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Multidimensional Pain Inventory (MPI): Adaptation to Orthodontic Patients and Its Psychometric Properties

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Abstract

Background: Pain perception may result from orthodontic treatment and should be considered in clinical management. Its assessment should not be limited to the intensity of perceived pain but should also consider the psychosocial and behavioral aspects involved. **Objective:** The aims of this study were to adapt and validate the Multidimensional Pain Inventory (MPI) for orthodontic patients, and present a proposal to calculate an overall score of the pain-related aspects and compare these scores with the usual methodology used. **Methods:** Face validity of the MPI was estimated and orthodontic version (MPI-Orthodontic) was developed. Factorial validity was evaluated by confirmatory analysis. Convergent and discriminant validity and reliability were estimated. The fit of Second-Order Hierarchical Models was estimated. Concurrent validity of MPI-Orthodontic was evaluated against the Visual Analogue Scale. Invariance of the factorial models was evaluated for independent samples and according to sex and age. Overall score was calculated using the matrix of regression weights and compared to simple arithmetic mean. **Results:** 507 individuals (63.3% women; age: 26.32 (SD = 11.70) years) participated. For the fit of Part I (psychosocial aspects) of the MPI-Orthodontic, it added correlation between two items and excluded one item; for Part II (behavioral aspects) two items were excluded. The models presented adequate fit to the sample. Reliability was adequate. MPI-Orthodontic presented inva-

riance for independent samples and adequate concurrent and divergent validity. Score obtained with the simple arithmetic mean was overestimated for Part I and underestimated for Part II. **Conclusion:** MPI-Orthodontic was valid, reliable and invariant for the evaluation of the orthodontic pain. It is recommended to calculate overall weighted scores for pain assessment.

Keywords

Pain Measurement, Orthodontics, Psychometrics, Validation Studies, Multidimensional Pain Inventory

1. Introduction

Orthodontic treatment aims to improve dentofacial appearance and function [1] [2]. However, this treatment may cause discomfort or pain in the patient and this may be a reason for treatment discontinuation [3].

Tecco *et al.* [4] observed that 95% of patients treated with conventional brackets reported pain on the first day after appliance installation. After insertion of an alignment and levelling arch, an orthodontic force is produced and the patient can perceive from a slight discomfort to the sensation of pain that can be immediate or delayed [5]. Immediate pain is related to the sudden placement of a heavy force on the tooth while the delayed response is represented by periodontal ligament hyperalgesia [5].

Although this orthodontic pain is a pathophysiological response, it is not only related to the magnitude of the applied force and to the response of a tissue physical damage. This pain is also related to the individual perception and/or sensation of each patient. This perception/sensation may be related to several aspects of the life of these individuals, for example cognitive, behavioral and psychosocial aspects [3] [6] [7]. Thus, the measurement of pain becomes a challenge.

One of the most common methods used to measure orthodontic pain is the visual analogue scale (VAS) [3]. This method consists of an exclusive evaluation of the perception of pain intensity [3]. Although this information is important, it does not provide additional relevant information in the study of pain such as measuring of pain quality and/or the impact of this pain in the life of individuals.

Some instruments have been proposed to evaluate the pain perception in a more comprehensive perspective. These include the Brief Pain Inventory (BPI) [8], the Short Form McGill Pain Questionnaire (SF-MPQ) [9] and the Multidimensional Pain Inventory (MPI) [10]. BPI was originally developed to evaluate chronic pain in patients with cancer [8] [11]. SF-MPQ [9] is a reduced version of McGill Pain Questionnaire proposed for the patient to specify the pain experience using descriptors. And MPI was originally developed for patients with chronic cancer [10].

Recently the SF-MPQ was adapted to measure the orthodontic pain and was named Ortho-SF-MPQ [12]. The author performed the validation (confirmatory factorial analysis) of the instrument and validity and reliability were attested in Indian patients undergoing corrective orthodontic treatment [12]. This instrument is a viable alternative for the measurement of pain, but, unlike BPI and MPI, it evaluates pain in the qualitative aspect and does not extend this evaluation to the quantitative and general aspects of individuals' lives. Thus, to adapt these instruments to orthodontic treatment-related pain measuring may be interesting for the availability of new instruments and to expand the knowledge of the pain perception of individuals seeking orthodontic treatment, which can certainly minimize abandonment of treatment.

The Multidimensional Pain Inventory (MPI) has already been translated and adapted for several countries [13] [14] [15] [16] [17], including Brazil [18]. This instrument is composed of 52 items divided into 12 aspects that are subdivided into 3 parts (one part evaluating psychosocial aspects and two evaluating behavioral aspects) [18] [19]. Zucoloto *et al.* [19] evaluated the psychometric properties of the Portuguese version of MPI in samples of Brazilian patients with orofacial pain. They attested to the validity, reliability, and invariance of this instrument. The validity, reliability, and invariance of this instrument were adequate. However, until the moment, no studies have been found in the literature with MPI assessing the pain caused by orthodontic treatment. This instrument proposes the evaluation of pain from a psychosocial and behavioral perspective and aims to identify not only the perception of pain experienced but also its interference in the life of the patient [19]. This latter aspect is particularly important in Orthodontics since it may provide relevant information regarding patient management and monitoring of the probability of abandoning treatment. For this purpose, it is possible to calculate an overall score of pain. Usually, it is suggested that the calculation of this score uses the simple arithmetic mean of the responses given by participants to each item. However, this method considers that all the items of the instrument have the same weight for the sample, which is not realistic.

Thus, believing in the importance of performing a multidimensional evaluation of orthodontic pain for a comprehensive patient care, the present study aimed: i. to adapt and estimate the psychometric properties (validity, reliability, and invariance) of MPI when applied to Brazilian patients in corrective orthodontic treatment, ii. to present a proposal to calculate the overall score of the pain-related aspects assessed by MPI and compare these scores with the usual methodology used.

2. Methods

2.1. Study Design and Sampling

The study presented a cross-sectional design with a non-probabilistic sampling (for convenience). Individuals undergoing orthodontic treatment (from January

to September 2017) in private orthodontic clinics and specialization courses in four cities in the interior of the State of São Paulo, Brazil, were invited to participate. Individuals aged 12 to 60 years that were in orthodontic treatment with fixed appliances, whether conventional, aesthetic or self-ligating brackets were included. Individuals undergoing treatment with an expansion device were excluded. The minimum sample size was calculated according to the proposal of Hair *et al.* [20], that established a minimum of 5 to 10 subjects per parameter of the model. Considering that the largest model to be tested (MPI-Part I) has 50 parameters to be estimated, the minimum sample size required was 250 to 500 individuals.

2.2. Study Variables

To characterize the sample, a questionnaire was used to collect information such as sex, age, and economic classification. The economic classification was estimated according to the Brazilian Economic Classification Criterion [21]. Information regarding orthodontic treatment was also collected, such as duration of treatment, difficulty or presence of pain in feeding after activation of the appliance, date of last activation and previous experience with orthodontic treatment. The Visual Analogue Scale (ranging from 0 to 10) was also applied to assess the pain experience on the first and second day after the last activation of the appliance.

To evaluate the psychosocial and behavioral aspects of orthodontic pain, it was used the Multidimensional Pain Inventory (MPI) described below.

2.3. Measuring Instrument

The MPI has originally proposed in the English language by Kerns *et al.* [10] containing 52 items subdivided into three independent parts. Part I assesses the psychosocial aspects of pain and is composed of 20 items (7-point Likert-type response scale—ranging from 1 to 7) distributed in 5 factors (pain severity, life interference, perceived self-control of life, mood/affectivity state, and appreciation of the amount of support received from close people). The scale of item 15 is inverted in relation to the other items of the "mood/affectivity state" factor. Still, items of the "perceived self-control of life" factor present inverted response scale in relation to the other factors. Part II assesses the perception of individuals with pain about the behavior of people close or intimate to them and is composed of 14 items (6-point Likert-type response scale—ranging from 1: "never" to 6 "very often") distributed in 3 factors (punishing responses, solicitous responses, and distracting responses). Part III contains 18 items (6-point Likert-type response scale—ranging from 1: "never" to 6 "very often") distributed in 4 factors (household chores, outdoor work, activities away from home, and social activities) and assesses the individual's behavior with pain in relation to work activities.

The Portuguese version of MPI was proposed by da Silva and Ribeiro [18]

containing 50 items. Zucoloto *et al.* [19] performed a validation study of MPI for a Brazilian sample of adults with chronic and/or acute orofacial pain. The authors suggest the application of the Portuguese version with 52 items (accompanying the original version). Thus, this was the proposal initially used in the present study. This version passed by the face validation process described below.

2.4. Face Validation

Two researchers of this study, one Orthodontic specialist and one Psychometric specialist with training in Dentistry, evaluated the content of the items of MPI for the application of this instrument in orthodontic patients aged 12 years and over. It should be clarified that after the evaluation of the three component parts of MPI, it was decided not to include Part III when evaluating patients undergoing orthodontic treatment. This fact was based on the evaluation of the content of Part III that refers to work activities, which often does not apply to very young individuals, or still, orthodontic pain usually does not present significant interference in this evaluated aspect. After the specialist's evaluation, the instrument composed of the Parts I and II was tested in a pilot study to verify its adequacy to the sample of orthodontic patients.

2.5. Pilot Study

Twenty individuals in corrective orthodontic treatment with age between 12 and 18 years participated in this stage (40% female, age: 14.40 (SD = 0.87) years). The MPI was applied to evaluate the Incomprehension Index (II). This index aims to identify individuals' difficulties in understanding the content of the items and filling of the instrument. II > 15% was considered indicative of the need to reformulate the item [22]. Six items of Part I (i6, i7, i9, i13, i14, i15) and one item of Part II (i14) were considered incomprehensible (II > 15%) and were reformulated.

In addition to the content of the items, it was observed that the participants had difficulty locating accurately in the Likert-type scale response points in both Parts I and II. This fact was observed mainly among the individuals with lower age. Thus, these scales were adapted. The scale of Part I was changed to a Likert-type scale response of 11 points (ranging from 0 to 10) and the scale of Part II to a Likert-type of 5 points (1: never, 2: rarely, 3: sometimes, 4: often, 5: very often). The final Portuguese version of the instrument was named MPI-Orthodontic (**Table 1**).

2.6. Psychometric Properties Analysis

2.6.1. Psychometric Sensitivity

The psychometric sensitivity of MPI-Orthodontic items was estimated using measures of central tendency, variability, and shape distribution of the responses given by participants. Absolute values of kurtosis and skewness below 7 and 3, respectively, were indicative of approximate normal distribution and, consequently, the psychometric sensitivity of the item was attested. Multivariate

Table 1. Multidimensional pain inventory adapted for orthodontic patients (MPI-Orthodontic)[a].

		Item	*Portuguese Version*	*English Version*
Part I—Psychosocial Aspect (factors)	Pain severity	i1	Na média, quão severa tem sido a sua dor após a ativação do aparelho?	On average, how severe has your pain been after the activation of the appliance?
		i2	O quanto de sofrimento você tem por causa de sua dor?	How much suffering do you experience because of your pain?
		i3	Estime o nível de sua dor após 24 - 48 horas após a ativação do aparelho ortodôntico.	Rate the level of your pain at 24 to 48 hours after the activation of the orthodontic appliance.
	Life interference	i4	Em geral, o quanto sua dor interfere com suas atividades diárias?	In general, how much does your pain interfere with your day-to-day activities?
		i5	Desde o momento em que sua dor começou, o quanto ela alterou sua capacidade de trabalhar/estudar ou realizar suas atividades diárias?	Since the time your pain began, how much has your pain changed your ability to work/study or perform your day-to-day activities?
		i6	O quanto sua dor alterou a sua satisfação ou prazer com as atividades sociais e de lazer?	How much has your pain changed the amount of satisfaction or enjoyment you get from taking part in social and recreational activities?
		i7	O quanto sua dor alterou a sua satisfação ou prazer com as atividades relacionadas à família?	How much has your pain changed the amount of satisfaction or enjoyment you get from family-related activities?
		i8	O quanto sua dor afetou seu relacionamento com os familiares ou pessoas próximas?	How much has your pain changed your relationship with your family or people close/intimate to you?
		i9	O quanto sua dor alterou a sua satisfação ou prazer durante sua participação no trabalho/escola ou nos seus estudos?	How much has your pain changed the amount of satisfaction or enjoyment you get from work/school?
		i10	O quanto sua dor afetou sua capacidade para fazer trabalhos domésticos/escolares?	How much has your pain changed your ability to do household or school chores?
		i11	O quanto sua dor alterou ou interferiu em sua amizade com pessoas diferentes de sua família?	How much has your pain changed or interfered your friendships with people other than your family?
		i12	Em geral, o quanto sua dor afetou sua capacidade para participar de atividades sociais?	How much has your pain changed your ability to participate in recreational and other social activities?
	Perceived self-control of life	i13	Após a ativação do aparelho, você sentiu que foi capaz de controlar as coisas que acontecem na sua vida?	After the activation of the appliance do you feel that you've been able to control all situations that occur in your life?
		i14	Após a ativação do aparelho, quanto você sentiu que foi capaz de lidar com problemas cotidianos (do seu dia-a-dia)?	After the activation of the appliance how much do you feel that you've been able to deal with your everyday problems?
	Mood/affectivity state	i15	De forma geral, como esteve o seu humor após a ativação do aparelho?	Rate your overall mood after the activation of the appliance.
		i16	Após a ativação do aparelho, estime o quão irritável você esteve.	After the activation of the appliance how irritable have you been?
		i17	Após a ativação do aparelho, estime o quão tenso você esteve.	After the activation of the appliance how tense have you been?
	Appreciation of the amount of support received from close people	i18	O quanto de apoio e suporte lhe tem sido dado por sua família ou pessoa próxima em relação a sua dor?	How supportive or helpful is your family or people close to you in relation to your pain?
		i19	O quão preocupada sua família ou pessoa próxima tem ficado com você por causa de sua dor?	How concerned is your family or people close to you about your pain?
		i20	O quão atenciosa sua família ou pessoa próxima tem sido com você por causa de sua dor?	How attentive is your family or people close to you because of your pain?

Continued

Part II—Behavioral Aspect (factors)	Punishing responses	i1	Ficam irritados comigo.	Gets irritated with me.
		i2	Ficam enraivecidos comigo.	Gets angry with me.
		i3	Ficam frustrados comigo.	Gets frustrated with me.
		i4	Ignoram-me.	Ignores me.
	Solicitous responses	i5	Cuidam de meus trabalhos domésticos ou caseiros.	Takes over my household chores.
		i6	Ajudam-me a repousar.	Tries to get me to rest.
		i7	Dão-me a medicação para a dor.	Gets me pain medication.
		i8	Dão-me algo para comer ou beber.	Gets me something to eat or drink.
		i9	Ligam ou desligam a TV.	Turns on or off the TV.
		i10	Pensam como podem ajudar-me.	Asks me what he/she can do to help.
	Distracting responses	i11	Lêem para mim.	Reads to me.
		i12	Contam-me alguma coisa que possa distrair-me da dor.	Talks to me about something else to take my mind off the pain.
		i13	Tentam me envolver em alguma atividade.	Tries to involve me in some activity.
		i14	Encorajam-me a ter/ou fazer algum hobby (atividade de lazer).	Encourages me to work on a hobby.

a. Campos, L.A., da Silva, J.A., Santos-Pinto, A., Marôco, J. and Campos, J.A.D.B. (2019) Multidimensional Pain Inventory (MPI): Adaptation to Orthodontic Patients and Its Psychometric Properties. Pain Studies and Treatment, 7, 1-20.

normality was evaluated using Mardia's Test, values lower than three were considered indicative of multivariate normality.

2.6.2. Construct Validity

The construct validity of the MPI-Orthodontic was assessed using factorial, convergent and discriminant validities. The factorial validity was estimated using Confirmatory Factorial Analysis (CFA) with Maximum Likelihood estimation. The indices used to assess the goodness of fit of the model were the ratio of chi-square to degrees of freedom (χ^2/df), the goodness of fit index (GFI), the comparative fit index (CFI) and the root mean square error of approximation (RMSEA) [23] [24]. The factor weights of the items (λ) were also considered. The model fit was considered adequate when $\lambda \geq 0.45$, $\chi^2/df \leq 2.0$, GFI and CFI ≥ 0.90 and RMSEA ≤ 0.10 [24]. To verify the existence of a correlation between errors of the items, the modification indices estimated from the Lagrange Multipliers (LM) were considered. LM values>11 were inspected [20] [24].

To evaluate in general, the psychosocial and behavioral aspects of pain, it was added a second-order factor in Part I called "Psychosocial Aspect" and in Part II called "Behavioral Aspect". The fit of the Second-Order Hierarchical Models (SOHM) constructed for Part I and Part II of MPI-Orthodontic was also evaluated.

Convergent validity was estimated from the Average Variance Extracted (AVE) according to Fornell and Larcker's proposal [25]. Value of AVE ≥ 0.50 was considered adequate. The discriminant validity was estimated from the cor-

relation analysis [25], it was considered adequate when AVE_i and $AVE_j \geq r_{ij}^2$.

2.6.3. Invariance

The analysis of the invariance of the models in independent samples was estimated using multigroup analysis and the CFI difference (ΔCFI) for factor weights (λ), intercepts (i), covariance and residuals. The invariance was assumed when absolute values ΔCFI of were lower than 0.01. First, the sample was randomly subdivided into two equal parts and was named "Test Sample" (n = 259) and "Validation Sample" (n = 248). When the factor weights of the models did not differ significantly (metric invariance), it is considered a weak invariance. If factor weights and intercepts do not differ between the groups (scalar invariance), it is considered strong invariance. If a significant difference in factor weights, intercept, covariance and residuals are not identified, it is considered the existence of strict invariance [24].

Some studies have shown that there is a difference in the mean response of orthodontic pain between the sex, in which women present a higher mean pain [12] [26] [27] [28] [29], and according to age group, in which adolescents present a higher mean of pain [29] [30] [31] [32]. Thus, the sample was also subdivided according to sex and age. The age group was defined based on the median age of the study participants who presented a wide range of age and normal distribution. Besides, this definition was sustained in the literature [29] [30] [31] [32]. The groups were formed by individuals < 22.8 years (G0, n = 254) and ≥22.8 (G1, n = 253) years. The invariance of the model was estimated among these two subgroups to verify whether MPI-Orthodontic is invariant in individuals with different sex and age group. The invariance was estimated as previously described.

2.6.4. Concurrent Validity

Concurrent validity of MPI-Orthodontic was assessed using Pearson's Correlational Analysis (r) between the first-order factors of the MPI-Orthodontic and the Visual Analogue Scale (VAS).

2.6.5. Reliability

The reliability was estimated using the standardized Cronbach's alpha coefficient (α) and composite reliability (CR) [25]. CR ≥ 0.70 and $\alpha \geq 0.70$ were considered adequate [24].

2.7. Calculating the Overall Score

After the fit of the MPI-Orthodontic to the sample, the overall score was calculated using the matrix of the factor score weights obtained via confirmatory factor analysis. The scores were calculated for both first-order (**Figure 1(a)** and **Figure 1(b)**) and second-order (**Figure 1(c)** and **Figure 1(d)**) factors. In order to maintain the exact metric of the instrument's original items (Part I: 0 - 10, Part II: 1 - 5), the proportion of the contribution of each item to the overall score was used to correct of the original factor score weights. The corrected weights

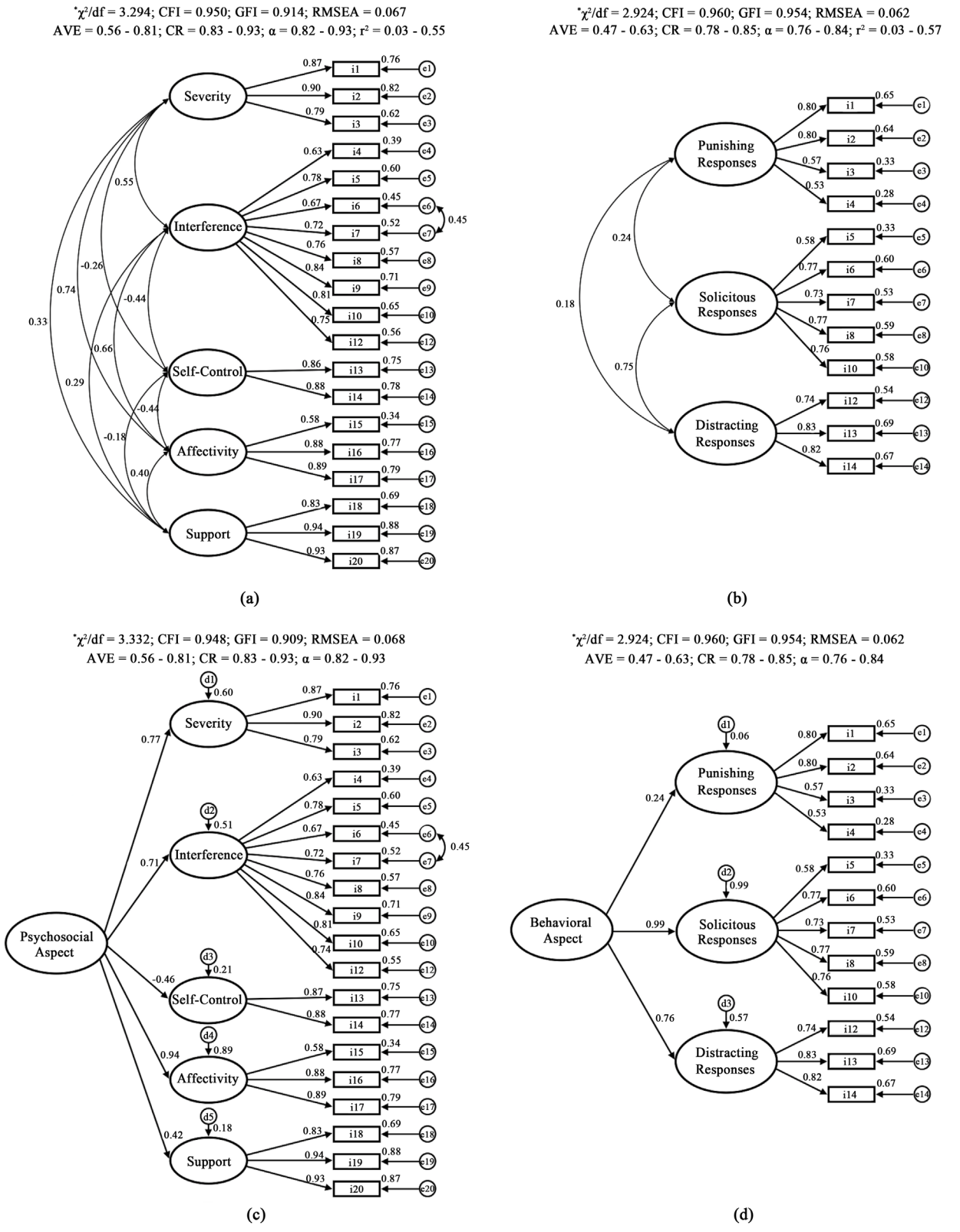

Figure 1. MPI-Orthodontic models tested fit to the sample of orthodontic patients ((a) First-order model Part I; (b) First-order model Part II; (c) Second-order hierarchical model Part I; (d) Second-order hierarchical model Part II).

were multiplied by each participant's response to the items and the estimated scores of each item were added, obtaining the overall score for each factor (overall weighted scores).

2.8. Comparison of Two Different Methods of Score Estimation

After estimating the overall weighted scores, these scores were compared to the scores de-fined as the simple arithmetic mean of the responses given to the items of MPI-Orthodontic. This comparison was performed using a repeated measures analysis of variance. The significance level adopted was 5%.

The analyses were performed in the IBM SPSS (v.22, SPSS An IBM Company, Chicago, IL) and AMOS (v. 22.0, SPSS An IBM Company, Chicago, IL) software.

2.9. Procedures and Ethical Aspects

For individuals aged between 12 and 18 years, such the participant as the legal guardians were consulted and agreed and signed the informed consent form to participate in the study. Individuals older than the age of 18 years agreed and signed the informed consent form to participate in the study. The Multidimensional Pain Inventory (MPI-Orthodontics) was applied through a face-to-face interview conducted by a single interviewer. The interviews were carried out in a reserved space in the waiting room of the participating clinics. The study was approved by the Research Ethics Committee of the São Paulo State University (Unesp), School of Dentistry, Araraquara (CAAE Registry No. 57050016.0.0000.5416).

3. Results

A total of 643 individuals undergoing orthodontic treatment were invited to participate. Of these, 513 individuals agreed to participated (adhesion rate of 79.8%) and 507 individuals answered the demographic questionnaire and MPI-Orthodontic adequately (response rate of 98.8%). The mean age of participants was 26.32 [Standard-Deviation (SD) = 11.70] years and 63.3% were female. Regarding the economic classification, 87 (17.2%) participants belonged to the class A (mean monthly income: R$ 20888.00, U$ 6445.12); 288 (56.8%) class B (R$ 4852.00 - R$ 9254.00, U$ 1497.12 - U$ 2855.38); 129 (25.4%) class C (R$ 1625.00 - R$ 2705.00; U$ 501.40 - U$ 834.64); and 3 (0.6%) class D - E (R$ 768.00, U$ 236.97). The values were Estimated from the quotation of 01/05/2018 of the Central Bank of Brazil—US$ 1.00 = R$ 3.24.

The majority of the participants (n = 295, 58.2%) did not present previous experience of orthodontic/orthopedic appliance use. It is also noted that the majority sought treatment voluntarily (n = 293, 57.8%), were happy with this treatment (n = 420, 82.8%) and reported difficulty or pain in feeding after appliance activation (n = 323; 63.7%).

Among those individuals who reported difficulty and/or painful sensitivity during feeding after orthodontic appliance activation, the mean duration of the difficulty and/or painful was 3.39 (SD = 2.12) days. The mean duration of the orthodontic treatment until the moment of the interview was 21.70 (SD = 19.15)

months. The mean time elapsed since last activation of the orthodontic appliance was 34.78 (SD = 22.64) days. The mean pain intensity (assessed from VAS) for the first day after the last appliance activation was 4.09 (SD = 2.59) and for the second day was 3.38 (SD = 2.61).

The summary measures of the responses for each item of Part I and Part II of the MPI-Orthodontic are shown in Table 2. Note that 4 items from Part I (i5, i8, i10, and i11) and 5 items from Part II (i2, i3, i4, i9, and i11) presented a violation of the normality distribution. However, the data presented multivariate normality (Mardia's Test: Part I = 2.64, Part II = 1.88).

Table 2. Descriptive statistics of the participant responses to the items of the Multidimensional Pain Inventory adapted for orthodontic patients (MPI-Orthodontic).

MPI-Orthodontic	Item	Mean	Median	Standard Deviation	Skewness	Kurtosis
Part I	i1	4.03	4	2.48	0.12	−0.73
	i2	3.42	3	2.91	0.47	−0.81
	i3	2.75	2	2.60	0.70	−0.44
	i4	1.91	0	2.68	1.34	0.82
	i5	0.84	0	1.88	2.63	7.06
	i6	1.36	0	2.47	1.90	2.72
	i7	0.94	0	2.13	2.41	5.18
	i8	0.74	0	1.81	2.88	8.57
	i9	0.91	0	2.09	2.57	6.10
	i10	0.62	0	1.70	3.24	10.74
	i11	0.42	0	1.33	4.13	20.14
	i12	0.83	0	1.83	2.57	6.59
	i13	8.59	10	2.19	−1.80	3.14
	i14	8.73	10	2.11	−1.96	3.68
	i15	7.72	9	2.82	−1.15	0.40
	i16	3.36	2	3.29	0.62	−0.92
	i17	2.75	1	3.17	0.86	−0.54
	i18	4.56	5	4.13	0.09	−1.67
	i19	4.28	4	4.07	0.23	−1.60
	i20	4.69	5	4.16	0.08	−1.67
Part II	i1	1.38	1	0.75	2.06	4.02
	i2	1.20	1	0.58	3.50	13.71
	i3	1.23	1	0.62	2.85	8.06
	i4	1.22	1	0.69	3.40	11.78
	i5	1.66	1	1.06	1.38	0.75
	i6	2.01	1	1.24	0.79	−0.78
	i7	2.60	3	1.43	0.16	−1.39
	i8	2.53	3	1.44	0.24	−1.44
	i9	1.31	1	0.89	2.91	7.40
	i10	2.71	3	1.41	0.04	−1.37
	i11	1.10	1	0.48	5.32	30.75
	i12	1.90	1	1.27	1.05	−0.29
	i13	1.88	1	1.27	1.04	−0.45
	i14	2.05	1	1.37	0.84	−0.80

During the fit of the complete model of the MPI-Orthodontic Part I to the sample (χ^2/df = 4.46, CFI = 0.92, GFI = 0.88, and RMSEA = 0.08), it was observed the existence of correlations between the errors of items from the inspection of the values of the Lagrange Multipliers (LM). There was a correlation between the errors of items 6 and 7 (LM = 101.51) and the error of item 11 with other items inside and outside the factor to which it belongs (LM = 36.24 - 61.28). Thus, the adequate fit was obtained by inserting a correlation between items 6 and 7 and excluding the item 11. The refined model presented adequate factorial, convergent, discriminant validity, and reliability (**Figure 1(a)**).

Regarding MPI-Orthodontic Part II, although the complete model presented adequate fit to the data (χ^2/df = 3.23, CFI = 0.94, GFI = 0.84, and RMSEA = 0.07), factor weights of items 9 (λ = 0.37) and 11 (λ = 0.42) were below the recommended cutoff value. After the exclusion of these items, the refined model presented adequate factorial validity and reliability (**Figure 1(b)**). The convergent validity was at the limit of decision making for the "Punishing Responses" factor but was adequate for the other factors. The discriminant validity was compromised between "Solicitous Responses" and "Distracting Responses" factors. The second-order hierarchical models (SOHM) elaborated after refinement of the first-order models (Part I and Part II) presented adequate fit to the data (**Figure 1(c)** and **Figure 1(d)**).

Table 3 presents the results of the multigroup analysis performed to assess the invariance of the models in independent samples (test and validation) and according to sex and age. It should be clarified that both Part I and Part II of the MPI-Orthodontic presented adequate fit to the subsamples (Test, Validation, Male, Female, G0, and G1) (χ^2/df ≤ 2.96, CFI ≥ 0.92, GFI ≥ 0.85 and RMSEA = 0.09). It is possible to note strong invariance (scalar) of pain assessed from MPI-Orthodontic considering independent samples and sex (ΔCFI < 0.01). Considering age, strong invariance was also observed for Part I while for Part II this invariance was weak (metric).

Table 4 presents the estimated weights using the matrix of the factor score weights (CFA) attributed to each MPI-Orthodontic item for the calculation of the Psychosocial and Behavioral overall score or its first-order factors. Still, **Table 4** presents the correlation values between MPI-Orthodontic factor and VAS. The high correlations observed between VAS and Severity and Psychosocial factors point to the adequate concurrent validity of MPI-Orthodontic. On the other hand, the lower values found for the other correlations suggest the adequate divergent validity of the instrument, once the VAS evaluates only the intensity of the perceived pain.

Table 5 presents a comparison of the mean score of the MPI-Orthodontic factors using two methods; overall weighted scores using the values obtained in the matrix of regression weights (**Table 4**) and simple arithmetic mean of the responses given to the items. In general, it is observed that when using the estimation method by the simple arithmetic mean, the score was overestimated for Part I and underestimated for Part II when compared to the overall weighted

Table 3. Goodness of fit indices of the MPI-orthodontic applied to the different subsamples (Test × Validation, Male × Female, G0 × G1) and multigroup analysis to evaluate the invariance of the models.

Sample	simultaneous CFA[a]			ΔCFI[b]				
	χ^2/df	CFI	RMSEA	β	λ	i	Cov	Res
Part I								
Test × Validation	2.36	0.93	0.05	-	0.003	0.000	0.001	0.004
Male × Female	2.66	0.91	0.06	-	0.007	0.003	0.003	0.014
G0 × G1	2.63	0.91	0.06	-	0.001	0.005	0.001	0.015
SOHM[c]								
Test × Validation	2.39	0.93	0.05	0.000	0.004	0.001	0.001	0.005
Male × Female	2.69	0.91	0.06	0.000	0.007	0.003	0.001	0.014
G0 × G1	2.65	0.91	0.06	0.000	0.001	0.005	0.000	0.014
Part II								
Test × Validation	2.16	0.94	0.05	-	0.006	0.002	0.001	0.005
Male × Female	2.84	0.90	0.06	-	0.000	0.006	0.001	0.037
G0 × G1	3.25	0.87	0.07	-	0.002	0.026	0.001	0.048
SOHM[c]								
Test × Validation	2.16	0.94	0.05	0.000	0.006	0.002	0.000	0.005
Male × Female	2.84	0.90	0.06	0.000	0.006	0.000	0.000	0.038
G0 × G1	3.25	0.87	0.07	0.000	0.002	0.026	0.001	0.048

a. CFA: confirmatory factor analysis, χ^2/df: ratio between chi-square and degrees of freedom, CFI: comparative fit index, RMSE: root mean square error of approximation. b. ΔCFI: comparative fit index difference; λ: factor weight, i: intercept, Cov: covariance, Res: residues, β: structural weight. c. SOHM: second-order hierarchical models.

Table 4. Correlation (r(p)) between the Visual Analogue Scale (VAS) and the MPI-Orthodontic factors and weights to be attributed to each item for the calculation of the overall MPI-Orthodontic Factor scores.

	Part I				Part II					
	Severity	Interference	Self-Control	Affectivity	Support	Psychosocial	Punishing	Solicitous	Distracting	Behavioral
VAS1[a]	0.804 (<0.001)	0.392 (<0.001)	−0.158 (0.001)	0.533 (<0.001)	0.289 (<0.001)	0.784 (<0.001)	0.195 (<0.001)	0.221 (<0.001)	0.178 (<0.001)	0.236 (0.001)
VAS2[b]	0.811 (<0.001)	0.426 (<0.001)	−0.146 (0.003)	0.547 (<0.001)	0.280 (<0.001)	0.796 (<0.001)	0.250 (<0.001)	0.192 (<0.001)	0.098 (0.045)	0.188 (0.005)
Item										
i1	0.311	0.008	0.005	0.047	0.004	0.072	0.316	0.019	0.005	0.021
i2	0.360	0.009	0.006	0.055	0.006	0.085	0.408	0.024	0.006	0.021
i3	0.167	0.004	0.003	0.026	0.002	0.039	0.142	0.008	0.002	0.007
i4	0.003	0.051	−0.003	0.006	0.000	0.013	0.110	0.007	0.001	0.007
i5	0.008	0.137	−0.008	0.018	0.001	0.037	0.003	0.108	0.027	0.107
i6	0.002	0.040	−0.002	0.005	0.000	0.010	0.005	0.203	0.050	0.200
i7	0.004	0.072	−0.004	0.009	0.001	0.020	0.004	0.144	0.035	0.143
i8	0.008	0.130	−0.008	0.017	0.001	0.035	0.004	0.169	0.041	0.164
i9	0.011	0.185	−0.012	0.024	0.002	0.050	-	-	-	-
i10	0.011	0.184	−0.012	0.024	0.002	0.050	0.004	0.168	0.041	0.164

Continued

i11	-	-	-	-	-	-	-	-	-	-
i12	0.007	0.122	−0.007	0.017	0.001	0.033	0.001	0.037	0.196	0.043
i13	0.007	−0.011	0.404	−0.024	−0.001	−0.037	0.002	0.061	0.319	0.064
i14	0.008	−0.014	0.486	−0.029	−0.002	−0.042	0.002	0.052	0.277	0.057
i15	0.010	0.004	−0.004	0.075	0.002	0.048	-	-	-	-
i16	0.035	0.014	−0.015	0.279	0.009	0.178	-	-	-	-
i17	0.041	0.015	−0.017	0.322	0.011	0.214	-	-	-	-
i18	0.001	0.000	0.000	0.003	0.147	0.005	-	-	-	-
i19	0.003	0.001	−0.001	0.011	0.434	0.017	-	-	-	-
i20	0.003	0.001	−0.001	0.009	0.371	0.014	-	-	-	-

a. Visual Analogue Scale of the first day after appliance activation; b. Visual Analogue Scale of the second day after appliance activation.

Table 5. Comparison of the MPI-Orthodontic factor scores calculated using two different estimation methods (overall weighted scores: attribution of weights obtained in the factor weights from the Confirmatory Factor Analysis and the score obtained by the simple arithmetic mean of the items).

MPI-Orthodontic Factor	Estimation Method	Mean	SD[a]	Repeated Measures ANOVA[b]		
				F	p	η_p^2
Part I						
Severity	Overall Weighted Scores	3.40	2.28	0.07	0.79	<0.01
	Simple Arithmetic Mean	3.40	2.41			
Interference	Overall Weighted Scores	0.78	1.56	344.09	<0.01	0.41
	Simple Arithmetic Mean	1.02	1.62			
Self-Control	Overall Weighted Scores	7.60	1.87	11877.13	<0.01	0.96
	Simple Arithmetic Mean	8.66	2.02			
Affectivity	Overall Weighted Scores	2.19	2.37	396.94	<0.01	0.44
	Simple Arithmetic Mean	2.80	2.66			
Support	Overall Weighted Scores	4.36	3.75	54.37	<0.01	0.10
	Simple Arithmetic Mean	4.51	3.85			
Psychosocial	Overall Weighted Scores	1.69	2.02	297.05	<0.01	0.37
	Simple Arithmetic Mean[c]	2.26	1.68			
Part II						
Punishing Responses	Overall Weighted Scores	1.29	0.52	31.24	<0.01	0.06
	Simple Arithmetic Mean	1.26	0.51			
Solicitous Responses	Overall Weighted Scores	2.21	0.97	145.47	<0.01	0.22
	Simple Arithmetic Mean	2.30	1.04			
Distracting Responses	Overall Weighted Scores	2.01	1.05	55.86	<0.01	0.10
	Simple Arithmetic Mean	1.94	1.13			
Behavioral	Overall Weighted Scores	2.20	0.96	501.53	<0.01	0.50
	Simple Arithmetic Mean	1.86	0.70			

a. SD: standard deviation; b. ANOVA: Analysis of Variance, η_p^2: partial eta square; c. to obtain the mean, the responses of items 13 and 14 of the self-control factor were reversed.

scores. This difference between the scores obtained from the different methods was statistically significant ($p < 0.01$).

4. Discussion

This study, for the first time in the literature, proposed and attested the validity, reliability, and invariance of a version of the Multidimensional Pain Inventory (MPI) to evaluate the pain of individuals undergoing orthodontic treatment (MPI-Orthodontic). In addition, a model for this instrument was proposed to provide overall scores related to psychosocial and behavioral aspects. In addition, a method was proposed to calculate factor scores of MPI-Orthodontic and was compared with the method commonly used in the literature.

The proposal of this work arises from the need to evaluate orthodontic pain more comprehensively. For this, it is necessary to consider different aspects inherent to the impact of pain in the life of the individuals and not only the intensity of the pain using, for example, Visual Analog Scale (VAS) as a measurement method [3]. The VAS exclusively evaluates the perception of pain intensity and does not extend the investigation to the quality and to the impact of pain in the individual's life. For this reason, Sandhu [12] recently validated the Short-Form McGill Pain Questionnaire adapted to Orthodontic Pain (Ortho-SF-MPQ) for a sample of individuals undergoing this treatment. This instrument evaluates, in addition to the intensity, the quality of the pain, which represents a gain for management of the patient. However, the Ortho-SF-MPQ does not evaluate the impact of pain on general aspects of individuals' lives. For this reason, we have proposed MPI-Orthodontic. The MPI evaluates the impact of pain on the individuals live considering psychosocial and behavioral aspects and it was elaborated from the cognitive behavioral theory.

Although MPI was originally created to evaluate chronic pain [10], Zucoloto *et al.* [19] attested the validity, reliability, and invariance of this instrument for Brazilian dental patients with acute pain. This fact indicates the possibility of using MPI for different painful conditions. Until now, no studies using MPI to assess pain in orthodontic patients have been found. Because orthodontic pain is a specific type of pain, adaptations were made to MPI, such as the exclusion of the Part III and adaptation of the content of some items.

After the establishment of the MPI version in the orthodontic context, the psychometric properties were evaluated. To obtain an adequate fit of Part I to the data (which assess the psychosocial aspect of pain) it was necessary to exclude item 11 and to insert a correlation between the errors of items 6 and 7. These modifications were performed after the inspection of the values of Lagrange Multipliers. Item 11 refers to how much orthodontic pain has altered or interfered in the friendship with different people in the family. This item presented a high correlation with other items of the same factor, which impaired the fit of the model. In other words, item 11 was redundant to assess the "interference of pain in life" of the individuals. Items 6 and 7 refer to how much orthodontic pain has altered the individual's satisfaction or pleasure with "social and

leisure" or "family-related" activities. Therefore, an important theoretical approximation between the content of these items is observed, which justifies their correlation. It is observed that suggestions of refinement with the elimination and/or insertion of correlations between errors of MPI items already been performed when this instrument is applied to cultures different from the North American [15] [17] [18] [19] [33].

Regarding Part II (which evaluates the behavioral aspect of pain), to obtain an adequate fit of the model, it was necessary to exclude items 9 and 11 due to the low factor weight obtained. These items respectively evaluate individuals' perceptions regarding the act of people to "turn on or turn off the TV" or "read to him/her" at the moment that he/she was experiencing pain caused by orthodontic treatment. It may be suggested that the orthodontic pain does not interfere with these activities. Therefore, although the concepts of solicitous and distracting responses are part of the behavioral aspect of pain caused by orthodontic treatment, the act of turning the television on or off or the act of reading do not make sense for the sample studied.

The present study also proposed and estimated the factorial validity of MPI-Orthodontic SOHM. A second-order factor was added to Part I (Psychosocial Aspect) and Part II (Behavioral Aspect) of the instrument. This allowed for the estimation of overall scores of psychosocial and behavioral aspects of pain, besides of each factor involved in them (Part I: pain severity, interference, self-control of perceived life, mood-affectivity state, and appreciation of the amount of support received from close people, Part II: punishing responses, solicitous responses, and distracting responses). This proposal extends the clinical application of the instrument and allows more general interpretations related to the evaluation of pain. SOHM showed adequate fit. It is suggested that the decision to use the first-order model or the SOHM should be based on the objective of the use of MPI-Orthodontic. In other words, if the focus is to verify the pain caused by orthodontic treatment in the psychosocial or behavioral aspects of pain, the SOHM should be used. On the other hand, if the objective is to evaluate each component factor of the psychosocial or behavioral aspect, the first-order model should be used.

After the fit of the models to the data has been checked, the maintenance of the factorial model in independent samples was observed ($\Delta CFI < 0.01$) which indicates the external validity of the presented results. Still, the invariance observed between sex and age groups showed similarity in the operationalization of MPI-Orthodontic to capture the pain concept in samples with different characteristics, extending the use of this instrument. These results allow future research on issues pointed out in literature such as that women [12] [26] [27] [28] [29] and adolescents [29] [30] [31] [32] present higher mean of pain.

Still, regarding the validity, the high correlations observed in the severity factor and psychosocial aspect with the VAS confirm the proximity of the evaluated concepts. However, it is warned that the MPI-Orthodontic allows a more comprehensive investigation of pain "intensity" than the visual scales, which may be

a strategy in the clinical management.

This study also proposed obtaining the overall scores of the first- and second-order factors (SOHM) of the MPI-Orthodontic, using the matrix of the factor score weights obtained in the confirmatory factor analysis for the sample studied (**Table 4**). The option of using this estimation method is due to the fact that the items and/or models of an instrument do not work in the same way in different situations. This fact occurs because the measurement of an abstract concept (such as pain) is directly related to the characteristics of the sample and the cultural context in which it is inserted [34]. Therefore, the operationalization of an instrument is directly influenced by the studied sample. For this reason, the calculation of the overall scores based on the sum and/or simple arithmetic mean of the responses given to the items is not a better strategy to obtain quality estimates, once they do not consider the operationalization of the instrument for the sample. It is worth mentioning that the confirmatory strategy is a required step for the use of any psychometric instrument whose theoretical model has already been established a priori (as is the case of the MPI), and from it, the matrix of the factor score weights is obtained automatically. These regression weights are specified for the sample [24] [35], so their use makes the estimates more accurate.

Table 5 shows that occurs an overestimation of the "Interference", "Self-Control", "Affectivity", "Support" and "Psychosocial" factors of Part I and an underestimation of factors of Part II when using the simple arithmetic mean to obtain the overall scores. This fact is directly related to the method used to estimate the overall score and it should be warned that the estimation by the simple arithmetic mean considers that all the items have the same participation in the composition of the factors, which is not realistic (**Figure 1**) [35] [36] [37]. Some individuals presented negative scores on the factors "Interference" (score ≥ −0.24), "Self-Control" (score ≥ −0.77), "Affectivity" (score ≥ −0.53), "Support" (score ≥ −0.03) and "Psychosocial" (score ≥ −0.79). This fact occurred due to differences between the response direction of the factors.

A limitation of this study may have been the non-probabilistic sampling design. However, this is a strategy commonly used in validation studies [12] [19] [36] [37]. To minimize the impact of this limitation, we used as an extended sample size. In addition, it was estimated the invariance of models that attested the external validity of the results. Moreover, it is suggested that the MPI-Orthodontic be tested in other samples to verify its properties in other contexts. The specific clinical variables of orthodontic treatment were not tested. Despite these limitations, this study presented a new instrument to evaluate pain in the orthodontic clinic and to calculate an overall score for the Psychosocial and Behavioral aspect of orthodontic pain using the matrix of the factor score weights, which makes the results more accurate. From the clinical point of view, this alternative may not seem viable due to its analytical complexity. However, once the regression weights are obtained to the sample, those data may be included in a program/application that may automatically generate results, making it viable to use

in the clinical routine. With these overall weighted scores, the clinician will be able to make the decision regarding the therapeutic strategy for the patient with orthodontic pain, considering the individual differences between patients. Besides, the overall weighted scores for each first-order factor will allow the study and evaluation of different proposals for orthodontic treatment with an emphasis on different aspects involved in pain.

Thus, it is expected that the presented results provide support for the use of this inventory to extend pain assessment in future clinical studies and clinical practice. In addition, it is expected to instigate future discussions regarding the need to incorporate more robust instruments to evaluate pain in individuals undergoing orthodontic treatment.

5. Conclusion

The Multidimensional Pain Inventory adapted for orthodontics (MPI-Orthodontic) was valid, reliable and invariant for the evaluation of pain caused by orthodontic treatment. It is recommended to use overall weighted scores to calculate the scores of psychosocial and behavioral aspects of pain, seeking the more accurate information for clinical decision making. There is a significant difference between the scores obtained by different estimation methods, which may have an impact on pain management.

Conflicts of Interest

The authors declare no conflicts of interest.

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