*Original Article*

# Association between arch width changes and long-term stability 20 years after orthodontic treatment with and without extractions

**Vjera Perkovic[a]; Moody Alexander[b]; Preston Greer[c]; Ervin Kamenar[d]; Sandra Anic-Milosevic[e]**

**ABSTRACT**

**Objectives:** To investigate long-term stability 20 years after orthodontic treatment and the association with arch width changes during treatment.

**Materials and Methods:** This retrospective study investigated 103 patients with Class I and II malocclusions treated with fixed appliances with and without extractions. The sample was treated by one experienced orthodontist and collected from a private orthodontic office. Dental casts were obtained pretreatment (T1), posttreatment (T2), and long-term postretention (T3); they were scanned and converted to STL files. Measurements were evaluated in for the upper and lower arch: intercanine width (IC), intermolar (IM) width, Little's irregularity index (LII).

**Results:** There were 73 female and 30 male patients. Class I was present in 74 patients and Class II in 29. Average postretention time was 17.2 ($\pm$6.5) years after an average active retention time of 3.4 ($\pm$1.17) years. Extraction was performed in 55 patients while 48 received nonextraction treatment. Bonferroni Post Hoc test showed that LII in the upper and lower arches at T1 was significantly higher in the extraction group ($P < .001$). Upper and lower arch LII at T3 was slightly higher in extraction cases but remained under 2.05 mm. LII at T3 in the upper and lower arches showed negative correlation with IM T3 in the upper arch (Pearson, $N = 103$, $P = .047$), while IC in the upper and lower arches at T3 correlated with IM T3 in the upper and lower ($N = 103$, $P < .001$).

**Conclusions:** Clinically relevant long-term stability in both arches was found in extraction and nonextraction cases. Intermolar width and its change during orthodontic treatment was an influential factor on long-term stability in extraction cases. (*Angle Orthod.* 2023;93:261–268.)

**KEY WORDS:** Stability; Orthodontics; Arch width

## INTRODUCTION

Orthodontic treatment consists of an active treatment period, in which teeth are moved into a desired position, and a retention period, where teeth are retained in the corrected position. After the retention period, which lasts a certain period of time, it is assumed the teeth will remain stable in the corrected position for many years after orthodontic treatment. However, different dental arches show different levels of stability, as demonstrated in previous studies.[1–7] It had been claimed that a longer period of posttreatment time (more than 10 years) shows greater instability.[2]

According to past research, biological or treatment-related factors, such as periodontal tissue, muscular imbalance, jaw growth, mandibular rotation, mandibular intercanine width, and mandibular incisor position, can have an impact on long-term stability.[4,8–10] Also, retention method and duration can affect treatment stability.[11] Yet, some previous studies did not exclude treatment-related stability factors proven to promote unstable long-term results. These factors should not be overlooked and must be incorporated into studies to fully understand long-term stability results. Perhaps this is why the literature shows variable results for long-term stability. For example, factors such as pronounced proclination of lower incisors, overexpansion of intercanine width, or quality of treatment outcome

[a] Research Assistant, Department of Orthodontics, Faculty of Dental Medicine, University of Rijeka, Rijeka, Croatia.
[b] Private Practice, Arlington, TX, USA.
[c] Private Practice, Waco, TX, USA.
[d] Assistant Professor, Faculty of Engineering, Laboratory for Precision Engineering, University of Rijeka, Rijeka, Croatia.
[e] Professor, Department of Orthodontics, School of Dental Medicine, University of Zagreb, Zagreb, Croatia.
Corresponding author: Dr Vjera Perkovic, Department of Orthodontics, University of Rijeka, Kresimirova 40, Rijeka 51000, Croatia
(e-mail: vjera.perkovic@yahoo.com)

Accepted: December 2022. Submitted: August 2022.
Published Online: February 06, 2023

can also affect treatment stability.[12–14] Studies that reported greater posttreatment irregularity often included patients treated at university training programs.[1,15,16] In addition, excessive proclination of lower incisors during treatment seems to be related to posttreatment retroclination.[17]

A larger number of studies investigated the mandibular arch since it seems that irregularity is greater in the mandibular arch.[2,3,7,15,18] Bjering et al. concluded that extraction of premolars significantly improved long-term stability of mandibular incisor alignment, while Swidi et al. concluded that irregularity increases were slightly greater in patients treated with mandibular premolar extractions.[2,7] Fewer studies compared extraction and nonextraction treatment long-term stability. A recent study by Cotrin et al. showed there was no difference in the long-term change in anterior alignment and transverse arch dimensions between patients treated with and without extractions; however, there was clinically unsatisfactory Little's irregularity index measures in the long-term period in both arches (>3.5 mm).[6]

In the current literature, no predictors of long-term stability after orthodontic treatment have been identified. This study aimed to investigate the effect of arch widths and their changes during treatment on the long-term stability of dental arches.

## MATERIALS AND METHODS

This retrospective study was approved by the Ethics Committee of the School of Dental Medicine, University of Zagreb (Protocol No. 05-PA-30-XV-3/2020). The study included dental casts from 103 patients. The sample was collected from a patient database of a private orthodontic office in Arlington, Texas, USA, and patients were treated by one experienced orthodontist (RWA) during the 1970s and 1980s. Inclusion criteria were: patients with initial Class I or Class II malocclusion treated with comprehensive orthodontic treatment with bonded fixed appliances in both arches with and without extraction of permanent premolars, full records before treatment, after treatment, and with a post-retention period of at least 5 years. Exclusion criteria were: missing permanent teeth (except third molars), Class III patients and craniofacial anomalies, missing full records, and circumferential supracrestal fiberotomy (CSF) performed. The active retention protocol lasted for 3 years with the following appliances: wraparound retainer in the upper arch and fixed retainer from canine to canine in the lower arch. Retention appliances were removed after 3 years and interproximal reduction (IPR) was performed in the lower intercanine segment in patients for whom this was not done during treatment. Dental casts were obtained at three time points: pretreatment (T1), posttreatment (T2), and long-term postretention of at least 5 years (T3). All dental casts were scanned with an Ortho Insight 3D scanner (Motion View LLC, Hixon, Tenn, USA) and converted to digital 3D dental casts (STL files). Linear measurements were evaluated in customized MATLAB software, programmed for this research, at all three timepoints:

1. Intercanine width (IC): measured as the distance between cusp tips of the left and right canines (mm) in the upper and lower arch.
2. Upper intermolar width (IM): measured as the distance between intersections of the transverse and buccal fissures of the left and right permanent first molars.
3. Lower intermolar width (IM): distance between mesiobuccally cusp tips of the left and right permanent first molars.
4. Little's irregularity index (LII): the sum of five linear displacements of anatomic contact points of the six anterior teeth, measured in the upper and lower arch.

Measurements were performed by one experienced and calibrated examiner (VP). Thirty days after initial measurements, 40 dental casts were randomly selected to check for intraexaminer reliability. There were no statistically significant systematic errors between repeated measurements. Random errors were calculated according to Dahlberg's formula and ranged between 0.05 to 0.21 mm. Statistical analyses was performed in STATISTICA 64, version 10 for Windows.

## RESULTS

There were 73 (70.9%) female and 30 (29.1%) male patients; 71.8% of cases were Class I and 28.2% were Class II at T1. The average post retention time was 17.2 $\pm$ 6.5 years after an average active retention time of 3.4 $\pm$ 1.17 years. Overall, T3 was 20.5 $\pm$ 6.51 years after orthodontic treatment was finished. Extraction was performed in 55 (53.4%) patients, and 48 patients (46.6%) were treated nonextraction. The average age at T1 was 12.8 $\pm$ 1.78 years, at T2 was 15.2 $\pm$ 1.78 years, and at T3 was 35.8 $\pm$ 6.53 years.

There was no significant difference in LII associated with sex or classification. However, there were significant differences in LII between extraction and nonextraction cases. LII according to treatment method and timepoint is shown in Table 1. At T1, the sample was divided into extraction or nonextraction groups according to their initial treatment plan even though extractions were not done in the T1 time period. LII in the upper arch showed a statistically significant difference between treatment modalities and among time periods as well as their interactions (analysis of

**Table 1.** Little's Irregularity Index (LII) According to Treatment Method at Different Timepoints

| Little Irregularity Index | Period | Treatment Method | N[a] | $\bar{x}$[b] | $s$[c] | Min[d] | Max[e] |
|---|---|---|---|---|---|---|---|
| Upper arch | T1 | Extraction | 44 | 6.96 | 2.93 | 1.31 | 14.49 |
| | | Nonextraction | 45 | 5.60 | 2.05 | 2.16 | 11.45 |
| | | Total | 89 | 6.27 | 2.60 | 1.31 | 14.49 |
| | T2 | Extraction | 55 | 0.54 | 0.63 | 0.00 | 2.48 |
| | | Nonextraction | 48 | 0.27 | 0.42 | 0.00 | 2.26 |
| | | Total | 103 | 0.41 | 0.56 | 0.00 | 2.48 |
| | T3 | Extraction | 55 | 1.69 | 1.27 | 0.00 | 5.54 |
| | | Nonextraction | 48 | 1.10 | 0.79 | 0.00 | 3.22 |
| | | Total | 103 | 1.42 | 1.11 | 0.00 | 5.54 |
| Lower arch | T1 | Extraction | 49 | 6.69 | 3.55 | 1.13 | 14.44 |
| | | Nonextraction | 48 | 4.53 | 2.68 | 0.37 | 12.27 |
| | | Total | 97 | 5.62 | 3.31 | 0.37 | 14.44 |
| | T2 | Extraction | 55 | 0.54 | 0.67 | 0.00 | 3.76 |
| | | Nonextraction | 48 | 0.41 | 0.39 | 0.00 | 1.35 |
| | | Total | 103 | 0.48 | 0.56 | 0.00 | 3.76 |
| | T3 | Extraction | 55 | 2.05 | 1.64 | 0.00 | 7.27 |
| | | Nonextraction | 48 | 1.52 | 1.27 | 0.09 | 6.53 |
| | | Total | 103 | 1.80 | 1.49 | 0.00 | 7.27 |

[a] number of participants; [b] mean; [c] standard deviation; [d] minimal value; [e] maximal value.

variance, $F = 3.05$, $df = 2$, $P < .005$). Figure 1 and Figure 2 show average LII values for extraction and nonextraction cases in the upper and lower arch, respectively. The Bonferroni post hoc test showed that average LII at T1 in the upper and lower arch was significantly higher in extraction cases ($P < .001$). At T2 and T3, these differences were not statistically significant. In both groups, there was a significant decline of LII at T2, which slightly increased at T3, but not significantly.

Intercanine width was greater in both arches in males at all three timepoints (Table 2). In females, upper arches treated with extraction showed decreased intercanine width at T3 and, in males, extractions caused an increase of intercanine width at T2 and T3. Similar results were seen in the lower arch (Figures 3 and 4). Lower arch intercanine width in males at T2 was significantly greater than intercanine width in females at T1. In females, intercanine width did not change significantly at different timepoints in nonextraction cases.

Intermolar widths in extraction cases are shown in Table 3. Intermolar width in females at T3 was significantly lower than in males. Figures 5 and 6 show average values of intermolar width in the upper and lower arch, respectively, for male and female extraction and nonextraction cases. Extraction significantly decreased intermolar width at T2 in both arches and maintained its value at T3. Changes in nonextraction treatment were opposite to those in extraction cases, but similar in the upper and lower arches. Intermolar width increased and maintained its value in both arches.

Before orthodontic treatment (T1), Pearson's correlation showed that LII in the upper arch was not

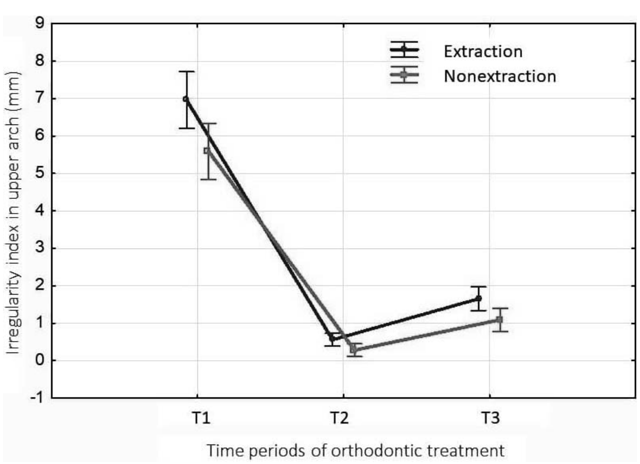


**Figure 1.** Average values of irregularity index in the upper arch at three timepoints in extraction and nonextraction cases.

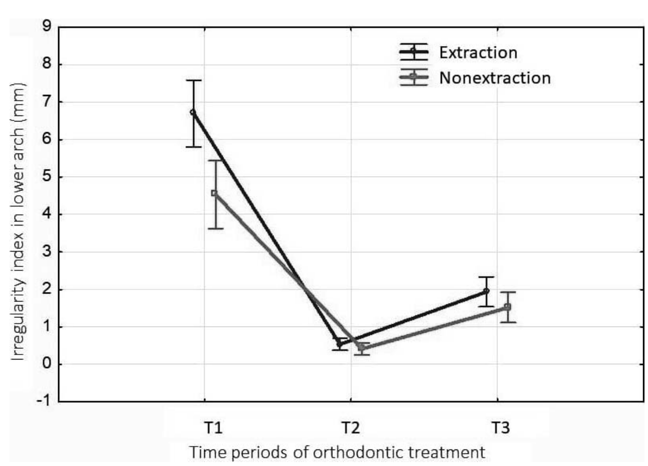


**Figure 2.** Average values of irregularity index in the lower arch at three timepoints in extraction and nonextraction cases.

**Table 2.** Intercanine Width According to Treatment Method at Different Timepoints.

| Intercanine Width | Period | Treatment Method | N[a] | $\bar{x}$[b] | $s$[c] | Min[d] | Max[e] |
|---|---|---|---|---|---|---|---|
| Upper arch | T1 | Extraction | 43 | 33.46 | 2.22 | 29.26 | 38.35 |
| | | Nonextraction | 47 | 33.96 | 2.46 | 28.77 | 40.60 |
| | | Total | 90 | 33.72 | 2.35 | 28.77 | 40.60 |
| | T2 | Extraction | 55 | 34.13 | 1.95 | 29.27 | 39.29 |
| | | Nonextraction | 48 | 33.86 | 1.45 | 30.75 | 36.81 |
| | | Total | 103 | 34.01 | 1.73 | 29.27 | 39.29 |
| | T3 | Extraction | 55 | 33.50 | 2.09 | 29.15 | 38.46 |
| | | Nonextraction | 48 | 33.88 | 1.79 | 29.24 | 37.14 |
| | | Total | 103 | 33.68 | 1.95 | 29.15 | 38.46 |
| Lower arch | T1 | Extraction | 49 | 25.23 | 1.93 | 22.47 | 30.19 |
| | | Nonextraction | 48 | 25.45 | 1.87 | 20.59 | 30.23 |
| | | Total | 97 | 25.34 | 1.90 | 20.59 | 30.23 |
| | T2 | Extraction | 55 | 26.13 | 1.39 | 22.21 | 30.18 |
| | | Nonextraction | 48 | 25.59 | 1.25 | 22.82 | 28.00 |
| | | Total | 103 | 25.88 | 1.35 | 22.21 | 30.18 |
| | T3 | Extraction | 55 | 24.87 | 1.47 | 22.53 | 28.11 |
| | | Nonextraction | 48 | 25.36 | 1.38 | 22.77 | 29.05 |
| | | Total | 103 | 25.10 | 1.45 | 22.53 | 29.05 |

[a] number of participants; [b] mean; [c] standard deviation; [d] minimal value; [e] maximal value.

significantly correlated to any arch width measurements. However, LII in the lower arch was significantly negatively correlated to all of the width measurements except the upper intercanine width. Therefore, higher LII in the lower arch was accompanied by narrower lower intercanine width and narrower intermolar width in both arches. At the T3 timepoint, in patients treated with extractions, there was a significant negative correlation between intermolar width treatment change in the upper arch (T2 − T1) and LII in the upper and lower arches (N = 55, $P = .010$; N = 55, $P < .001$) (Tables 4 and 5).

## DISCUSSION

This was a retrospective study in which the average evaluation time of long-term changes in stability after orthodontic treatment was 17 ± 6.5 years in postretention. The present study showed minimal misalignment in the postretention period with satisfactory alignment (LII under 3 mm) in 95 (92.2%) cases in the upper arch, and 85 (82.5%) cases in the lower arch. Overall, these results demonstrated excellent stability for such a long postretention period. Although only a few studies investigated long-term changes over 10 years posttreatment, the findings were in agreement with two other studies with similar postretention time periods, but only with extraction cases. Vaden et al. studied extraction cases 15 years postretention and found minimal irregularity in both arches.[19] Dyer et al. investigated long-term stability 24 years postretention in extraction cases. Maxillary LII was stable long term, while mandibular LII at T3 was less than 3.5 mm in 77% of patients.[20] In both studies, patients were treated

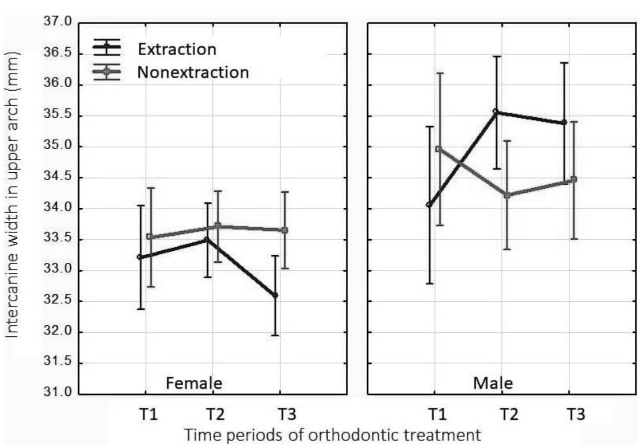


**Figure 3.** Average values of intercanine width in the upper arch at three timepoints in extraction and nonextraction cases for males and females.

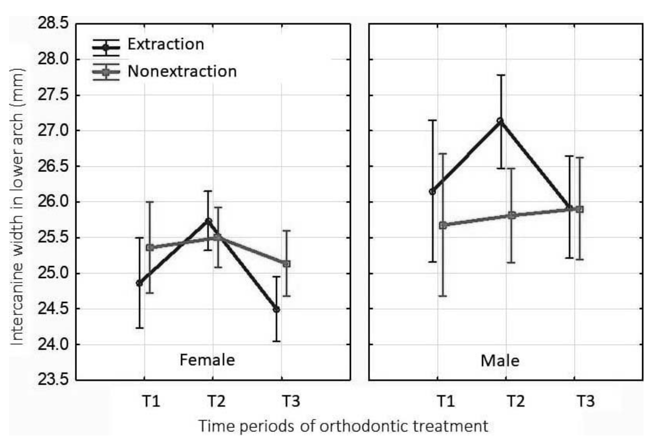


**Figure 4.** Average values of intercanine width in the lower arch at three timepoints in extraction and nonextraction cases for males and females.

**Table 3.** Intermolar Width According to Treatment Method at Different Timepoints

| Intermolar Width | Period | Treatment Method | N[a] | $\bar{x}$[b] | $s$[c] | Min[d] | Max[e] |
|---|---|---|---|---|---|---|---|
| Upper arch | T1 | Extraction | 55 | 43.46 | 2.79 | 38.57 | 53.01 |
| | | Nonextraction | 48 | 45.69 | 2.89 | 38.75 | 51.78 |
| | | Total | 103 | 44.50 | 3.03 | 38.57 | 53.01 |
| | T2 | Extraction | 55 | 42.45 | 2.10 | 38.26 | 47.85 |
| | | Nonextraction | 48 | 46.99 | 2.68 | 41.91 | 53.59 |
| | | Total | 103 | 44.56 | 3.29 | 38.26 | 53.59 |
| | T3 | Extraction | 55 | 42.05 | 2.40 | 36.45 | 48.16 |
| | | Nonextraction | 48 | 46.98 | 2.81 | 41.77 | 53.19 |
| | | Total | 103 | 44.35 | 3.58 | 36.45 | 53.19 |
| Lower arch | T1 | Extraction | 55 | 44.34 | 3.14 | 39.10 | 52.14 |
| | | Nonextraction | 48 | 45.90 | 2.66 | 40.14 | 51.19 |
| | | Total | 103 | 45.07 | 3.01 | 39.10 | 52.14 |
| | T2 | Extraction | 55 | 42.41 | 2.12 | 39.23 | 46.93 |
| | | Nonextraction | 48 | 46.84 | 2.42 | 42.79 | 52.69 |
| | | Total | 103 | 44.48 | 3.16 | 39.23 | 52.69 |
| | T3 | Extraction | 55 | 42.08 | 2.51 | 37.24 | 47.37 |
| | | Nonextraction | 48 | 46.93 | 2.49 | 42.22 | 53.42 |
| | | Total | 103 | 44.34 | 3.48 | 37.24 | 53.42 |

[a] number of participants; [b] mean; [c] standard deviation; [d] minimal value; [e] maximal value.

by one orthodontist whose treatment philosophy was to keep the roots in the basal bone. Other studies showed poor stability in the long term (more than 10 years).[1,6,21] Little et al. conducted one of the first comprehensive long-term stability studies that showed poor stability results. In the study, satisfactory mandibular anterior alignment (under 3.5 mm) was found in less than 30% of cases in a 10-year postretention period, while only 10% of cases showed satisfactory alignment 10 to 20 years postretention. The sample consisted of extraction cases and the quality of treatment was not evaluated. The study concluded that there was no perfect stability in the long term and retention should be permanent.[1] A more recent study compared long-term dental arch changes in a postretention period of 37 years. There were no differences between extraction and nonextraction cases; however, both groups showed moderate Little's irregularity index (>3.5 mm) in both arches in the long term.[6,21] Eventhough long-term changes were investigated in previous literature, no predictors for long-term stability were established, though some clinical treatment guidelines for better stability were given.

The explanation for good stability of anterior alignment in extraction and nonextraction cases in this study perhaps lies in the fact that good diagnostics and treatment decisions were made in the beginning. Many studies did not address this problem, which resulted in inconsistent conclusions. We may assert now that, when stability guidelines are not respected, instability is inevitable.

The orthodontist who treated the patients in this study previously developed a technique, having long-

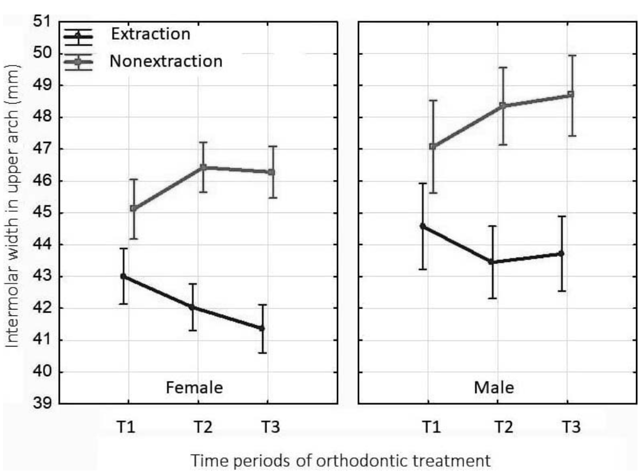


**Figure 5.** Average values of intermolar width in the upper arch at three timepoints in extraction and nonextraction cases for males and females.

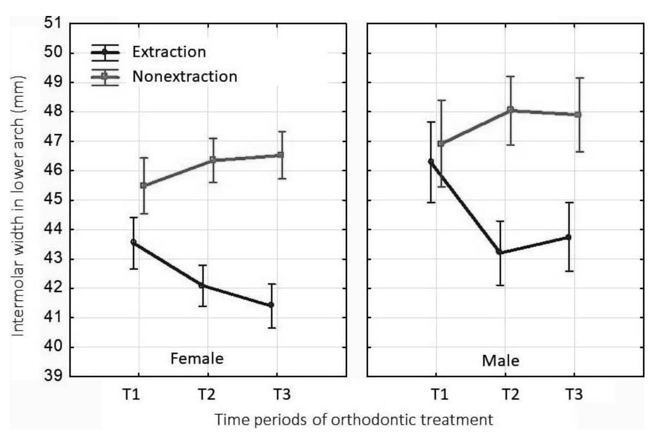


**Figure 6.** Average values of intermolar width in the lower arch at three timepoints in extraction and nonextraction cases for males and females.

**Table 4.** Correlation Between Little's Irregularity Index and Intercanine and Intermolar Width Changes in Patients Treated With Extractions

| Variable | LII_U_T3 | LII_U_T32 | LII_L_T3 | LII_L_T32 |
|---|---|---|---|---|
| IC_U_T21 | 0.1341 | −0.1228 | 0.2838 | 0.2179 |
| | N = 43 | N = 43 | N = 43 | N = 43 |
| | *P* = .391 | *P* = .433 | *P* = .065 | *P* = .160 |
| IC_L_T21 | −0.1315 | −0.1467 | −0.0690 | −0.0360 |
| | N = 49 | N = 49 | N = 49 | N = 49 |
| | *P* =.368 | *P* = .314 | *P* = .638 | *P* = .806 |
| IM_U_T21 | **−0.3430** | −0.1681 | −0.1235 | 0.0510 |
| | **N = 55** | N = 55 | N = 55 | N = 55 |
| | ***P* = .010** | *P* = .220 | *P* = .369 | *P* = .711 |
| IM_L_T21 | **−0.5054** | −0.3751 | 0.0130 | 0.1392 |
| | **N = 55** | N = 55 | N = 55 | N = 55 |
| | ***P* = 0** | *P* = .005 | *P* = .925 | *P* = .311 |

**Table 5.** Correlation Between Little's Irregularity Index and Intercanine and Intermolar Width Changes in Patients Treated Nonextraction

| Variable | LII_U_T3 | LII_U_T32 | LII_L_T3 | LII_L_T32 |
|---|---|---|---|---|
| IC_U_T21 | 0.0304 | 0.0367 | −0.0062 | −0.0835 |
| | N = 47 | N = 47 | N = 47 | N = 47 |
| | *P* = .839 | *P* = .807 | *P* = .967 | *P* = .577 |
| IC_L_T21 | 0.0685 | −0.0673 | 0.1923 | 0.2139 |
| | N = 48 | N = 48 | N = 48 | N = 48 |
| | *P* = .644 | *P* = .650 | *P* = .190 | *P* = .144 |
| IM_U_T21 | 0.0405 | −0.0307 | 0.0080 | 0.0038 |
| | N = 48 | N = 48 | N = 48 | N = 48 |
| | *P* = .784 | *P* = .836 | *P* = .957 | *P* = .980 |
| IM_L_T21 | −0.1608 | 0.0526 | −0.1071 | −0.1006 |
| | N = 48 | N = 48 | N = 48 | N = 48 |
| | *P* = .275 | *P* = .723 | *P* = .469 | *P* = .496 |

[a] **This Note is for Tables 4 and 5.** Note: IC_U_T21 indicates upper intercanine width change from T1 to T2 period; IC_L_T21, lower intercanine width change from T1 to T2 period; IM_U_T21, upper intermolar width change form T1 to T2 period; IM_L_T21, lower intermolar width change from T1 to T2 period; LII_U_T3, upper Little Irregularity Index at T3 period; LII_U_T32, upper Little Irregularity Index change from T2 to T3 period; LII_L_T3, lower Little Irregularity Index at T3 period; LII_L_T32, lower Little Irregularity Index change from T2 to T3 period.

term stability as a treatment goal, and incorporated principles into a treatment technique promoting stability, such as keeping the teeth inside the basal bone, limiting proclination of lower incisors to 3°, and limiting expansion of intercanine width to a maximum of 1 mm.[8] According to his philosophy, if teeth were placed in the appropriate positions during active treatment, interproximal reduction was properly performed, and third molars were resolved, then the chance of the result remaining stable after retainer removal was excellent. Since several studies have concluded that third molars do not influence crowding, that issue was not addressed in the current study.[22]

Another aspect that might have contributed to stability in this study was interproximal reduction (IPR), which was performed at the end of the retention period in the lower canine-to-canine segment. IPR was done only in cases where it was not done during the treatment, whether the treatment method was extraction or nonextraction. Contact points were modified into contact surfaces, which were used as a stabilizing procedure. The amount of IPR was not indicated. However, other authors have observed and promoted this method.[3, 23–26]

Intercanine width changed as expected and as has been reported in previous research.[7,18] In nonextraction cases, changes between each timepoint were minimal: less than 0.5 mm in both arches. In extraction cases, changes were greater but still less than 1 mm with slightly larger change in long-term postretention in the lower arch. Greater changes are attributed to the movements of canines into extraction spaces. It was not the study's aim to compare changes between males and females, but there was a notable difference in intercanine width between genders. Males showed wider arches than females at all timepoints. In extraction cases, changes of intercanine width were similar in both arches between females and males: it reduced from end of treatment to the postretention period. Interestingly, in nonextraction female cases, intercanine width reduced from T2 to T3, while it increased in males. Perhaps this difference could be attributed to the fact that narrower arches (such as those in which extraction was performed or female arches in contrast to male arches) in general tend to have greater posttreatment changes.[27]

Though intermolar width was a variable that showed very little change in extraction and nonextraction cases in both arches and had presented with good stability long term, intermolar width was associated with stability in this research. Treatment changes of intermolar width in upper arch in extraction cases significantly negatively correlated with Little's irregularity index in the upper arch in the postretention period. Thus, greater change in intermolar width in extraction cases in the upper arch influenced stability in the postretention period. It may be concluded that, in these cases, extraction was a good decision, since an extraction created a narrower arch that contributed to better stability. In contrast, if patients were treated with nonextraction, overexpansion would be performed and stability may have been worse. Also, male patients presented with greater intermolar width at all timepoints in extraction and nonextraction cases.

Since good stability of the dental arches was reported 17 years out of retention, the findings did not support research suggesting long-term use of fixed or removable retainers to maintain satisfactory alignment. In this study, the active retention protocol lasted for 3 years. This was considered important since patients were treated and retained throughout the critical growth ages when greatest irregularity changes are expected to occur.[2] One recent study investigated relapse with removable retainers and the associations of short- and long-term wear with stability.[28] Mandibular irregularity was significantly greater with a shorter wear time than with a longer wear time at the end of the 12-month follow-up period. The amount of mandibular LII after a 1-year retention period was almost the same as LII at 17 years out of retention reported in this study.

When discussing long-term alignment, physiological changes should also be considered. There is a trend toward arch constriction with age, which some studies call dental arch maturation. According to others, it is difficult to distinguish relapse changes and normal adaptations due to aging. In untreated subjects, research has shown that, in 10 years (from age 20 to 30) Little's Irregularity Index in the lower arch increased only 1 mm, while intercanine width decreased by 0.43 mm. Some studies showed that changes in untreated subjects were smaller than in treated patients.[29] Even so, in the current study, arch dimensions and alignment changes were minimal, especially in nonextraction cases where intercanine width changes were in the range of 0.02–0.23 mm, and extraction cases were 0.63–1.26 mm. Since the changes were similar to those reported in untreated subjects, further research is needed to establish the difference between relapse and changes expected to occur with aging.

This study had certain limitations. The first was that the sample was not randomly selected, but taken from a pool of previously treated patients. Some of them were contacted by telephone or mail and asked to come for recall, while some were relatives of current patients in treatment (at the time of collecting data) who would accompany them to the orthodontic office and, for that reason, they were asked to participate. Additionally, treatment selection was not randomized but carefully selected. This will often be an issue, since it is not possible to randomize treatment protocols in orthodontics. There are specific indications that determine when a case should be treated with or without extractions. With limitations considered, the results should be interpreted with caution.

Since randomized controlled trials might be difficult to conduct for 15 years or more, future studies should focus on researching the long-term stability of dental arches, but with treatment guidelines that promote stability as inclusion criteria. Also, associations between anterior alignment and IPR should be investigated in future studies.

## CONCLUSIONS

- Upper and lower arches in extraction and nonextraction cases after orthodontic treatment showed good stability in the long-term postretention period.
- Long-term stability in extraction cases and nonextraction cases is achievable.
- Upper intermolar width and its change during orthodontic treatment may be an influential factor on long-term stability in extraction cases while, in the lower arch of extraction and nonextraction cases, factors associated with stability are yet to be established.

## REFERENCES

1. Little RM, Riedel RA, Artun J. An evaluation of changes in mandibular anterior alignment from 10-20 years postretention. *Am J Orthod Dentofacial Orthop*.1988;93:423–428.
2. Swidi AJ, Griffin AE, Buschang PH. Mandibular alignment changes after full-fixed orthodontic treatment: a systematic review and meta-analysis. *Eur J Orthod*. 2019;41:609–621.
3. Freitas KMS, de Freitas MR, Castanha Henriques JF, Pinzan A, Janson G. Postretention relapse of mandibular anterior crowding in patients treated without mandibular premolar extraction. *Am J Orthod Dentofacial Orthop*. 2004; 125:480–487.
4. Erdinc AE, Nanda RS, Isiksal E. Relapse of anterior crowding in patients treated with extraction and nonextraction of premolars. *Am J Orthod Dentofacial Orthop*. 2006; 129:775–784.
5. Shah AA. Postretention changes in mandibular crowding: a review of the literature. *Am J Orthod Dentofacial Orthop*. 2003;124:298–308.
6. Cotrin P, Martins Gambardela-Tkacz C, Moura W, et al. Anterior tooth alignment and arch dimensions changes: 37-year follow-up in patients treated with and without premolar extraction. *Am J Orthod Dentofacial Orthop*. 2020;158:5–15.
7. Bjering R, Sandvik L, Midtbo M, Vandevska-Radunovic V. Stability of anterior tooth alignment 10 years out of retention. *J Orofac Orthop*. 2017;78:275–283.
8. Alexander RG. *The Alexander Discipline Volume 2: Long-Term Stability. 1st ed*. Hanover Park, IL: Quintessence Publishing Co, Inc; 2011.
9. Maltha JC, von den Hoff JW. Biological basis for orthodontic relapse. In: Katsaros C, Elisades T, eds. *Stability, Retention and Relapse in Orthodontics*. Quintessence Publishing, Berlin. 2017. p.16.
10. Al Yami AE, Kuijpera- Jagtman AM, Van't Hof MA. Stability of orthodontic treatment outcome: follow up until 10 years postretention. *Am J Orthod Dentofacial Orthop*.1999;115: 300–304.
11. Al-Moghrabi D, Johal A, O'Rourke N, et al. Effects of fixed vs removable orthodontic retainers on stability and periodontal health: 4-year follow-up of a randomized controlled trial. *Am J Orthod Dentofacial Orthop*. 2018;154:167–174.
12. Hansen K. Treatment and posttreatment effects of the Herbst appliance on the dental arches and arch relationships. *Semin Orthod*. 2003;9:67–73.
13. Elms TN, Buschang PH, Alexander RG. Long-term stability of Class II division 1 nonextraction cervical face-bow therapy: cephalometric analysis. *Am J Orthod Dentofacial Orthop*. 1996;109:386–392.
14. Burke SP, Silveira AM, Goldsmith J, Yancey JM, Van Stewart A, Scarfe WC. A meta-analysis of mandibular

intercanine width in treatment and postretention. *Angle Orthod*. 1998;68:53–60.
15. Myser SA, Campbell PM, Boley J, Buschang PH. Long-term stability: postretention changes of mandibular anterior teeth. *Am J Orthod Dentofacial Orthop*. 2013;144:420–429.
16. Artun J, Garol JD, Little RM. Long-term stability of mandibular incisors following successful treatment of Class II, Division 1 malocclusions. *Angle Orthod*. 1996;66:229–238.
17. Mills JRE. The long-term results of the proclination of lower incisors. *Br Dent J*. 1967;120:355–363.
18. Anwar AS. Postretention changes in mandibular crowding: a review of literature. *Am J Orthod Dentofacial Orthop*. 2003; 124:298–308.
19. Vaden JL, Harris EF, Zeigler Gardner RL. Relapse revisited. *Am J Orthod Dentofacial Orthop*.1997;111:543–553.
20. Dyer KC, Vaden JL, Harris EF. Relapse revisited-again. *Am J Orthod Dentofacial Orthop*. 2012;142:221–227.
21. Freitas KMS, Guirro WJG, de Freitas DS, de Freitas MR, Janson G. Relapse of anterior crowding 3 and 33 years postretention. *Am J Orthod Dentofacial Orthop*. 2017;152: 798–810.
22. Karasawa LH, Rossi AC, Groppo FC, Prado FB, Caria PH. Cross-sectional study of correlation between mandibular incisor crowding and third molars in young Brazilians. *Med Oral Patol Oral Cir Bucal*. 2013;18:505–509.
23. Peck S. Extractions, retention and stability: the search for orthodontic truth. *Eur J Orthod*. 2017;39:109–115.
24. Peck S, Peck H. Crown dimensions and mandibular incisor alignment. *Angle Orthod*. 1972;42:148–153.
25. Boese LR. Fiberotomy and reproximation without mandibular retention, nine years in retrospect: part I and part II. *Angle Orthod*. 1980;50:88–97, 169–178.
26. Dugoni SA, Lee JS, Varela J, Dugoni AA. Early mixed dentition treatment: post-retention evaluation of stability and relapse. *Angle Orthod*.1995;65:311–320.
27. Buschang PH. Class I malocclusions—The development and etiology of mandibular malalignments. *Semin Orthod*. 2014;20:3–15.
28. İshakoğlu S, Çokakoğlu S. Evaluation of relapse with thermoplastic retainers equipped with microsensors. *Angle Orthod*. 2022;92:340–346.
29. Mauad BA, Silva RC, Aragón ML, Pontes LF, Silva Júnior NG, Normando D. Changes in lower dental arch dimensions and tooth alignment in young adults without orthodontic treatment. *Dental Press J Orthod*. 2015;20:64–68.