Original Article

Which one closes extraction spaces faster: en masse retraction or two-step retraction? *A randomized prospective clinical trial*

Patricia Pigato Schneider[a]; Ki Beom Kim[b]; André da Costa Monini[c]; Ary dos Santos-Pinto[d]; Luiz Gonzaga Gandini Júnior[d]

ABSTRACT

Objectives: To compare the time to close extraction spaces between en masse (ER) and two-step retraction (TSR).

Materials and Methods: Forty-eight patients with bimaxillary protrusion underwent treatment with extraction of four first premolars. All patients were randomly allocated to one of two groups: ER (n = 24) or TSR (n = 24). The main outcome was the time required to close spaces between ER and TSR; the closing time of spaces between females and males was a secondary outcome. The size of premolars was measured on the models and data were collected on clinical records at the following times: retraction start date (T1) and space closure completion date (T2). The total time to close the extraction spaces was calculated for each extracted premolar (T1 to T2). The Kaplan Meier method and the Log-Rank test were used to compare the groups.

Results: The time to close extraction spaces showed significant differences between the ER and TSR groups. While ER took between 12.1 and 13.8 months, TSR took between 24.7 and 26.8 months. The TSR group showed a significant difference between sexes; male patients took 5.5 months longer than female patients for the extraction spaces to close.

Conclusions: TSR takes between 1.8 and 2.2 times longer than ER to close the extraction spaces and it took longer in males than females. (*Angle Orthod.* 2019;89:855–861.)

KEY WORDS: Treatment time; Space closure; En masse retraction; Two-step retraction

INTRODUCTION

One of the first questions that new orthodontic patients ask is "How long will I need to wear braces?," and many factors can influence the answer.[1–4] The treatment time for each patient has been shown to depend on the their cooperation,[5] dental and facial characteristics, as well as the orthodontist's experience and his or her treatment decisions.[1]

Extraction treatment plans have been linked with longer treatment times,[1–3,6] and premolar extractions are the most significant in this time variation.[4,6–9] According to Fink and Smith,[9] each premolar extraction increases treatment time by approximately 0.94 months with four premolar extraction cases taking longer than two premolar extraction cases.[7,9]

Two basic biomechanical strategies can be used to close extraction spaces: two-step retraction (TSR) or en masse retraction (ER). In the first step of TSR, only the canine in each quadrant is retracted. In the second step, all the incisors are retracted until the residual spaces are closed.[10–14] In ER, the incisors and canines are retracted in just one step.[15]

In clinical practice, orthodontists are looking for space closing mechanics that provide good anchorage control and shorter treatment time.[13] In theory, TSR was believed to result in less anchorage loss,[10,14] so it has been the clinical choice of orthodontists for many years.[10,13] However, randomized clinical trials

[a] PhD Student, Department of Orthodontics, School of Dentistry at Araraquara, UNESP, São Paulo State University, Araraquara, São Paulo, Brazil.

[b] Associate Professor, Department of Orthodontics, Center for Advanced Dental Education, Saint Louis University, Saint Louis, Missouri, USA.

[c] Private Practice, Goiânia, Goiás, Brazil.

[d] Adjunct Professor, Department of Orthodontics, School of Dentistry at Araraquara, UNESP, São Paulo State University, Araraquara, São Paulo, Brazil.

Corresponding author: Dr Luiz Gonzaga Gandini Júnior, Department of Orthodontics, Room 113, School of Dentistry at Araraquara, UNESP, São Paulo State University, Humaitá, 1680, Araraquara, São Paulo Brazil, 14801-903
(e-mail: luiz.gandini@unesp.br)

Accepted: March 2019. Submitted: October 2018.
Published Online: July 1, 2019

Table 1. Baseline Skeletal and Dental Characteristics of Subjects Between ER and TSR[a]

Variable	Mean (SD) ER	Mean (SD) TSR	*P* Value	Sig
FMA, °	24.7 (5.2)	21.9 (6.8)	.116	ns
SNGoMe, °	30.6 (6.3)	27.9 (6.8)	.166	ns
PFH/AFH, mm	66.4 (5.0)	68.5 (6.4)	.207	ns
Overjet, mm	3.3 (1.3)	3.6 (1.2)	.405	ns
Overbite, mm	0.9 (2.0)	1.5 (1.5)	.211	ns
L1-Apo, mm	7.1 (2.7)	6.1 (2.6)	.188	ns
U1-Apo, mm	10.5 (2.4)	9.9 (3.0)	.429	ns
PgNperp, °	1.0 (6.7)	1.2 (8.1)	.458	ns
Convexity, NA-Apo, °	7.1 (4.0)	6.9 (3.1)	.817	ns
Lower Lip to E-Plane, mm	4.5 (3.8)	3.1 (3.2)	.159	ns
Maxillary crowding, mm	3.6 (0.6)	3.5 (1.1)	.740	ns
Mandibular crowding, mm	2.7 (0.7)	2.8 (0.6)	.729	ns

[a] SD indicates Standard Deviation; Sig, significance; ns, not significant by the Student's *t*-test at $P < .05$; SNGoMe, angle between Sella-Nasion and Gonion-Ment; PFH/AFH, relation between Posterior Facial Height/Anterior Facial Height; PgNperp, distance between Pg to Nperp line; L1Apo, protrusion of the lower incisor; U1Apo, protrusion of the upper incisor; FMA, angle between Frankfort horizontal plane and Mandibular plane; Convexity, angle between NA and Apo; Lower Lip to E-Plane, distance from Lower Lip to E-plane.

(RCTs)[14,16,17] have shown no difference in the mesial movement of molars between ER and TSR. The evaluation of the space closing time between retraction techniques has not been adequately explored in the literature as a factor that affects the total duration of orthodontic treatment,[1–4] and this question still needs to be investigated. "Retraction time" was reported briefly only as a secondary outcome in a few studies[14,16,17] showing no significant differences. In addition, the sample of these previous studies did not differentiate between Class I and Class II patients and some of the patients were still in the active growing phase. Additionally, some of these previous studies used various types of anchorage reinforcement (miniscrews, headgear or conventional anchorage).[14,18]

Despite the importance of being able to predict orthodontic treatment duration accurately,[1–4,7–9] no RCT was found in the literature that compared the time spent for space closing between ER and TSR. The purpose of this RCT was to evaluate the time required to close the spaces for each premolar extracted between the two retraction methods, without anchoring devices. Additionally, whether there was a difference in space closure time between male and female patients within ER and TSR groups.

MATERIALS AND METHODS

This RCT was approved by the Ethics Committee on Human Research of the School of São Paulo State University (ethical approval No. 01/09).

The initial sample was recruited between February and October of 2010 and consisted of 52 participants. The inclusion criteria were: Brazilian of at least 18 years of age, all permanent teeth erupted (except third molars), Class I bimaxillary protrusion malocclusion with mild crowding in the upper and lower incisors $\leq$4 mm, no previous orthodontic treatment history, good oral hygiene and no systemic diseases. Four participants were excluded due to periodontal disease or missing teeth. All selected participants had similar dental and skeletal characteristics (Table 1).

The participants were randomly allocated in a 1:1 ratio to either the ER group or the TSR group (Table 2) using a simple randomization technique.

Initial images, models, and radiographs were obtained before starting orthodontic treatment. All 48 participants received conventional orthodontic treatment with the same type of fixed appliances. Upper and lower 0.022-inch tubes were soldered to bands for the first and second molars and conventional 0.022-inch straight-wire brackets (Ovation; GAC International Inc, Bohemia, NY, USA) were bonded from the right second premolar to the left second premolar. Leveling and aligning were conducted until 0.020-inch stainless steel (SS) wires could be passively inserted into the brackets. The second premolar was tied to the second molars with 0.010-inch ligature wire bilaterally. Each patient had the four first premolars extracted at that time. Then, 7–14 days after extractions, space closing mechanics were activated.

In the ER group, all incisors were retracted in a single step. Archwires used were 0.017- $\times$ 0.025-inch SS and Nickel-titanium (NiTi) closed-coil springs activated to 200 g (GAC International) were attached from the hooks of the first molars to the hooks soldered

Table 2. Demographic Description of the Two Study Groups[a]

Group	n	Sex Female	Sex Male	Starting Age, Mean (SD) (y)	Age Range, y
ER	24	14	10	23.9 (3.43)	19–32
TSR	24	15	9	22.0 (4.8)	18–34

[a] SD indicates Standard Deviation; y, years.

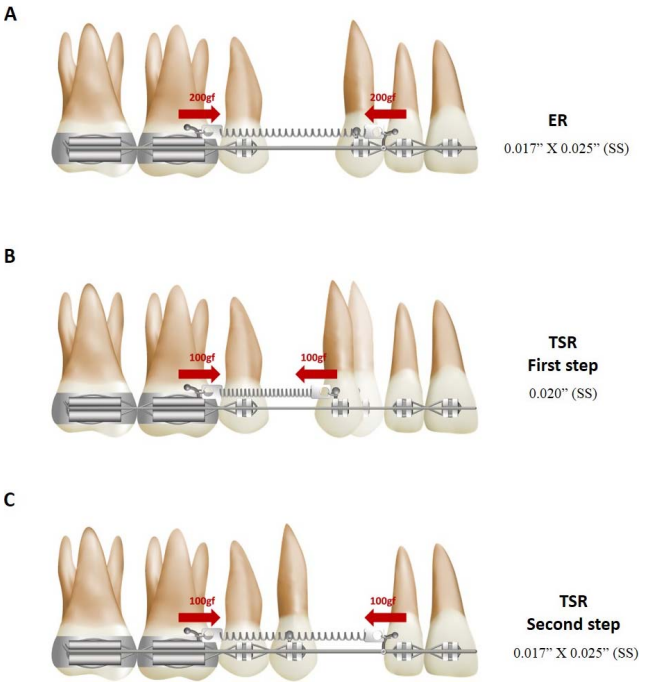

Figure 1. (A) ER group; (B) First step in TSR group; (C) Second step in TSR group. ER indicates en masse retraction; TSR, two-step retraction.

to the archwires between the lateral incisor and the canine (Figure 1A). In the TSR group, a 0.020-inch SS arch wire with flush omega loops tied back to the first molars was used for the retraction of the canines. NiTi closed-coil springs activated to 100 g were secured from the hooks of the first molar to the hooks of the canine brackets with 0.010-inch ligature wire (Figure 1B). After canine retraction, the posterior teeth and canines were tied using 0.0100-inch ligature wire bilaterally. For incisor retraction, 0.017- × 0.025-inch SS wires were inserted and NiTi closed-coil springs, activated to 100 g, were attached from the cervical hooks of the first molars to the soldered hooks located distally to the lateral incisors (Figure 1C). No auxiliary devices were used in either group during retraction.

The patients were evaluated every 4–5 weeks and the springs were reactivated and checked using a Correx Tension Gauge (Haag-Streit, Bern, Switzerland) to maintain the same activation until space closure was complete. All appointment dates and clinical procedures performed were correctly noted in the patient's clinical records; any absences and bracket, band or wire breaks were also recorded. Patients were informed if an appointment was missed and it was rescheduled as soon as possible, within a week. In the case of breaks or loss, the appointment was rescheduled on the same day.

The principal investigator analyzed each patient's clinical records after treatment was completed. Clinical dates were collected regarding the orthodontic procedures performed at the following times: the starting date of retraction (T1) and the date of space closure completion (T2) for each premolar. The total retraction time (from T1 to T2) was calculated for each premolar in months and recorded into a Microsoft Excel spreadsheet. The size of each first premolar was measured using a digital caliper (Mitutoyo, Hampshire, UK) from the initial models.

Statistical Analysis

An investigator blinded to the group assignment measured the size of the first premolars. All premolars were measured twice at an interval of 4 weeks. Measurement reliability was evaluated using intraclass correlation (ICC), estimated by means of confidence intervals. The results indicated strong intra-examiner reliability (ICC = 0.96).

Two descriptive graphics using the Kaplan-Meier method were constructed. The Kaplan-Meier curve is a descriptive analysis performed to follow what is happening with the studied event during the follow-up time.[19] In this RCT, the studied event was the "extraction space closing time" with ER and TSR. Using this statistical methodology, it was possible to obtain not only the total time for space closure for ER and TSR, but also to estimate the probability that extraction spaces had not yet closed after a certain period during the follow-up time.

The first descriptive Kaplan-Meier survival curve was constructed to evaluate space closure time with ER and TSR for each premolar extracted. In this way, for both ER and TSR, the curves were constructed considering the size of the extraction spaces of all premolars (four spaces per patient), with a total of 96 extraction spaces to be closed during the follow-up time. In this curve, the horizontal axis detailed the follow-up time from the beginning of retraction to the end of space closure. The vertical axis represented the cumulative proportion (%) of the spaces that were still open for each extracted premolar. On the vertical axis, the 1.0 proportion denoted that 100% of the spaces were not yet closed and the 0.0 proportion indicated that all the space was already closed.

A second descriptive Kaplan-Meier survival curve aimed to compare the space closure time between males and females within each group. The log-rank test was used to compare the Kaplan-Meier survival curves. A level of significance of 5% was used ($\alpha = 0.05$).

RESULTS

The CONSORT diagram shows the flow of the 52 participants who were initially enrolled. Four patients

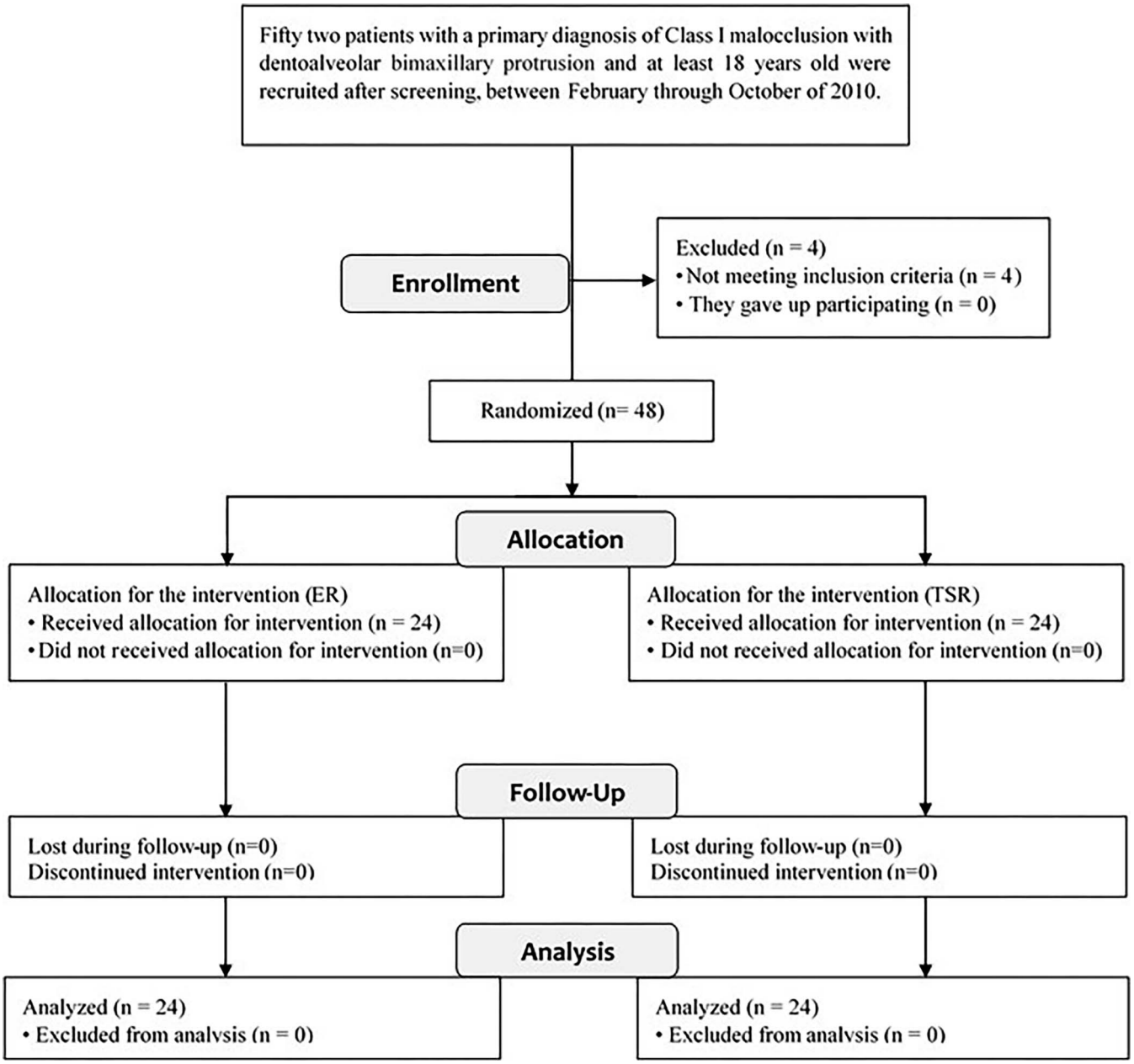

Figure 2. CONSORT flow chart showing subject flow during the trial.

were excluded and 48 patients were randomly assigned between the ER or TSR groups in which treatment was performed and analyzed (Figure 2). There were no significant differences in the baseline data of the patients between groups (Table 1 and 2).

Figure 3 shows the first descriptive Kaplan-Meier survival curve representing the cumulative proportion of the extracted premolar spaces that were still open as a function of space closure time with ER and TSR. The average of space closure time corresponds to the 0.5 proportion on the Y axis, which represents the time when 50% of the extraction spaces were not yet closed. This value was around 11.0 months for the ER group and 26.0 months for the TSR group.

Table 3 shows the results of the comparison of the Kaplan-Meier survival curves using the log-rank test. There was a significant difference in the space closure times between ER and TSR ($P < .001$). However, no significant difference was found for intragroup premolar space closure times ($P > .200$). A confidence interval of 95%, determined by the average ± 1.96 standard error, showed the estimation of the space closure time variation between 12.1 and 13.8 months for the ER group and between 24.7 and 26.8 months for the TSR group.

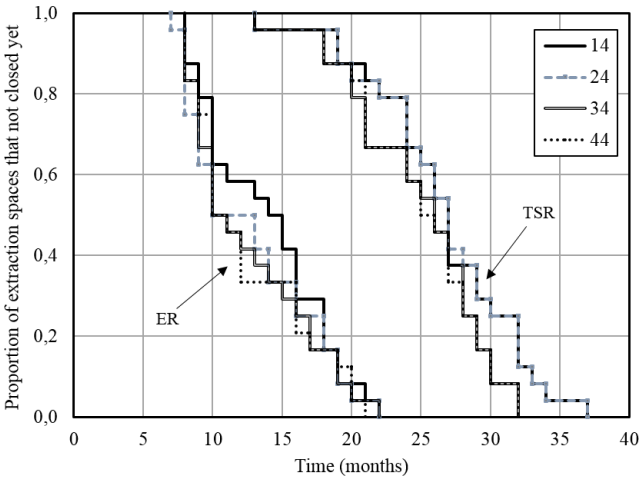

Figure 3. Kaplan-Meier curve showing the cumulative proportion of extraction spaces not yet closed during the follow-up time in the ER and TSR groups.

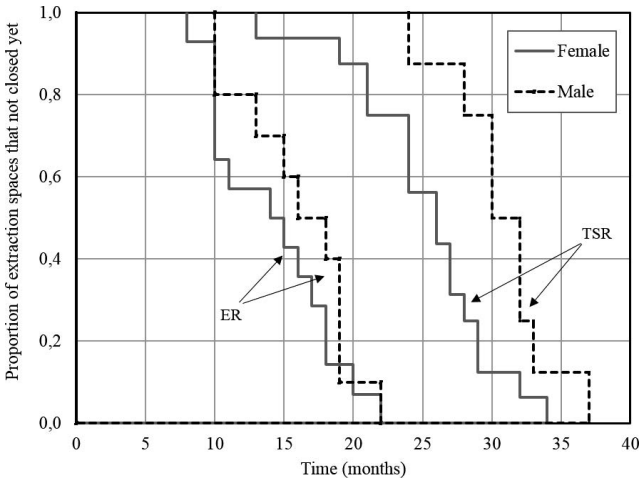

Figure 4. Kaplan-Meier curve of the cumulative proportion of extraction spaces not yet closed during the follow-up time with ER and TSR subdivided by female and male sexes.

Figure 4 shows the second descriptive Kaplan-Meier survival curve that represents the cumulative proportion of the extraction spaces that were not yet closed as a function of the follow-up time, subdivided into females and males within the ER and TSR groups.

Table 4 shows that male patients in the TSR group took a significantly longer time for space closure. There was a significant difference between males ($P < .001$) and females ($P < .001$). In the ER group, no significant difference was found in the retraction time between sexes ($P = .353$). Within the TSR group, a significant difference ($P < .05$) was found with males taking longer than females.

DISCUSSION

Previous studies have shown that both ER and TSR were efficient methods for space closure.[14,16,18] However, the duration of retraction time with each of these techniques still needed investigation. To date, this is the only study to provide descriptive analysis of the space closure time for each premolar; since extraction spaces within the same individual patient may have closed at different times.

The follow-up of extraction space closure time (Figure 3) showed that some patients achieved full space closure after 7 months in the ER group, while it occurred after 13 months in the TSR group. In addition, 50% of the extraction spaces were closed by the 11th month for ER, while it was the 26th month for TSR. Although the follow-up time showed that upper premolars in TSR took longer than lower premolars, there was no significant difference in the time of space closure among the premolars within each group (Table 3).

In agreement with the belief of a majority of orthodontists,[10,13] the distance between the Kaplan-Meier curves of the two groups during the follow-up time and the average value confirmed that there was a statistically significant difference in closure time of the extraction spaces between ER and TSR. Results showed that TSR took between 1.8 and 2.2 times longer than ER for extraction space closure. Heo et al.,[16] Xu et al.,[14] and Upadhyay et al.[18] also found similar results; however, the differences in their studies were not statistically significant. One randomized controlled trial was conducted[16] in adult patients

Table 3. Mean of Time for Space Closure (Months) for Each Extracted Premolar Between ER and TSR Groups

	ER		TSR		
Premolars[a]	n	Mean (SE)	n	Mean (SE)	*P* Value[b]
14	24	13.9 (0.9)	24	26.6 (1.1)	
24	24	12.8 (1.0)	24	26.6 (1.1)	
34	24	12.6 (0.9)	24	24.9 (1.0)	
44	24	12.6 (0.9)	24	24.8 (1.0)	
Global	96	13.0 (0.5)	96	25.7 (0.5)	<.001*
P Value[c]		0.868		0.209	

* Significant by the log-rank test; SE indicates Standard Error.
[a] Total of 96 extracted premolar per group.
[b] Between ER and TSR groups.
[c] Between premolars within ER or TSR groups.

Table 4. Mean of Time of Space Closure Between ER and TSR Groups According to Sex

	ER		TSR		
Gender	n	Mean (SE)	n	Mean (SE)	*P* Value[a]
Female	14	14.2 (1.2)	16	25.3 (1.3)	<.001*
Male	10	16.1 (1.3)	8	30.8 (1.3)	<.001*
P Value[b]		0.353		0.023*	

* Significant by the log-rank test; SE indicates Standard Error.
[a] Between ER and TSR groups within gender.
[b] Between female x male within ER or TSR.

without the use of additional anchorage devices, but the retraction time was evaluated only for the closing of upper premolar extraction spaces. In addition, none of these studies[14,16,18] described in their methodology how data collection was performed.

The influence of patient sex on the space closure time was also examined. The results showed that there was a significant difference between females and males in ER and TSR. The follow-up of the extraction space closure time (Figure 4) showed that, in the TSR group, female patients started having full closure in the 13th month after the beginning of retraction while male patients started in the 24th month. Extraction spaces took 5.5 months longer to close in male patients compared with female patients using TSR. No significant difference was found between sexes within the ER group. No studies have been previously published in the orthodontic literature regarding sex differences for space closure. The only information available in the literature regarding differences in treatment time between men and women showed that women were more committed to treatment than men and that orthodontic treatment for boys took longer.[5] However, some studies reported that there were sex-specific features that differed between male and female adult bone anatomy.[20–23] This sexual dimorphism and differences in the maxilla and mandible could be reasons why extraction spaces in males took longer to close than those in females.

The methodology of this study was designed to produce parity between groups, excluding the influence of age, as well as skeletal and dental characteristics within the sample. The following factors may have contributed to the time differences observed:

(1) The sample was limited to patients older than 18 years of age to reduce the effects that growth may cause in recorded tooth movements. Dudic et al.[24] demonstrated that younger patients who started treatment before 16 years of age had significantly more tooth movement compared with older patients and, consequently, finished orthodontic treatment in less time.
(2) The treatment plans used in this study involved the alignment and leveling of all teeth with a 0.020-inch SS wire before the extraction of premolars. In this way, on the date of the start of retraction (T1), the initial position of the teeth was as standardized as possible, recognizing that any differences in alignment could influence the movement velocity during retraction.[13]
(3) No additional anchoring devices were used. Upadhyay et al.[18] demonstrated that, when ER was performed with miniscrews, minimum molar movements occurred during space closure and therefore affected the retraction time.
(4) Sliding mechanics with NiTi springs were chosen for extraction space closure. NiTi springs are commonly used by orthodontists[25] and their shape-memory phenomenon produced better force consistency,[10,26] which remained over a prolonged time of activation.[26,27]
(5) To reduce effects in the case of appliance breakage,[2,4,8] the patients were instructed to notify the orthodontist as soon as possible and have repair performed on the same day.

The shorter retraction time with ER can be clinically significant, particularly when also considering that some studies[14,16,17] showed no difference in the anchorage loss during space closure between TSR and ER. Therefore, the orthodontist's classical choice for TSR[10,13] should be reconsidered. When undergoing TSR, the canines tend to rotate and tip more than when they are retracted with the incisors[10,14] and, therefore, will require additional treatment time to be realigned.[14] Additionally, TSR can be unesthetic due to the creation of a gap distal to the lateral incisors. The risk of external apical root resorption is also increased with longer treatment time.[28] For these reasons, ER should be considered more often to close extraction spaces unless anterior crowding or midline discrepancies are present. In these cases, separate canine retraction may be indicated to create space for the incisors and prevent protrusion.[13] If more retraction of the anterior teeth is needed, anchorage reinforcement may be considered.

CONCLUSIONS

When comparing the time for closure of extraction spaces between en masse retraction (ER) and two-step retraction (TRS), the following conclusions were drawn:

- ER closed the spaces faster than TSR. TSR took between 1.8 and 2.2 times longer than ER to close the extraction spaces.
- Time for TSR was significantly longer for males than females.
- There was no significant difference in the time of space closure among upper and lower premolars.

ACKNOWLEDGMENTS

We thank for all the support provided from CAPES AND FAPESP (process no2015/10099-0 - São Paulo Research Foundation), School of Dentistry at Araraquara (UNESP), Brazil and Center for Advanced Dental Education (CADE), Saint Louis University, USA.

REFERENCES

1. Mavreas D, Athanasiou AE. Factors affecting the duration of orthodontic treatment: a systematic review. *Eur. J. Orthod*. 2008;30:386–395.
2. Skidmore KJ, Brook KJ, Thomson WM, Harding WJ. Factors influencing treatment time in orthodontic patients. *Am. J. Orthod Dentofacial Orthop*. 2006;129:230–238.
3. Fisher MA, Wenger RM, Hans MG. Pretreatment characteristics associated with orthodontic treatment duration. *Am. J. Orthod Dentofacial Orthop*. 2010;137:178–186.
4. Beckwith FR, Ackerman RJ, Cobb CM, Tira DE. An evaluation of factors affecting duration of orthodontic treatment. *Am. J. Orthod Dentofacial Orthop*. 1999;115: 439–447.
5. Starnbach HK, Kaplan A. Profile of an excellent orthodontic patient. *Angle Orthod*. 1975;45:141–145.
6. Vig PS, Weintraub JA, Brown C, Kowalski CJ. The duration of orthodontic treatment with and without extractions: a pilot study of five selected practices. *Am. J. Orthod Dentofacial Orthop*. 1990;97:45–51.
7. Janson G, Maria FRT, Barros SEC, Freitas MR, Henriques JFC. Orthodontic treatment time in 2- and 4-premolar-extraction protocols. *Am. J. Orthod Dentofacial Orthop*. 2006;129:666–671.
8. Vig KW, Weyant R, Vayda D, O'Brien K, Bennett E. Orthodontic process and outcome: efficacy studies–strategies for developing process and outcome measures: a new era in orthodontics. *Clin Orthod Res*. 1998;1:147–155.
9. Fink DF, Smith RJ. The duration of orthodontic treatment. *Am J Orthod Dentofacial Orthop*. 1992;102:45–51.
10. Proffit W, Fields H. The second stage of comprehensive treatment: correction of molar relationship and space closure. In: *Contemporary Orthodontics*. St. Louis, MO: CV Mosby; 2000:552–575.
11. Felemban NH, Al-Sulaimani FF, Murshid ZA, Hassan AH. En masse retraction versus two-step retraction of anterior teeth in extraction treatment of bimaxillary protrusion. *J Orthod Sci*. 2013;2:28–37.
12. Kuhlberg AJ, Priebe DN. Space closure and anchorage control. *Semin Orthod*. 2001;7:42–49.
13. Nanda R, Kuhlberg A, Uribe F. Biomechanic basis of extraction space closure. In: *Biomechanics and Esthetic Strategies in Clinical Orthodontics*. St. Louis, MO: Elsevier Saunders; 1997:194–210.
14. Xu TM, Zhang X, Oh HS, Boyd RL, Korn EL, Baumrind S. Randomized clinical trial comparing control of maxillary anchorage with 2 retraction techniques. *Am J Orthod Dentofacial Orthop*. 2010;138:544.e1–9.
15. Bennett JC, McLaughlin RP. Controlled space closure with a preadjusted appliance system. *J Clin Orthod*. 1990;24:251–260.
16. Heo W, Nahm DS, Baek SH. En masse retraction and two-step retraction of maxillary anterior teeth in adult Class I women. A comparison of anchorage loss. *Angle Orthod*. 2007;77:973–978.
17. Schneider PP, Gandini Júnior LG, Monini AC, Pinto AS, Kim KB. Comparison of anterior retraction and anchorage control between en masse retraction and two-step retraction: a randomized prospective clinical trial. Angle Orthod 2019;89: 190–199.
18. Upadhyay M, Yadav S, Nagaraj K, Patil S. Treatment effects of mini-implants for en-masse retraction of anterior teeth in bialveolar dental protrusion patients: a randomized controlled trial. *Am J Orthod Dentofacial Orthop*.2008;134:18–29.e1.
19. Goel MK, Khanna P, Kishore J. Understanding survival analysis: Kaplan-Meier estimate. *J Ayurveda Res*. 2010;1: 274–278.
20. Alarcón JA, Bastir M, Rosas A. Variation of mandibular sexual dimorphism across human facial patterns. *Homo Int Z Vgl Forsch Am Menschen* 2016;67:188–202.
21. Gómez Y, García-Sanz V, Zamora N, et al. Associations between mandibular symphysis form and craniofacial structures. *Oral Radiol*. 2018;34:161–171.
22. Manzanera E, Llorca P, Manzanera D, García-Sanz V, Sada V, Paredes-Gallardo V. Anatomical study of the maxillary tuberosity using cone beam computed tomography. *Oral Radiol*. 2018;34:56–65.
23. Alias A, Ibrahim A, Abu Bakar SN, et al. Anthropometric analysis of mandible: an important step for sex determination. *Clin Ter*. 2018;169:217–223.
24. Dudic A, Giannopoulou C, Kiliaridis S. Factors related to the rate of orthodontically induced tooth movement. *Am J Orthod Dentofacial Orthop*. 2013;143:616–621.
25. Monini AC, Gandini Júnior LG, dos Santos-Pinto A, Maia LGM, Rodrigues WC. Procedures adopted by orthodontists for space closure and anchorage control. *Dent Press J Orthod*. 2013;18:86–92.
26. Miura F, Mogi M, Ohura Y, Karibe M. The super-elastic Japanese NiTi alloy wire for use in orthodontics. Part III. Studies on the Japanese NiTi alloy coil springs. *Am J Orthod Dentofacial Orthop*.1988;94:89–96.
27. Fraunhofer JA, Bonds PW, Johnson BE. Force generation by orthodontic coil springs. *Angle Orthod*. 1993;63:145–148.
28. Casa MA, Faltin RM, Faltin K, Sander FG, Arana-Chavez VE. Root resorptions in upper first premolars after application of continuous torque moment. *J Orofac Orthop*. 2001;62: 285–295.