

Research Article

Treatment time of Class I malocclusion four-premolar extraction protocol, with and without crowding: A retrospective study



Cintia Helena Zingaretti Junqueira-Mendes^a, Lucas Marzullo Mendes^a,
Marcelo Vinicius Valerio^c, Daniela Garib^{d,*}, Guilherme Janson^b

^a Department of Orthodontics, Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil

^b Professor and Head, Department of Orthodontics, Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil

^c Orthodontic Graduate Student, Department of Orthodontics, Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil

^d Associate Professor, Department of Orthodontics, Bauru Dental School, University of São Paulo, Bauru, São Paulo, Brazil

ARTICLE INFO

Article history:

Received 2 August 2019

Received in revised form

20 October 2019

Accepted 23 October 2019

Available online 29 November 2019

Keywords:

Class I malocclusion

Malocclusion

Time-to-treatment

Tooth extraction

ABSTRACT

Objective: The aim of this study was to compare the treatment times in cases treated with extractions with mild and severe crowding.

Design and Setting: Anterior crowding of 150 Class I malocclusion cases, treated with four first-premolar extractions, was measured with Little's Irregularity Index (LII). After excluding the cases with moderate maxillary LII (middle quartiles), the remaining 74 cases were divided into mild crowding (mean age 13.94 years, 14 male, 23 female) and severe crowding (mean age 14.69 years, 17 male, 20 female) groups, with 37 individuals each (LII smaller than 7.83 mm and greater than 12.18 mm, respectively).

Methods: Anterior crowding was digitally measured in digitized dental casts. The groups were matched regarding sex, initial age, and Objective Grading System index.

Results: Treatment time was statistically similar between both groups. However, there was significantly shorter treatment time in patients with extreme maxillary incisor irregularity (18.34 mm) as compared with patients with insignificant maxillary incisor irregularity (5.50 mm).

Conclusion: Treatment times of Class I malocclusions with mild and severe crowding, treated with four first-premolar extractions are similar.

© 2019 World Federation of Orthodontists.

1. Introduction

Orthodontic treatment time plays a direct role in patients' willingness to engage in treatment. Mechanical factors potentially influencing orthodontic treatment duration have been reported in the orthodontic literature, such as number of extractions, malocclusion severity, patient compliance, use of adjunctive micro-vibration devices, and laser application, among others [1].

The relationship that extraction establishes with treatment time remains controversial. Although it is generally related to a longer

treatment [2], it is not unanimous [3]. The reason for disagreement may be that most of the studies usually do not specify the extraction protocol, as well as do not address a specific malocclusion. Two maxillary premolar extraction protocols provided more efficient treatment than nonextraction protocols for complete Class II malocclusions [4]. Samples involving Class I, II, and III malocclusions mask the influence of the anteroposterior molar relationship correction in treatment time [5].

Severity of the initial malocclusion is one of the aspects referred to as influencing treatment time [6]. Some studies show positive association between treatment time and initial malocclusion severity indicators, such as the occlusal index and cephalometric variables [6,7].

Crowding has been investigated as a possible factor in increasing treatment time [6,7]. Parrish et al. [6] concluded that crowding was associated with an average increase of 30 days in treatment duration. Fisher et al. [7] verified that maxillary crowding, starting from 6 mm, was associated with long treatment duration of approximately 30 months or more. However, these studies did not address how crowding was treated, which could strongly impact the time needed for its correction [8].

Funding: This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior–Brasil (CAPES) – Finance Code 001.

Competing interest: Authors have completed and submitted the ICMJE Form for Disclosure of potential conflicts of interest. None declared.

Provenance and peer review: Not commissioned; Externally peer reviewed.

This article is based on the research submitted by Dr Cintia Helena Zingaretti Junqueira-Mendes in partial fulfillment of the requirements for the degree of PhD in Orthodontics at Bauru Dental School, University of São Paulo.

* **Corresponding author.** Orthodontic Graduate Student, Department of Orthodontics, Bauru Dental School, University of São Paulo, Alameda Dr. Octávio Pinheiro Brisolla, 9–75, Vila Universitária, Bauru, São Paulo 17012–901, Brazil.

In Class I malocclusion cases, when there is dental protrusion or crowding, four premolar extractions may be indicated [9]. In bimaxillary protrusion Class I patients, although there is no significant crowding, dental protrusion may cause excessively convex profiles, often with lip incompetence. Removal of four first premolars allows subsequent incisor and lip retractions [10]. To match patients' expectations, substantial retraction is needed, consuming most of the space provided by premolar removal. This concern encourages professionals to strongly reinforce anchorage. Consequent to the orthodontic mechanics, space closure is usually slow and time-consuming [11].

In crowded arches, initial canine distalization provides spaces for incisor leveling and alignment. When crowding is severe, most of the space provided is used for incisor leveling and alignment, and the amount of anterior teeth retraction is reduced to minimum residual spaces [12]. It is speculated that this could provide shorter treatment time in the four-premolar extraction protocol in patients with crowding, as compared with bimaxillary protrusion patients, with minimum or no crowding. In this context, this study aimed to compare the treatment time in cases of Class I malocclusions, with mild and severe crowding, treated with four first-premolar extractions.

2. Materials and methods

This study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo (protocol number 32063914.2.0000.5417), and all patients guardians signed an informed consent. An experienced orthodontist and current PhD student (C.H.Z.J.M.) performed all the procedures of this investigation.

2.1. Sample size

Sample size was calculated for each group based on an alpha error of 0.05 and a test power of 80%, to detect a mean difference of 4.6 months between the groups, with an estimated standard deviation of 5.86 months [5]. The results showed that 26 individuals were needed in each group.

2.2. Sample selection

Using the records from a 510 Class I orthodontically treated patients from the Orthodontic Department at Bauru Dental School, University of São Paulo, an initial sample retrospectively composed of 150 patients who met the following criteria were obtained: 1) availability of orthodontic records in good condition (initial and final dental casts, final panoramic radiographs, and legible charts); 2) presence of all permanent teeth fully erupted, up to the first molars; 3) no tooth agenesis, supernumerary teeth, or retained deciduous teeth; 4) bilateral Class I malocclusion; 5) no posterior crowding greater than 2 mm per side in each arch; 6) orthodontically treated with Edgewise appliances (0.022 × 0.028-inch) with four first-premolar extractions; and 7) all permanent teeth up to the second molars present, except first premolars, on the post-treatment dental casts. These patients were treated in the period between January 1974 and October 2003.

From the clinical charts, the following data were extracted: identification, sex, birth date, initial and final treatment dates, treatment protocol, and mechanics used.

Using these data, patients' initial ages and total treatment times were calculated. The starting date was considered when first molar bands were placed or first direct bonding occurred, whereas the final date was considered when the appliances were removed.

In the whole sample, the leveling and alignment phase consisted of a usual wire sequence, characterized by an initial 0.015-inch

twist-flex or a 0.016-inch nickel-titanium, followed by 0.016, 0.018, 0.020, and 0.019 × 0.025-inch stainless steel archwires (3M Unitek, Monrovia, CA). Deep bite was corrected with accentuated and reversed curve of Spee. Cases with severe initial anterior tooth crowding required initial canine retraction, whereas cases with absence of or mild crowding went directly to leveling and alignment. The extraction spaces were closed with sliding "en masse" retraction of the anterior teeth on a stainless steel rectangular archwire. Extraoral appliances were used in the maxillary arch and lip bumpers in the mandibular arch, as anchorage reinforcement, when necessary. Skeletal anchorage was not used in any patient.

2.3. Crowding evaluation

The amount of crowding was evaluated using Little's Irregularity Index (LII), which corresponds to the sum, in millimeters, of the five distances between the anatomic contacts from the mesial aspect of the left canine through the mesial aspect of the right canine [13]. All initial dental casts were digitized with the 3Shape R700 scanner (3Shape A/S, Copenhagen, Denmark), and LII was measured on the mandibular and maxillary initial arches using OrthoAnalyzer 3D software (3Shape A/S).

One anterior and two posterior orientation points were used to trace each mandibular and maxillary occlusal plane. The anterior point was the midpoint of the incisal edge of the right central incisor. The posterior points were the first molar mesiopalatal cusp tips in the maxillary and first molar mesiobuccal cusp tips in the mandibular casts. In this way, all dental arches had the LII measured exclusively on its own occlusal plane [14], as originally recommended [13]. The operator was able to use the zoom tool, to closely visualize the landmarks, and more precisely identify them [14] (Fig. 1A and B).

The maxillary LII was used to create two groups, with mild and severe crowding. As this variable did not show normal distribution (Shapiro Wilk test, $P = 0.000$) the lower and upper quartiles (7.83 and 12.18, respectively) were used to compose two groups (Fig. 2A). All cases with LII in the middle quartiles were excluded. The remaining individuals ($n = 74$) were grouped in Mild (MC, Fig. 3A and B) and Severe Crowding (SC) groups, as follows:

- MC Group ($n = 37$): individuals with LII smaller than 7.83 mm.
- SC Group ($n = 37$): individuals with LII greater than 12.18 mm.

The influence of the whole-sample maxillary and mandibular LII values ($n = 150$) on treatment time also was investigated.

2.4. Orthodontic outcome analysis

Quality of the orthodontic outcomes was evaluated with the Objective Grading System (OGS), of the American Board of Orthodontics [15]. It consists of the evaluation of eight items (alignment, marginal ridge levels, buccolingual inclination, overjet, anteroposterior occlusal relationships, occlusal contacts, interproximal contacts, and root parallelism). To evaluate the casts, a metal gauge with 0.5-mm thickness and 1.0-mm height was used (ABO Measuring Gauge, St. Louis, MO). This thickness and height allowed it to be used as a parameter to measure deviations from normal.

For each failure, one or two points were subtracted from the case, depending on the severity of the problem (Table 1). The final individual OGS index corresponded to the sum of lost points in each factor.

2.5. Method error

For the intraexaminer error analyses, 30% of the initial sample ($n = 45$) was randomly selected and the LII and OGS indexes were

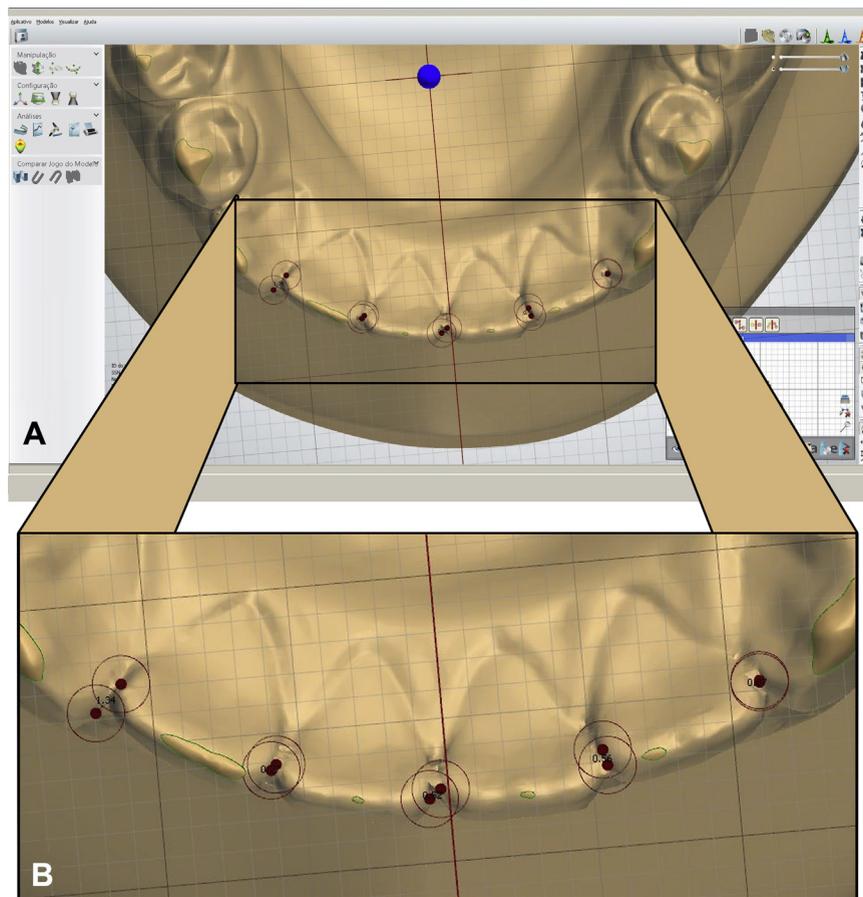


Fig. 3. (A) Mild crowding arch example, where LII values were low. After they are added, the whole value became greater than 3 mm. (B) Closer zoom view.

measured again, 30 days after the first evaluation, by the same calibrated examiner (C.J.).

To estimate the random errors, Dahlberg's formula was used [16]. For systematic errors, paired *t* tests were applied [17]. These tests were performed with Microsoft (Redmond, WA) Excel 2010 worksheet, preformatted for this purpose.

2.6. Statistical analyses

Means and standard deviations were calculated and Kolmogorov-Smirnov and Lilliefors tests were applied to each variable to evaluate normal distribution. Age, treatment time, and maxillary and mandibular LII did not show normal distribution, therefore intergroup comparisons for these variables were performed with nonparametric tests.

Intergroup comparability was performed with χ^2 , Mann-Whitney, and *t* tests regarding sex distribution, initial ages, and the OGS index, respectively. Maxillary and mandibular LII values were compared by Mann-Whitney tests. Treatment times of the two groups were compared by Mann-Whitney test.

Pearson correlation coefficients were calculated between treatment time and maxillary and mandibular LII, and between maxillary and mandibular LII. All statistical tests were performed with Statistica software (version 7.0; StatSoft Inc., Tulsa, OK). Results were considered significant at $P < 0.05$.

Table 1

Objective Grading System summarized description

Item	Marginal error	Subtracted points
Alignment	0.5 to 1 mm	1 per each deviated tooth
	1 mm or more	2 per each deviated tooth
Marginal ridges leveling	0.5 to 1 mm	1 per each posterior interproximal contact
	1 mm or more	2 per each posterior interproximal contact
Buccolingual inclination	1.1 to 2 mm	1 per each posterior tooth
	2 mm or more	2 per each posterior tooth
Occlusal contacts	Until 1 mm	1 per each posterior tooth with no contact
	1 mm or more	2 per each posterior tooth with no contact
Anteroposterior relationship	1 to 2 mm	1 per each superior tooth from canine to 2nd molar
	2 mm or more	2 per each superior tooth from canine to 2nd molar
Overjet	Until 1 mm	1 per each superior tooth with no contact
	More than 1 mm	2 per each superior tooth with no contact
Interproximal contacts	0.6 a 1 mm	1 per each interproximal contact
	More than 1 mm	2 per each interproximal contact
Root angulation	Not parallel roots	1 per each occurrence
	Root contacts the adjacent	2 per each occurrence

Table 2

Intraexaminer random and systematic errors (Dahlberg's formula and dependent *t* tests) for LII and OGS Index

	1st measurement		2nd measurement		Dahlberg	<i>P</i>
	Mean	SD	Mean	SD		
	LII (n = 45)					
Maxilla	9.97	2.63	9.91	2.67	0.73	0.697
Mandible	8.87	3.14	8.91	3.14	0.78	0.817
OGS (n = 23)	23.00	8.15	23.57	8.78	2.30	0.416

LII, Little Irregularity Index; OGS, Objective Grading System; SD, standard deviation.

3. Results

The random errors were within acceptable levels [18,19] (Table 2). There were no significant systematic errors.

The groups were comparable regarding sex distribution, initial age, and OGS (Table 3). The maxillary and mandibular LII were significantly smaller in the MC than in the SC group. Treatment times were statistically similar in both groups.

There were no significant correlations between treatment time and maxillary or mandibular LII (Table 4). Maxillary and mandibular LII were significantly correlated with each other.

Although there was no significant intergroup treatment time difference, treatment time in the SC group was numerically shorter than in the mild crowding group (Table 3). Therefore, comparable subgroups of 15 patients at the extreme ends of maxillary and mandibular LII distribution were also compared (Fig. 2B). The subgroups were referred to as Extremely Mild Crowding (EMC) and Extremely Severe Crowding (ESC) and were tested regarding normal distribution with Kolmogorov–Smirnov and Lilliefors tests, so that parametrical and nonparametric tests were adequately applied to each variable (Table 5). In this condition, the extremely crowded cases had significantly shorter treatment time than cases with negligible maxillary and mandibular crowding (Table 5).

4. Discussion

The aim of this study was to evaluate whether extensive anterior retraction would require greater treatment time than correcting severe crowding with four premolar extractions. To achieve this, these two conditions had to be isolated from other variables that could influence the results. Because correction of anteroposterior discrepancies is able to increase treatment time [5], a Class I malocclusion sample was chosen.

Dividing the groups according to the amount of crowding, formed authentic groups of severe crowding (SC group) and

Table 3

Results of intergroup comparability regarding sex, initial age, OGS, and descriptive analysis and comparison of treatment times

Variables	MC group (n = 37)		SC group (n = 37)		<i>P</i>
	Male	Female	Male	Female	
	Mean	SD	Mean	SD	
	Sex (n/%)	14/45.16	23/53.49	17/54.84	
Age, y	13.94	2.32	14.69	3.86	0.563†
OGS, lost points	21.68	7.50	24.11	8.75	0.203‡
Maxillary LII, mm	6.47	1.02	15.36	3.40	0.000 ^{1,§}
Mandibular LII, mm	7.70	2.63	9.61	3.61	0.011 ^{1,§}
T time, mo	30.75	9.84	27.73	10.13	0.149†

MC, mild crowding; OGS, Objective Grading System; SC, severe crowding; SD, standard deviation.

* χ^2 test.

† Mann-Whitney test.

‡ *t* test.

§ Statistically significant at *P* < 0.05.

Table 4

Results of the Pearson correlation test between treatment time and maxillary and mandibular LII, and between maxillary and mandibular LII

N = 150	<i>R</i>	<i>P</i>
Treatment time × Maxillary LII	−0.0914	0.266
Treatment time × Mandibular LII	−0.0765	0.352
Maxillary LII × Mandibular LII	0.2138	0.009*

LII, Little Irregularity Index.

* Statistically significant at *P* < 0.05.

protruded patients (MC group). Crowding of the maxillary arch was chosen to divide the groups, based on the greater amount of time that maxillary anterior retraction usually takes, compared with the mandibular, due to greater difficulty in torque and anchorage control in the maxillary arch [20–23]. With larger crowns, longer and wider roots, movement occurs slowly, and may cause greater root resorption [24]. Furthermore, the maxillary and mandibular LII were correlated (Table 4). Therefore, if the groups had been separated based on the mandibular LII, the results probably would be similar.

Although the sample size calculation indicated that 26 patients would be necessary in each group, 37 patients fit the inclusion criteria and were included to increase the test power.

The group with greater crowding had a numerically shorter treatment time, although it was not significantly different from the mild crowding group (Table 3). This supports the statement that the necessary anchorage to correct equivalent dentoalveolar protrusion and anterior crowding is similar [25,26]. If the required anchorage is similar, treatment time also will be similar. This is especially true in the groups that used extraoral headgear and lip bumpers, which are patient compliance–dependent devices. With this, it cannot be ascertained that even the patients who needed maximum anchorage to have complete retraction of the anterior teeth, to reduce their dentoalveolar and lip protrusion, or correct the amount of anterior crowding, did in fact provide maximum anchorage. Therefore, similar anchorage loss may have occurred, in both groups.

However, when the extreme subgroups of mild and severe crowding were compared, the severe crowding subgroup had a significantly shorter treatment time than the mild crowding subgroup, contradicting the statement by Andrews [25,26] that the necessary anchorage to correct equivalent dentoalveolar protrusion and crowding is similar. However, this may have occurred because the amount of protrusion corrected was not evaluated, to ascertain whether it was equivalent to the amount of crowding of the severe crowded group. Most likely, the amount of protrusion corrected was greater than the amount of crowding and consequently

Table 5

Comparability between the most extreme subgroups regarding sex, initial age, OGS, descriptive analysis, and comparison of treatment times

Variables	EMC subgroup (n = 15)		ESC subgroup (n = 15)		<i>P</i>
	Male	Female	Male	Female	
	Mean	SD	Mean	SD	
	Sex, n/%	4/26.67	11/73.33	9/60.00	
Age, y	14.67	2.69	14.38	2.38	0.756†
OGS, lost points	24.00	7.79	23.73	9.58	0.934‡
Maxillary LII	5.50	0.85	18.34	3.61	0.000 ^{1,§}
Mandibular LII	6.40	2.04	9.42	4.31	0.021 ^{1,§}
T time, mo	35.00	9.13	27.54	10.35	0.046 ^{1,§}

EMC, extremely mild crowding; ESC, extremely severe crowding; LII, Little Irregularity Index; OGS, Objective Grading System; SD, standard deviation.

* χ^2 test.

† Mann-Whitney test.

‡ *t* test.

§ Statistically significant at *P* < 0.05.

required more time to be corrected. Therefore, this constitutes a limitation of this study and requires that a subsequent investigation has to be undertaken to clarify this issue. For this, the amount of mandibular anterior crowding must be measured in millimeters and must be equivalent to the amount of mandibular incisor protrusion, cephalometrically evaluated. The amount of incisor protrusion correction also must be evaluated.

Theoretically, only a posterior crowding amount (at the premolar area), similar to the amount of protrusion to be corrected, will require less treatment time to close the extraction spaces than to retract the anterior teeth, when similar anchorage reinforcement is used [25,26]. This happens because, in extraction cases, anchorage reinforcement is not necessary to correct a lingually displaced second premolar that only needs to be moved buccally, for example [25,26]. However, in extraction cases, anchorage reinforcement is needed when distal movement of the first premolar and/or canine is necessary, to provide space for anterior teeth leveling and alignment [25–29].

Summarizing, treatment time is similar in Class I malocclusions with mild and severe crowding, treated with four first-premolar extractions. Future studies with equivalent crowding and protrusion amounts are necessary to complement the current investigation.

5. Conclusions

- There was no significant difference in treatment time of Class I malocclusions with mild and severe crowding, treated with four first-premolar extractions.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES) – Finance Code 001.

References

- [1] Skidmore KJ, Brook KJ, Thomson WM, Harding WJ. Factors influencing treatment time in orthodontic patients. *Am J Orthod Dentofacial Orthop* 2006;129:230–8.
- [2] 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.
- [3] Kelly BM, Springate SD. Specialist orthodontics in the general dental service. *Br Dent J* 1996;180:209–15.
- [4] Janson G, Barros SE, de Freitas MR, Henriques JF, Pinzan A. Class II treatment efficiency in maxillary premolar extraction and nonextraction protocols. *Am J Orthod Dentofacial Orthop* 2007;132:490–8.
- [5] Janson G, Maria FR, Barros SE, Freitas MR, Henriques JF. Orthodontic treatment time in 2- and 4-premolar-extraction protocols. *Am J Orthod Dentofacial Orthop* 2006;129:666–71.
- [6] Parrish LD, Roberts WE, Maupome G, Stewart KT, Bandy RW, Kula KS. The relationship between the ABO discrepancy index and treatment duration in a graduate orthodontic clinic. *Angle Orthod* 2011;81:192–7.
- [7] Fisher MA, Wenger RM, Hans MG. Pretreatment characteristics associated with orthodontic treatment duration. *Am J Orthod Dentofacial Orthop* 2010;137:178–86.
- [8] Leon-Salazar R, Janson G, Henriques JF, Leon-Salazar V. Influence of initial occlusal severity on time and efficiency of Class I malocclusion treatment carried out with and without premolar extractions. *Dental Press J Orthod* 2014;19:38–49.
- [9] Lim HJ, Ko KT, Hwang HS. Esthetic impact of premolar extraction and non-extraction treatments on Korean borderline patients. *Am J Orthod Dentofacial Orthop* 2008;133:524–31.
- [10] Solem RC, Marasco R, Guitierrez-Pulido L, Nielsen I, Kim SH, Nelson G. Three-dimensional soft-tissue and hard-tissue changes in the treatment of bimaxillary protrusion. *Am J Orthod Dentofacial Orthop* 2013;144:218–28.
- [11] Rizk MZ, Mohammed H, Ismael O, Bearn DR. Effectiveness of en masse versus two-step retraction: a systematic review and meta-analysis. *Prog Orthod* 2018;18:41.
- [12] Freitas KM, Freitas DS, Valarelli FP, Freitas MR, Janson G. PAR evaluation of treated Class I extraction patients. *Angle Orthod* 2008;78:270–4.
- [13] Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. *Am J Orthod* 1975;68:554–63.
- [14] Dowling AH, Burns A, Macauley D, Garvey TM, Fleming GJ. Can the intra-examiner variability of Little's Irregularity Index be improved using 3D digital models of study casts? *J Dent* 2013;41:1271–80.
- [15] Casco JS, Vaden JL, Kokich VG, et al. Objective grading system for dental casts and panoramic radiographs. American Board of Orthodontics. *Am J Orthod Dentofacial Orthop* 1998;114:589–99.
- [16] Dahlberg G. Statistical methods for medical and biological students. New York: Interscience Publications; 1940.
- [17] Houston WJB. The analysis of errors in orthodontics measurements. *Am J Orthod* 1983;83:382–90.
- [18] Moerenhout BA, Gelaude F, Swennen GR, Casselman JW, Van Der Sloten J, Mommaerts MY. Accuracy and repeatability of cone-beam computed tomography (CBCT) measurements used in the determination of facial indices in the laboratory setup. *J Craniomaxillofac Surg* 2009;37:18–23.
- [19] Navarro RL, Ultramari-Navarro PV, Fernandes TM, et al. Comparison of manual, digital and lateral CBCT cephalometric analyses. *J Appl Oral Sci* 2013;21:167–76.
- [20] Greco M, Giancotti A. Sliding mechanics in extraction cases with a bidimensional approach. *Prog Orthod* 2007;8:144–55.
- [21] Giancotti A, Greco M. Modified sliding mechanics in extraction cases with a bidimensional approach. *Prog Orthod* 2010;11:157–65.
- [22] Li Y, Tang N, Xu Z, Feng X, Yang L, Zhao Z. Bidimensional techniques for stronger anterior torque control in extraction cases: a combined clinical and typodont study. *Angle Orthod* 2012;82:715–22.
- [23] Chopra SS, Mukherjee M, Mitra R, Kochar GD, Kadu A. Comparative evaluation of anchorage reinforcement between orthodontic implants and conventional anchorage in orthodontic management of bimaxillary dentoalveolar protrusion. *Med J Armed Forces India* 2017;73:159–66.
- [24] Chaushu S, Kaczor-Urbanowicz K, Zadurska M, Becker A. Predisposing factors for severe incisor root resorption associated with impacted maxillary canines. *Am J Orthod Dentofacial Orthop* 2015;147:52–60.
- [25] Andrews L. The straight wire appliance. Syllabus of philosophy and techniques. 2nd ed. San Diego, CA: Larry F. Andrews Foundation of Orthodontic Education and Research; 1975.
- [26] Andrews LF. The straight-wire appliance. Extraction brackets and "classification of treatment." *J Clin Orthod* 1976;10:360–79.
- [27] Feldmann I, Bondemark L. Orthodontic anchorage: a systematic review. *Angle Orthod* 2006;76:493–501.
- [28] Melsen B, Bosch C. Different approaches to anchorage: a survey and an evaluation. *Angle Orthod* 1997;67:23–30.
- [29] Diedrich P. [Different orthodontic anchorage systems. A critical examination]. *Fortschr Kieferorthop* 1993;54:156–71.