332$), 0.12 mm in both males and females ($P = .827$), and 0.13 mm and 0.12 mm in the maxilla and mandible, respectively ($P = .534$). There was however a significant difference in the mean daily alignment rate between adolescents (0.15 mm) and adults (0.10 mm) ($P = .019$).

Conclusion: The rate of incisor and canine alignment was not affected significantly by recent/healed post-extraction protocol, gender, and dental arch. However, the rate was significantly faster in adolescents.

Keywords: Dental arch, incisor and canine alignment, Little's irregularity index, orthodontics, recent/healed extraction

INTRODUCTION

The duration of fixed orthodontic appliance therapy is considered by many patients as relatively long. This discourages many potential patients from undergoing orthodontic treatment.[1] Thus, any method or intervention that leads to a reduction in the duration of orthodontic treatment is highly desirable.[1] Uribe et al.[2] reported that adolescents and adults, as well as the parents of patients, desire that orthodontic treatment be completed in the shortest possible time. A shortened treatment time reduces patients' burn-out and enables the orthodontist

Corresponding author: Adedayo Ayomide Olabintan, e-mail: mideday@yahoo.com

Received: March 1, 2021
Accepted: September 13, 2021

to treat more patients and predict treatment costs more accurately.[3] Other benefits of shorter treatment time for patients include reduced risk of root resorption, caries, plaque, and calculus accumulation, as well as periodontal diseases, and enamel decalcification.[4] Excessively short treatment time however poses risks of incomplete and unstable corrections as adequate time is required for angulation and torque correction, tissue regeneration, and stability of results.[5]

During orthodontic treatment planning, premolar teeth extraction is often indicated as an adjunct to fixed orthodontic appliance therapy, to relieve crowding, flatten the curve of Spee, and correct overbite. Others include dental and skeletal Class 2 corrections and treatment stability. All these desirable treatment modalities have been reported to contribute to increased overall treatment time.[5]

Generally, tooth alignment is carried out in the first stage of fixed orthodontic appliance treatment; therefore, a proper alignment usually involves bringing malposed teeth into the arch while also specifying and controlling the anteroposterior position (inclination) of incisors, arch width posteriorly, and the dental arch form.[6] The final stage of the treatment period is required to achieve residual space closure after utilizing a part of the extraction spaces to unravel crowding or retract the anterior segment.[7]

To shorten the tooth alignment phase in fixed orthodontic appliance therapy for patients with anterior segment crowding during premolar teeth extraction, this study attempted to explore the effect of healing time on extraction sockets, among other anatomic and sociodemographic factors that may aid or assist orthodontic tooth movement. Extraction sockets have been reported to heal in overlapping stages with bone formation composed of poorly calcified osteoid at the base and periphery of the socket from the seventh day and with bone trabeculae subsequently filling two-thirds of the socket fundus by 38-day post-extraction.[8] A study by Hasler et al.[9] reported faster tooth movement in the less calcified bone of recent extraction sites compared to HE sites, as the less calcified bone resorbs faster and also due to the presence of more cells with osteoclastic potential.

The tooth alignment rate during treatment is dependent on several technical factors, including correct bracket positioning, inter-bracket span, space availability, method of ligation, and the bracket system.[10] Currently, there is a paucity of literature relating sociodemographic and anatomic factors and the impact of the healing time of extraction sockets, thus necessitating this study. The main objective of this study is, therefore, to compare the rates of incisor and canine alignment in recent and healed first premolar teeth extractions, during fixed orthodontic appliance therapy, and to relate tooth alignment rate to sociodemographic and anatomic factors in a group of Nigerians seeking orthodontic treatment.

METHODS

Study Design

This study was a prospective study carried out at the orthodontic clinic of a teaching hospital.

Material

This study was approved by the Research and Ethics Committee of the teaching hospital (ERC/2016/10/10). Informed consent was obtained from every study participant. The inclusion criteria included patients 12 years and above, patients in the permanent dentition stage, and patients with an indication of bilateral maxillary and or mandibular first premolar teeth extractions to relieve moderate to severe crowding. Finally, all patients who did not require active canine retraction before alignment were also included. The exclusion criteria included patients with hypodontia, underlying periodontal diseases, history of previous extractions, or those requiring asymmetric extractions. Others were patients on non-steroidal anti-inflammatory drugs or systemic conditions that could delay wound healing.

Methods

Consenting patients who met the inclusion criteria were recruited for this study from patients who presented at the orthodontic clinic of the teaching hospital.

The sample size was determined using the formula for calculating sample size for comparative studies.

$$N = 4o^2 \frac{(Zcrit + Zpwr)^2}{D^2}$$

where N is the sample size for the 2 groups, Ơ is the standard deviation, and D is the effect size (2.48-1.7 = 0.78).

Values for standard deviation and effect size were obtained from earlier studies by Scott et al.[6] At a power of 90%, statistical power (Zpwr) is 1.282. With a significance criterion of 95%, Zcrit is 1.960.

$$N = 4 \times 0.79^2 \frac{(1.960 + 1.282)^2}{0.78^2} = 43$$

This was then approximated to 50 dental arches (25 arches in each group) to address possible attrition.

Participants were randomly assigned to the recent extraction (RE) and healed extraction (HE) groups of 25 dental arches each, using a computer-generated randomization program on Graphpad.com (Figure 1).

For this study, the extraction protocols were adjudged "recent" and "healed" when treatment was commenced within 3-7 days and 5-6 weeks post-extraction, respectively. This was modeled according to a study by Amler[8] that showed commencement of bone formation on the seventh day and bone filling of at least two-thirds of the socket by the 38th day.

After randomization, baseline (T0) impressions for the study cast were made for each participant. First premolar teeth extractions were subsequently carried out in 2 stages by an experienced oral surgeon using extraction forceps only (Nova Instruments, Wokingham, Berkshire, UK). This was done under close monitoring by one of the researchers (A.A.O) to ensure atraumatic extraction procedures. The extractions on one side (right or left) in the maxilla and/or mandible were carried out in

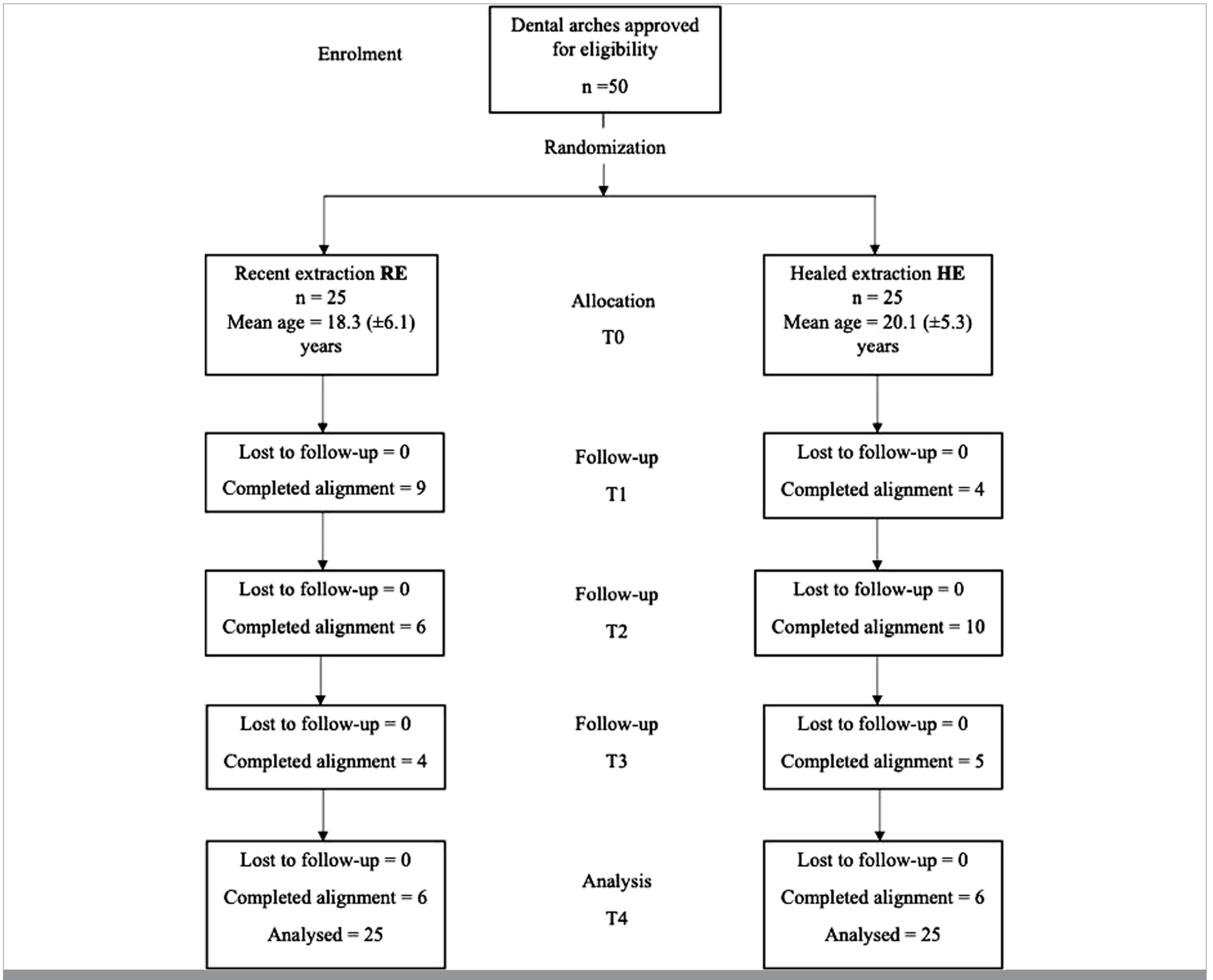

Figure 1. Consolidated standards of reporting trials (CONSORT) flowchart of the randomization procedure and follow-up visits

one visit, followed by extraction on the contralateral side after 3 days.

Fixed orthodontic appliance set-ups were carried out within 3-7 days after premolar teeth extractions for participants in the RE group and 5-6 weeks after the first premolar teeth extractions for the HE group.

Both groups received fixed orthodontic appliances with conventional 0.022-inch slot McLaughlin-Bennett-Trevisi (MBT) brackets. All brackets were obtained from a single manufacturer (Yahong ortho, Zhejiang, China) and were carefully positioned by one of the researchers (A.A.O.) to ensure consistency. Stainless steel (0.010 inch) lace back wire (G & H Orthodontics, Franklin, Ind, USA) was also tied lightly from canine to molar teeth in all quadrants for control of canine crown position according to MBT straight wire prescription.

Similarly, 0.016-inch NiTi archwires from another manufacturer (Orthoclassic, McMinnville, Oregon, USA) were ligated with elastic modules using the figure of eight ligation method. It was anticipated that the 0.016-inch archwires will have minimal effects on arch expansion. Bendbacks were incorporated at the end of the archwires using a ligature wire tucker to minimize the forward tipping of the incisors. The 0.016 inch round NiTi archwires were maintained throughout the first 16 weeks of the initial tooth alignment phase following the technique by Wahab et al.[11] for the 2 groups, except there was a need for replacement with another 0.016-inch NiTi wire. In addition, there was no bracket replacement in patients throughout the study period.

Alginate impressions for study casts were also made at 4 weeks (T1), 8 weeks (T2), 12 weeks (T3), and 16 weeks or less (T4) depending on the length of time required to attain the full initial tooth alignment. The irregularity index scores were determined using Little's Irregularity Index (LII).[12] Little's Irregularity Index scores were calculated from the measurements recorded with a carbon fiber composite digital caliper (Fuzhou, Fujian, China) on the study casts at the different time intervals. The rate of incisor and canine alignment was determined as the difference between the irregularity score at baseline and the final tooth alignment period (16th week or less), divided by the number of days to attain alignment. The alignment rates were compared between the RE and HE groups, dental arches, genders, and age groups.

Statistical Analysis

Data analysis was carried out using the Statistical Package for Social Sciences (SPSS) software package (IBM SPSS version 20; Armonk, NY, USA). Descriptive statistics were carried out for sociodemographic variables. Chi-square was used to determine the differences in categorical groupings for gender, age group, and dental arch between the RE and HE groups. The mean age difference in both groups was assessed using independent samples *t*-test. The intra-class correlation coefficient was used to determine the reliability of cast measurements for 10 randomly selected dental casts within at least 2 weeks interval. The results showed a high degree of reliability with a correlation coefficient of 0.97 and a 95% confidence interval of 0.90-0.99 for LII scores.

A normality check for data was performed using the Shapiro–Wilk test, and non-parametric tests were subsequently carried out on the skewed data. Repeated measures analysis of variance (ANOVA) was used to test for changes in LII score over time, and Bonferroni post hoc test was subsequently used for pairwise comparisons. Mann–Whitney *U* test was used to compare the alignment rates between groups, and multiple linear regression was used to test the relationship of groups and other variables to alignment rate. RE or HE group, age group, gender, and dental arch were each tested as predictors of the alignment rate while controlling for other variables. The statistical significance level was set at $P < .05$.

RESULTS

Table 1 shows the sociodemographics of the study participants. There were more female (60%) and adult dental arches (60%) in the sample population. Similarly, the sample had more mandibular (52%) than maxillary (48%) arches. The mean ages of the RE and HE groups were 18.3 (±6.1) and 20.1 (±5.3) years, respectively, while the overall mean age was 19.18 (±5.7) years. There were, however, no statistically significant differences in age, gender, or dental arch distribution between the RE and HE groups.

Table 1. Distribution of study participants by age, gender, and dental arch

Background Characteristics	RE (n = 25)		HE (n = 25)			
	N	%	N	%	χ^2	*P*
Age group (years)						
12-17	12	48.0	8	32.0	1.333	.248
18-32	13	52.0	17	68.0		
Gender						
Male	13	52.0	7	28.0	3.000	.083
Female	12	48.0	18	72.0		
Dental arch						
Maxillary arch	10	40.0	14	56.0	1.282	.258
Mandibular arch	15	60.0	11	44.0		

RE, recent extraction; HE, healed extraction.

Figure 2 shows the line graph comparing the mean LII scores between the RE and HE groups, over the 16-week follow-up period. There was a steady decline in LII score, that is improvement in incisal and canine alignment over the 16-week study period. At baseline (T0), the mean LII score for the RE group was 7.76 mm and 7.79 mm for the HE group ($P = .683$). At 4 weeks (T1), the mean LII scores were further reduced to 3.58 mm and 4.14 mm for the RE and HE groups, respectively ($P = .453$). At 8 weeks (T2), it was 1.41 mm and 1.79 mm for RE and HE groups, respectively ($P = .576$). At 12 weeks (T3), it was 0.74 mm and 0.86 mm for RE and HE groups, respectively ($P = .948$). Finally, at 16 weeks (T4), the mean LII scores were 0.25 mm and 0.56 mm for RE and HE groups, respectively ($P = .630$).

A repeated measure ANOVA test was done to determine changes in LII scores at baseline and 4 weekly intervals. The results showed that there were significant changes with time, F (4, 24) = 17.22, $P < .001$ in RE and F (4, 24) = 21.61, $P < .001$ in HE groups. Table 2 shows the Bonferroni post hoc test highlighting the time intervals where significant changes occurred. There were significant reductions in the irregularity scores within the RE and HE groups between T0 and all other time intervals, T1 and all other time intervals, and T2 and T3 in the HE group. Similarly, significant differences were observed between RE and HE groups in the timelines of T0-T2 ($P = .030$) and T1-T2 ($P = .006$).

Figure 3 shows the trend of changes in LII scores across gender. The line graph shows that the male participants had a higher LII score at baseline T0 (9.4 mm) compared to the females 6.7 mm ($P = .033$). The LII scores at 4 weeks (T1) were 5.53 mm and 2.75 mm ($P = .007$), and at 8 weeks (T2), they were 2.06 mm and 1.29 mm ($P = .316$). The LII scores at 12 weeks (T3) were 1.12 mm and 0.58 mm ($P = .390$), and by the 16th week (T4), they were 0.67 mm and 0.23 mm ($P = .294$) in males and females, respectively.

Figure 4 displays the comparison of mean LII scores at the follow-up visits across age groups. The mean LII scores at baseline (T0) were 7.85 mm and 7.73 mm ($P = .976$), at 4 weeks (T1) they were 3.26 mm and 4.26 mm ($P = .221$), at 8 weeks (T2) they were 1.0 mm and 2.0 mm (P = 0=.094), at 12 weeks (T3) they were 0.29 mm and 1.14 mm ($P = .057$), and at 16 weeks (T4) they were 0 and 0.67 mm ($P = .022$) in adolescents and adults, respectively. A significant difference was only observed in LII scores between adolescents and adults at the 16th week.

Figure 5 is a line graph comparing mean LII scores between mandibular and maxillary arches over the 16-week follow-up period. A steady decline in the LII scores was observed as the study progressed into the 16th week (T4). The LII scores at baseline (T0) were 8.25 mm and 7.35 mm ($P = .586$), at 4 weeks (T1) were 4.17 mm and 3.58 mm ($P = .654$), at 8 weeks (T2) were 1.85 mm and 1.37 mm ($P = .759$), at 12 weeks (T3) were 0.85 mm and 0.75 mm ($P = .726$), and at 16 weeks (T4) were 0.45 mm and 0.36 mm ($P =$

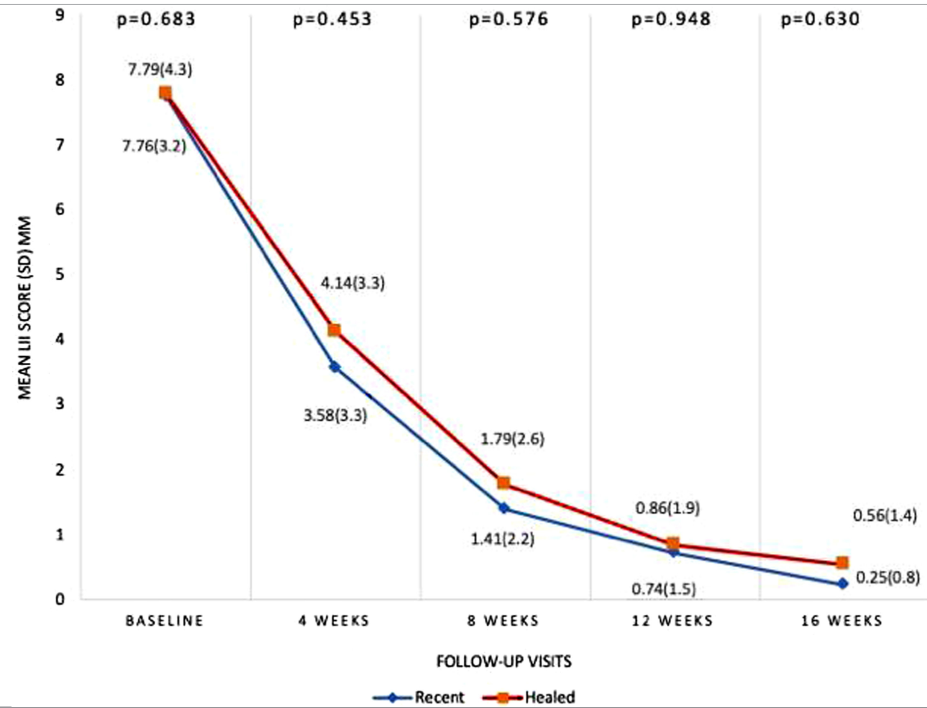

Figure 2. Comparison of mean irregularity scores between recent and healed extraction groups over the 16-week follow-up period

.809) in the upper and lower arches, respectively. These findings showed no significant differences in the LII scores in both dental arches at all follow-up intervals.

The RE/HE protocols, gender, age, and dental arch differences in alignment rate are shown in Table 3. The mean and median alignment rates per day in the RE group were 0.13 mm (3.9 mm per month) and 0.11 mm, respectively, while the mean and median alignment rates per day in the HE group came to 0.11 mm (3.3 mm per month) and 0.09 mm, respectively. There was however no statistically significant difference (*P* = .332).

The mean and median incisor and canine alignment rates in the males were 0.12 mm and 0.11 mm, respectively, while the mean and median alignment rates in the females were 0.12 mm and 0.10 mm, respectively. There was no statistically significant difference in the initial alignment rate between both genders (*P* = .827).

However, there was a statistically significant difference in the alignment rate among adolescents (12-17 years) compared to adults (18-32 years). The mean and median alignment rates in the adolescents were 0.15 mm and 0.14 mm, respectively and 0.10 mm and 0.09 mm, respectively (*P* = .019) in the adults.

The mean alignment rate in the maxillary arch was 0.13 mm per day (3.9 mm per month), while the median was 0.11 mm per day. The mean mandibular alignment rate was 0.12 mm per day (3.6 mm per month) and the median was 0.09 mm per day. The

Table 2. Bonferroni post hoc test for pairwise comparisons of changes in irregularity scores at follow-up visits in RE and HE groups

	RE group					HE group					
Period	Diff	*t*	*P*	95 % CI		Diff	*t*	*P*	95% CI		Intergroup *P* value
T0-T1	−4.18	−8.76	<.001*	−5.1	−3.2	−3.7	−7.8	<.001*	−4.6	−2.7	.148
T0-T2	−6.36	−13.3	<.001*	−7.3	−5.4	−6.0	−12.8	<.001*	−6.9	−5.1	.031*
T0-T3	−7.02	−14.7	<.001*	−8.0	−6.1	−6.9	−14.8	<.001*	−7.9	−6.0	.306
T0-T4	−7.51	−15.7	<.001*	−8.5	−6.6	−7.2	−15.5	<.001*	−8.2	−6.3	.076
T1-T2	−2.2	−4.6	<.001*	−3.1	−1.2	−2.3	−5.0	<.001*	−3.3	−1.4	.006*
T1-T3	−2.8	−6.0	<.001*	−3.8	−1.9	−3.3	−7.0	<.001*	−4.2	−2.4	.097
T1-T4	−3.3	−7.0	<.001*	−4.3	−2.4	−3.6	−7.7	<.001*	−4.5	−2.7	.064
T2-T3	−0.7	−1.4	.165	−1.6	0.3	−0.9	−2.0	.049*	−1.9	−0.004	.161
T2-T4	−1.2	−2.4	.017	−2.1	−0.2	−1.2	−2.6	.010	−2.2	−0.3	.452
T3-T4	−0.5	−1.02	.309	−1.4	0.5	−0.3	−0.6	.523	−1.2	0.6	.416

*Statistical significance.
Diff, difference; RE, recent extraction; HE, healed extraction; T0, baseline; T1, 4 weeks; T2, 8 weeks; T3, 12 weeks; T4, 16 weeks.

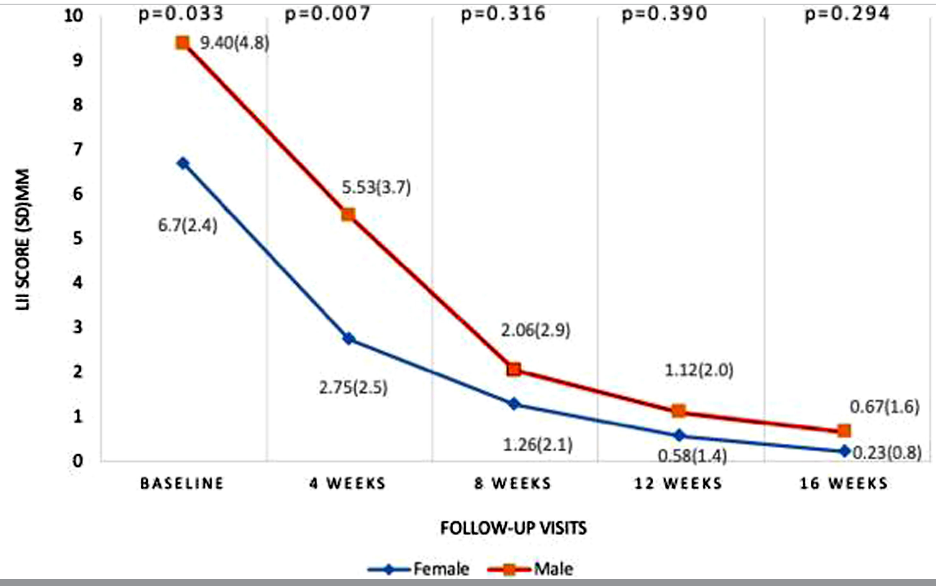

Figure 3. Comparison of mean irregularity scores between participants' gender over the 16-week follow-up period

difference in the maxillary and mandibular alignment rates was not statistically significant (*P* = .534).

Table 4 shows multiple linear regression of the relationship between the rate of alignment and patient group status, controlling for RE/HE protocols, age group, gender, and dental arch. There was evidence that the age group was a predictor of the alignment rate. The alignment rate per day in adolescents (<18 years) was higher by 0.004 compared with adults (≥18 years). The higher rate observed was statistically significant (*P* = .005). Recent extraction group had higher alignment rate of 0.014 mm per day compared to the HE group across the study period; however, the higher alignment rate was not significantly different (*P* = .411). Male participants had 0.010 mm less alignment rate per day compared with females. This difference was also not statistically significant (*P* = .558). The lower arch had 0.007 mm less alignment rate per day in comparison to the upper arch, and the reduction was also not significantly different (*P* = .675).

DISCUSSION

This study compared the rates of initial tooth alignment in recent and healed first premolar extraction cases during fixed orthodontic appliance therapy and aimed at establishing a premolar

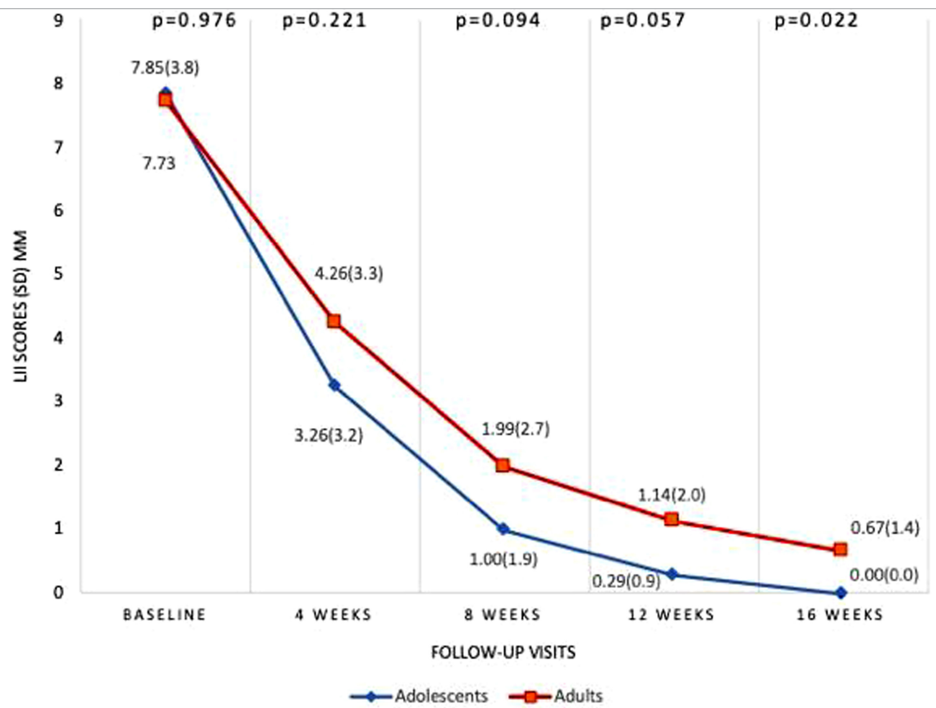

Figure 4. Comparison of mean irregularity scores between participants' age groups over the 16-week follow-up period

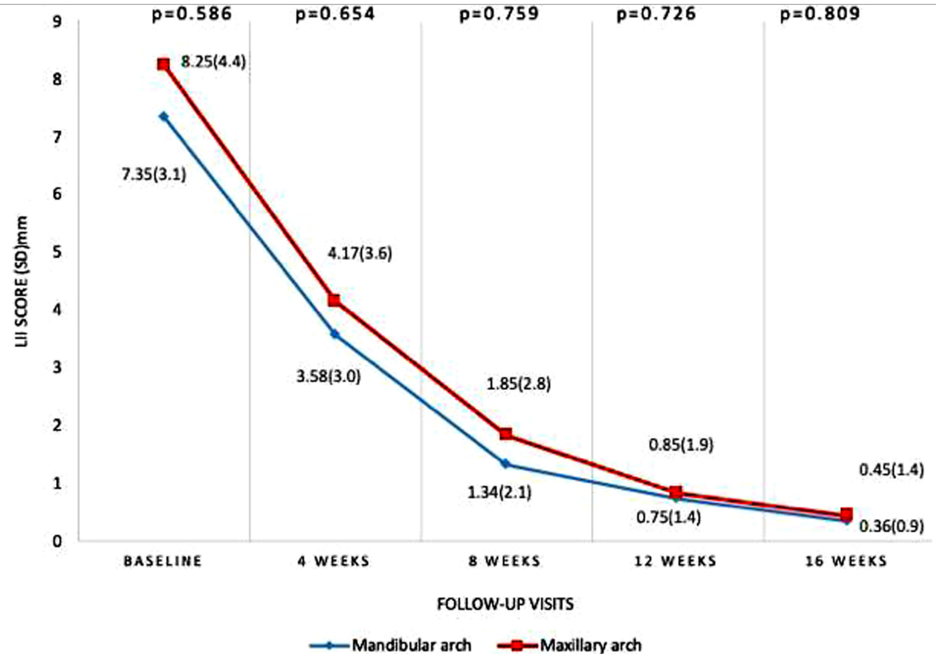

Figure 5. Comparison of mean irregularity scores between participants' dental arches over the 16-week follow-up period

extraction protocol among other factors that could provide faster incisor and canine alignment during fixed orthodontic appliance therapy. It is worthy of note that several adjunctive physical and surgical procedures and the use of medications have been utilized in hastening fixed orthodontic treatment time[5]; however, this study hoped to accelerate treatment without the use of any adjunctive therapy. Randomization into groups was only based on the 2 extraction protocols. To the best of our knowledge, this is the first reported study in the literature that related tooth alignment to RE and HE protocols.

The gender pattern, which tends to favor more female participants in this report, is in agreement with other previous studies that recorded a higher number of females seeking orthodontic treatment.[13] This observation may be related to greater concerns for dental appearance in the female gender than their male counterparts. Reports on orthodontic treatment needs and other epidemiologic studies have shown very limited gender differences in the incidence or severity of malocclusions. But, orthodontic treatment uptakes have substantially skewed toward the female gender.[14] Females are not only more likely to receive orthodontic treatment than their male counterparts but also perceived to need orthodontic treatment by their parents and referring dentists.[15] There are, therefore, social and cultural differences in the perception and uptake of orthodontic treatment with an obvious lower threshold for female patients.[16]

Table 3. Extraction protocol, gender, age, and dental arch differences in alignment rate

		Alignment Per Day (mm)				
Variables	**N**	**Mean (SD)**	**Median**	**Min**	**Max**	**Mann–Whitney *U* Test, *P***
Extraction protocol						
RE	25	0.13 (0.07)	0.11	0.05	0.29	.332
HE	25	0.11 (0.05)	0.09	0.04	0.28	
Gender						
Male	20	0.12 (0.07)	0.11	0.05	0.29	.827
Female	30	0.12 (0.06)	0.10	0.04	0.29	
Age group (years)						
12-17	20	0.15 (0.08)	0.14	0.05	0.29	.019*
18-32	30	0.10 (0.03)	0.09	0.04	0.17	
Dental arch						
Maxillary arch	24	0.13 (0.07)	0.11	0.05	0.29	.534
Mandibular arch	26	0.12 (0.06)	0.09	0.04	0.29	

*Statistical significance.
SD, standard deviation; RE, recent extraction; HE, healed extraction; Min, minimum; Max, maximum.

Table 4. Multiple regression analysis of the relationship between alignment rate controlling for recent and healed extraction protocols, age group, gender, and dental arch

Variables	Coefficient	95% CI		Standard Error	*P*
Extraction protocol					
RE	1				
HE	−0.014	−0.049	0.020	0.017	.411
Age group (years)					
Adolescents (<18)	1				
Adults (≥18)	−0.052	−0.088	−0.017	0.018	.005*
Gender					
Female	1				
Male	−0.010	−0.046	0.025	0.018	.558
Dental arch					
Maxillary arch	1				
Mandibular arch	−0.007	−0.041	0.027	0.017	.675
Constant	0.168	0.127	0.208	0.020	<.001

*Statistical significance.
RE, recent extraction; HE, healed extraction.

The present study, though not statistically significant, showed a relatively faster rate of tooth alignment in the RE group compared to the HE group. In a related study, Hasler et al.[9] revealed a faster rate of canine retraction into RE sites. This may directly support the report that tooth movement is faster in the less calcified bone of a RE site compared to HE sites, as the less calcified bone resorbs faster.[9] The presence of more cells with osteoclastic potential is also a possible explanation for this phenomenon.[9] The tooth alignment rates recorded in our study are consistent with another reported study on the efficiency of tooth alignment.[6] The findings of the present study are however at variance with the results of an animal study by Murphey et al.[17] which reported a faster retraction into HE sites using heavy forces for canine distalization.

The rate of incisor and canine alignment in the maxillary arch was marginally higher than that of the mandible, though not significantly different. This also confirms the findings of Dudic et al.[18] that reported no difference in the rate and amount of tooth alignment, irrespective of tooth position and direction of tooth movement. However, Giannopoulou et al.[19] in a study of orthodontic tooth movement and location in the arch reported a faster rate of tooth movement in the maxilla than in the mandible. A similar observation from a study on orthodontic tooth movement in dogs concluded that tooth movement was significantly faster in the maxilla than in the mandible. This is because the maxilla is composed of relatively thin cortices and has a higher rate of bone resorption which initiates more rapid bone turnover in the mandible.[20] Higher bone turnover is linked with increased tooth movement, compared to normal or low bone turnover.[20] Increased bone density in the mandibular molar region is believed to offer more resistance to tooth movement in the mandible, compared to the maxillary molar region.[21]

The passive nature of canine retraction during tooth alignment in the present study may also be responsible for the insignificant rate of incisal and canine alignment in the maxilla compared to the mandible.

Reports on gender differences in the literature are varied; however, findings from this study are consistent with the report of Dudic et al.[18] which revealed no gender differences in tooth movement. The effects of gender on the rate of tooth movement have been studied in relation to estrogen deficiency or estrogen replacement in post-menopausal osteoporotic women. Bone formation in response to mechanical force is defective in osteoporotic women.[21] Estrogen deficiency increases bone remodeling, while tooth movement is slower in estrogen replacement.[22]

A review by Omar et al.[23] revealed that hormonal changes in pregnancy could hasten tooth movement in pregnant rats when compared to the non-pregnant rats.[23] Since the report on the rats cannot be directly extrapolated to humans, the absence of post-menopausal osteoporotic or pregnant women in our study may be responsible for the lack of gender differences in the alignment rate.

In the present study, incisor and canine alignment was significantly faster in adolescent participants when compared to adults. This aligns with the findings of Dudic et al.[18] which identified age as an important factor in tooth movement. The authors found faster tooth movement in patients whose ages were less than 16 years compared to those that were 16 years and above. Ren et al.[24] also reported faster mesiodistal tooth movement in juvenile rats compared to adult rats. A possible explanation for faster tooth movement in adolescent patients may be due to higher cellularity of periodontal ligaments exhibited in adolescents than adults.[25] The efficiency of osteoclastic activity, which is responsible for bone resorption, is an important factor that cannot be ignored and has been postulated to influence tooth movement. Ren et al.[26] found that within 2 weeks, the maximum number of osteoclasts was attained at the compression sites of the periodontal ligament in young rats. But it took 4 weeks for the same level to be attained in adult rats. Thereafter, the rate of tooth movement was found to be comparable in both young and adult rats. The authors concluded that the osteoclasts in younger rats were more efficient than those of older rats. It was, therefore, suggested that more osteoclasts are required in older rats to bring about the same rate of tooth movement observed in younger rats. Chugh et al[21] also surmised that the faster tooth movement in children compared to adults might be a result of less bone density in children.

Similarly, Ren et al.[27] reported that the significantly elevated levels of interleukin-6 and granulocyte–macrophage colony-stimulating factor in the gingival crevicular fluid and the mediator levels in juveniles are more responsive than the levels in adults. This confirms the finding that the initial tooth movement in juveniles is faster than in adults. Kawasaki et al.[28] suggested that the age-related reduction in the amount of tooth movement might be influenced by a decrease in the receptor activator of nuclear factor kappa-B ligand/osteoprotegerin ratio in gingival crevicular fluid, during the early stages of orthodontic tooth movement.[28] Observation from this study is however at variance with the conclusion of Mavreas et al.[7] who reported that age differences did not seem to play an important role in the duration of orthodontic treatment during the permanent dentition stage. This disparity might have arisen from the research methodology adopted by Mavreas et al.[7] which was mainly a systematic review of several aggregate reports, with methodological deficiencies and biased conclusions.

The results of the present report are reliable for the techniques described. In fact, the incorporation of certain procedures, surgical or physical, could have significant influences on the results. For example, the use of temporary anchorage devices which provide absolute anchorage due to their mechanical properties for space closure mechanics could have impacted the alignment rates.[29,30]

One unavoidable limitation of this study is a gap between the exact day of full alignment and the 4-weekly follow-up visits, which may not necessarily reflect the real-time tooth alignment. Also, the paucity of literature on extraction protocols and tooth alignment rate may have limited proper study comparison. Further studies on this subject are recommended to corroborate findings from the present study. Also, studies on space closure with temporary anchorage devices following this post-extraction protocols will be of great interest.

CONCLUSION

Generally, our study showed that the rate of incisor and canine alignment was not affected significantly by RE/HE protocol, gender, or dental arch. However, incisor and canine alignment was significantly faster in adolescents when compared with adults.

Ethics Committee Approval: Ethics committee approval was received from the Ethics Committee of the Obafemi Awolowo University Teaching Hospitals' Complex, Ile Ife, Nigeria with protocol number ERC/2016/10/10.

Informed Consent: Informed consent and assent were obtained from participants.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - A.A.O, O.D.O., K.A.K.; Design - A.A.O, O.D.O., K.A.K.; Supervision - A.A.O, O.D.O., K.A.K.; Materials - A.A.O, O.D.O., K.A.K.; Data Collection and/or Processing - A.A.O, O.D.O., K.A.K.; Analysis and/or Interpretation - A.A.O, O.D.O., K.A.K.; Literature Review - A.A.O, O.D.O., K.A.K.; Writing - A.A.O, O.D.O., K.A.K.; Critical Review - A.A.O, O.D.O., K.A.K.

Acknowledgments: We acknowledge Dr. Olusola Fajobi who assisted with the data analysis.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Tsichlaki A, Chin SY, Pandis N, Fleming PS. How long does treatment with fixed orthodontic appliances last? A systematic review. *Am J Orthod Dentofacial Orthop*. 2016;149(3):308-318. [CrossRef]
2. Uribe F, Padala S, Allareddy V, Nanda R. Patients', parents', and orthodontists' perceptions of the need for and costs of additional procedures to reduce treatment time. *Am J Orthod Dentofacial Orthop*. 2014;145(4):S65-S73. [CrossRef]
3. Skidmore KJ, Brook KJ, Thomson WM, Harding WJ. Factors influencing treatment time in orthodontic patients. *Am J Orthod Dentofacial Orthop*. 2006;129(2):230-238. [CrossRef]
4. Shenava S, Nayak UK, Bhaskar V, Nayak A. Accelerated orthodontics–a review. *Int J Sci Study*. 2014;1:35-39.
5. Moresca R. Orthodontic treatment time: can it be shortened? *Dent Press J Orthod*. 2018;23(6):90-105. [CrossRef]
6. Scott P, DiBiase AT, Sherriff M, Cobourne MT. Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: a randomized clinical trial. *Am J Orthod Dentofac Orthop*. 2008;134(4):470:e1-470:e70. [CrossRef]
7. Mavreas D, Athanasiou AE. Factors affecting the duration of orthodontic treatment: a systematic review. *Eur J Orthod*. 2008;30(4):386-395. [CrossRef]
8. Amler MH. Disturbed healing of extraction wounds. *J Oral Implantol*. 1999;25(3):179-184. [CrossRef]
9. Häsler R, Schmid G, Ingervall B, Gebauer U. A clinical comparison of the rate of maxillary canine retraction into healed and recent extraction sites-a pilot study. *Eur J Orthod*. 1997;19(6):711-719. [CrossRef]
10. Proffit WR, Fields HW, Larson B, Sarver DM. Contemporary orthodontics. 6th ed. St. Louis, Mo: *Elsevier Mosby;* 2018; pp. 501-517.
11. Wahab RMA, Idris H, Yacob H, Ariffin SHZ. Comparison of self-and conventional-ligating brackets in the alignment stage. *Eur J Orthod*. 2012;34(2):176-181. [CrossRef]
12. Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. *Am J Orthod*. 1975;68(5):554-563. [CrossRef]
13. Souza R, Oliveira AFd, Pinheiro SMS, Cardoso JP. Magnani MBBdA. Expectations of orthodontic treatment in adults: the conduct in orthodontist/patient relationship. *Dent Press J Orthod*. 2013;18(2):88-94.
14. Harris EF, Glassell BE. Sex differences in the uptake of orthodontic services among adolescents in the United States. *Am J Orthod Dentofacial Orthop*. 2011;140(4):543-549. [CrossRef]
15. Liepa A, Urtane I, Richmond S, Dunstan F. Orthodontic treatment need in Latvia. *Eur J Orthod*. 2003;25(3):279-284. [CrossRef]
16. Geron S, Atalia W. Influence of sex on the perception of oral and smile esthetics with different gingival display and incisal plane inclination. *Angle Orthod*. 2005;75(5):778-784. [CrossRef]
17. Murphey Jr WH. Oxytetracycline microfluorescent comparison of orthodontic retraction into recent and healed extraction sites. *Am J Orthod*. 1970;58(3):215-239. [CrossRef]
18. Dudic A, Giannopoulou C, Kiliaridis S. Factors related to the rate of orthodontically induced tooth movement. *Am J Orthod Dentofacial Orthop*. 2013;143(5):616-621. [CrossRef]
19. Giannopoulou C, Dudic A, Pandis N, Kiliaridis S. Slow and fast orthodontic tooth movement: an experimental study on humans. *Eur J Orthod*. 2016;38(4):404-408. [CrossRef]
20. Verna C, Melsen B. Tissue reaction to orthodontic tooth movement in different bone turnover conditions. *Orthod Craniofac Res*. 2003;6(3):155-163. [CrossRef]
21. Chugh T, Jain AK, Jaiswal RK, Mehrotra P, Mehrotra R. Bone density and its importance in orthodontics. *J Oral Biol Craniofac Res*. 2013;3(2):92-97. [CrossRef]
22. Lerner UH. Bone remodeling in post-menopausal osteoporosis. *J Dent Res*. 2006;85(7):584-595. [CrossRef]

23. Omar M, Kaklamanos EG. Does the rate of orthodontic tooth movement change during pregnancy and lactation? A systematic review of the evidence from animal studies. *BMC Oral Health*. 2020;20(1):237. [CrossRef]
24. Ren Y, Maltha JC, Van 't Hof MA, Kuijpers-Jagtman AM. Age effect on orthodontic tooth movement in rats. *J Dent Res*. 2003;82(1):38-42. [CrossRef]
25. Reitan K. Clinical and histologic observations on tooth movement during and after orthodontic treatment. *Am J Orthod*. 1967;53(10): 721-745. [CrossRef]
26. Ren Y, Kuijpers-Jagtman AM, Maltha JC. Immunohistochemical evaluation of osteoclast recruitment during experimental tooth movement in young and adult rats. *Arch Oral Biol*. 2005;50(12):1032-1039. [CrossRef]
27. Ren Y, Maltha JC. Van Ren Y, et al. Cytokine levels in crevicular fluid are less responsive to orthodontic force in adults than in juveniles. *J Clin Periodontol*. 2002;29(8):757-762. [CrossRef]
28. Kawasaki K, Takahashi T, Yamaguchi M, Kasai K. Effects of aging on RANKL and OPG levels in gingival crevicular fluid during orthodontic tooth movement. *Orthod Craniofac Res*. 2006;9(3):137-142. [CrossRef]
29. Amasyalı M, Sabuncuoğlu FA, Oflaz U. Intraoral molar distalization with intraosseous mini screw. *Turk J Orthod*. 2018;31(1):26-30. [CrossRef]
30. Sfondrini MF, Gandini P, Alcozer R, Vallittu PK, Scribante A. Failure load and stress analysis of orthodontic miniscrews with different transmucosal collar diameter. *J Mech Behav Biomed Mater*. 2018;87:132-137. [CrossRef]