UNIVERSIDADE DE SÃO PAULO FACULDADE DE ODONTOLOGIA DE BAURU

MARCELO VINICIUS VALERIO

Longitudinal evaluation of extraction space closure, at final, medium and long-term, and its association with the adopted protocol, in patients treated in the last 40 years, with several initial malocclusions

Avaliação longitudinal do espaço da extração, ao final, em médio e longo prazos, e sua associação com o protocolo adotado, em pacientes tratados nos últimos 40 anos, com diversas maloclusões iniciais

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FOLHA DE APROVAÇÃO

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ABSTRACT

ABSTRACT

LONGITUDINAL EVALUATION OF EXTRACTION SPACE CLOSURE, AT FINAL, MEDIUM AND LONG TERM, AND ITS ASSOCIATION WITH THE ADOPTED PROTOCOL, IN PATIENTS TREATED IN THE LAST 44 YEARS, WITH SEVERAL INITIAL MALOCCLUSIONS

Introduction: This study aimed to evaluate and quantify extraction spaces and their behavior at the end of treatment, short- and long-term stages, in orthodontic patients treated with extractions. Methods: The sample comprised dental casts of 1546 orthodontic patients treated with extractions with several malocclusions. Dental casts were divided into 3 groups, according to the chronological stage: at the end of treatment (T0), 1-year posttreatment (short-term, T1) and 5-year posttreatment (longterm, T2). Extraction spaces were measured in the three stages with a digital caliper. The descriptive analyses of the longitudinal space behavior were performed by amounts of patients, percentage of patients and percentage of quadrants. Intergroups comparison of space dimension in the three stages were performed by Analysis of Variance, followed by Tukey tests when necessary. Results: Class II malocclusion was the most prevalent sagittal discrepancy, followed by Class I and Class III, respectively. More than a half of the patients presented 1-4 quadrants open at the end of treatment. Less than 10% of quadrants persisted open at the three stages. Most of relapse and late closure occurred in the first year after treatment. About 5% of quadrants closed at T0 presented relapse at T1. Less than 3% of quadrants closed at T1 presented relapse at T2. Space dimension decreased significantly in the long-term evaluation. Conclusions: The percentage of patients with open spaces at the end of treatment was substantially large. Despite of the late space closure tendency, several spaces may remain open in the long-term. There was significant reduction in extraction space dimension in the long-term.

Keywords: Orthodontic Space Closure. Malocclusion. Extraction.

Resumo

RESUMO

AVALIAÇÃO LONGITUDINAL DO ESPAÇO DA EXTRAÇÃO, AO FINAL, EM MÉDIO E LONGO PRAZOS, E SUA ASSOCIAÇÃO COM O PROTOCOLO ADOTADO, EM PACIENTES TRATADOS NOS ÚLTIMOS 44 ANOS, COM DIVERSAS MÁS OCLUSÕES INICIAIS

Introdução: O objetivo deste estudo foi avaliar e quantificar os espaços das extrações e seu comportamento ao final do tratamento, em curto e longo prazos. Materiais e métodos: a amostra consistiu em modelos ortodônticos de 1546 pacientes tratados ortodonticamente com extrações com diversas más oclusões. Os modelos foram divididos em 3 grupos, de acordo com o estágio cronológico: ao final do tratamento (T0), 1 ano pós-tratamento (curto prazo, T1) e 5 anos pós-tratamento (longo prazo, T2). Os espaços das extrações foram mensurados nos três estágios com um paquímetro digital. As análises descritivas do comportamento longitudinal foram realizadas por quantidade de pacientes, porcentagem de pacientes e porcentagem de quadrantes. A comparação intergrupos da dimensão do espaço nos três estágios foi realizada através da Análise de Variância, seguida pelo Teste Tukey quando necessário. Resultados: A má oclusão de Classe II foi a discrepância sagital mais prevalente, seguida pela Classe I e Classe II, respectivamente. Mais da metade dos pacientes apresentaram 1-4 quadrantes abertos ao final do tratamento. Menos de 10% dos quadrantes persistiram abertos nos três estágios. A maioria das reaberturas e fechamentos tardios ocorreu no primeiro ano pós-tratamento. Aproximadamente 5% dos quadrantes fechados em T0 apresentaram reabertura em T1. Menos de 3% dos quadrantes fechados em T1 apresentaram reabertura em T2. A dimensão do espaço diminuiu significativamente na avaliação em longo prazo. **Conclusão:** A porcentagem de pacientes com espaços abertos ao final do tratamento foi substancialmente grande. Apesar da tendência de fechamento tardio, muitos espaços podem restar abertos em longo prazo. Houve redução significante na dimensão dos espaços das extrações em longo prazo.

Palavras-chave: Fechamento de Espaço Ortodôntico. Má Oclusão. Extração Dentária.

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LIST OF ABBREVIATIONS AND ACRONYMS

- **T0** End of treatment stage.
- T1 1-year posttreatment stage.
- **T2** 5-year posttreatment stage.
- T0-T1 Short-term period.
- T1-T2 Long-term period.

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1 INTRODUCTION

1 INTRODUCTION

In the beginnings, Orthodontic world was ruled by the expansionist philosophy of Angle, (ANGLE, 1907) which determined that orthodontic treatment should be conducted in order to keep all teeth in the mouth. Nonetheless, every dogma comes to an end. Since Tweed realized that extractions could bring benefits to the soft-tissue when correctly indicated, (TWEED, 1944) extraction protocols were largely employed in the orthodontic daily life over the years. (JANSON; MARIA; BOMBONATTI, 2014; LITT; NIELSEN, 1984; PECK; PECK, 1979; S., 1963; SALZMANN, 1947; TOOD et al., 1999; TWEED, 1944;1952; WILLIAMS, 1979; WISTH; OFTEDAL, 1982; ZHYLICH; SURI, 2011)

Significant profile changes, (JANSON; FUZIY; et al., 2007) space achievement, (AL-ANI; MAGEET, 2018) skeletal and dental error compensation (TWEED, 1944) and treatment efficiency improvement (JANSON et al., 2016; JANSON; BARROS; et al., 2007) were some goals of their routinely application. Since the start of this extraction practice, (ERIKSON; KAPLAN; AISENBERG, 1945) the orthodontic scientific community had been studying each extraction treatment protocol effects, as cephalometric changes, (JANSON; ALIAGA-DEL CASTILLO; NIEDERBERGER, 2017; JANSON; CARVALHO; et al., 2007) dental movement and radicular resorption, (BARROS et al., 2017; COLLETT; FLETCHER, 2000; LUECKE; JOHNSTON, 1992; STEYN; DU PREEZ; HARRIS, 1997; WALDMAN, 1982) their tegumentary effects (BISHARA et al., 1995; JANSON et al., 2015; SINGH; MALDONADO; THIND, 2004; ULGEN, 1986; ZIERHUT et al., 2000) and stability. (BATTAGEL, 1994; BOLEY et al., 2003; JANSON; ARAKI; et al., 2014; JANSON et al., 2010; YOSHIZUMI; SUEISHI, 2016)

Since proximal contact is one of the six keys to normal occlusion, (ANDREWS, 1972) space closure stability have been also studied. (EDWARDS, 1971; JANSON; VALARELLI; et al., 2017; OFTEDAL, B.; WISTH, P. J., 1982; PANCHERZ, 1984; WISTH; OFTEDAL, 1982) Studies evaluating space closure stability found that relapse is frequently present in short-term. (EDWARDS, 1971; GARIB et al., 2016; JANSON; VALARELLI; et al., 2017) Moreover, the influence of several factors in space relapse were evaluated. (B.E. ERIKSON, 1945; CHIQUETO et al., 2011; EDWARDS, 1971;

GARIB et al., 2016; HATASAKA, 1976; MCCOLLUM; PRESTON, 1980; PARKER, 1972; REDLICH; SHOSHAN; PALMON, 1999; REITAN, 1969; ROBERTSON; SCHULTZ; LEVY, 1977; VECERE, 1983) Nonetheless, the tendency of space relapse seems has no determinant predictor factor, but it would happen as consequence of the combination of many of them. (GARIB et al., 2016)

However, despite of the importance of space closure stability, there is one interesting additional information present in the stability studies: the reported frequent presence of open extraction spaces at the final of treatment. (CROSSMAN; REED, 1978; JANSON; VALARELLI; et al., 2017; OFTEDAL, B.; WISTH, J., 1982; PANCHERZ, 1984) The absence of proximal contact can favor food impaction, dental and periodontal injury, (EDWARDS, 1971) as well as, malocclusion relapse. (STORNIOLO, 2014)

Extraction space closure is one of the orthodontic treatment goals which can be achieved during the in-office part of treatment, that is that, without the need of patient compliance. (BURSTONE, 1982; SIATKOWSKI, 1997; ZIEGLER; INGERVALL, 1989) Therefore, it can be achieved in almost all of orthodontic treatments and it should be. The difficult in obtaining space closure had been reported since the Bands Era, (OFTEDAL, B.; WISTH, J., 1982) when the whole orthodontic treatment was performed with bands on all of the teeth. Although this Era has come to the end, orthodontic extraction spaces continued to be mentioned as occasionally found in stability studies, (GARIB et al., 2016; JANSON; VALARELLI; et al., 2017; WISTH; OFTEDAL, 1982) sometimes as persistent at long-term stage. (JANSON; VALARELLI; et al., 2017; OFTEDAL, B.; WISTH, P. J., 1982)

Therefore, considering that open spaces at the end of treatment were often reported in previous studies, (CROSSMAN; REED, 1978; JANSON; VALARELLI; et al., 2017; OFTEDAL, B.; WISTH, J., 1982) but always as occasional findings, it is interesting to further investigate the prevalence of open spaces at the end of treatment and their behavior over time. Short-term behavior and stability of closed extraction spaces was qualitatively evaluated in previous study. (GARIB et al., 2016) In addition, quantitative analysis of extraction spaces, in long-term, was also performed. (JANSON; VALARELLI; et al., 2017) That is why, the aim of this study was to evaluate and quantify extraction space remaining rate and its behavior at the end of treatment, short- and long-term stages, in orthodontic patients treated with extractions.

ARTICLE

2 ARTICLE

The article presented in this Dissertation was formatted according to the American Journal of Orthodontics and Dentofacial Orthopedics instructions and guidelines for article submission.

LONGITUDINAL EVALUATION OF EXTRACTION SPACE CLOSURE AT THE FINAL, SHORT AND LONG-TERM STAGES, IN SEVERAL MALOCCLUSIONS, TREATED IN THE LAST 44 YEARS

Introduction: This study aimed to evaluate and quantify extraction spaces and their behavior at the end of treatment, short- and long-term stages, in orthodontic patients treated with extractions. Methods: The sample comprised dental casts of 1546 orthodontic patients treated with extractions with several malocclusions. Dental casts were divided into 3 groups, according to the chronological stage: at the end of treatment (T0), 1-year posttreatment (short-term, T1) and 5-year posttreatment (longterm, T2). Extraction spaces were measured in the three stages with a digital caliper. The descriptive analyses of the longitudinal space behavior were performed by amounts of patients, percentage of patients and percentage of quadrants. Intergroups comparison of space dimension in the three stages were performed by Analysis of Variance, followed by Tukey tests when necessary. Results: Class II malocclusion was the most prevalent sagittal discrepancy, followed by Class I and Class III, respectively. More than a half of the patients presented 1-4 quadrants open at the end of treatment. Less than 10% of guadrants persisted open at the three stages. Most of relapse and late closure occurred in the first year after treatment. About 5% of quadrants closed at T0 presented relapse at T1. Less than 3% of quadrants closed at T1 presented relapse at T2. Space dimension decreased significantly in the long-term evaluation. **Conclusions:** The percentage of patients with open spaces at the end of treatment was substantially large. Despite of the late space closure tendency, several spaces may remain open in the long-term. There was significant reduction in extraction space dimension in the long-term.

Keywords: Orthodontic Space Closure. Malocclusion. Extraction.

INTRODUCTION

Dental extraction is one of the most used procedures over the years to obtain space, dissolution of crowding, sagittal discrepancy correction and profile esthetic improvement in adult patients.¹⁻¹⁰ Although performed with correct and precise indication, extractions bring two concerns to orthodontic treatment: the need of complete space closure at the end of treatment and the stability of proximal contact

after closing.^{8,11-16} Incomplete closure results in unesthetic condition in smile and functional problems derived from food impaction, as gingival inflammation and its injury, leading to a localized periodontal damage.¹¹ Besides, no proximal contact between adjacent teeth could allow their movement, affect occlusion forces¹⁷ and favoring malocclusion relapse. Space closure should consist of one of the main goals of orthodontic treatment, since proximal contact is one of the six keys of the normal occlusion.¹⁸ Besides, this is a non-compliance-dependent goal, which is achievable though the routinely in-office orthodontic procedures.

The stability of the closure is as important as closing the space until the end of treatment. The reopening of extraction spaces have already been studied and associated with several factors, such as gingival invagination, root parallelism, initial malocclusion type, poor intercuspation, amounts of initial crowding and incisors retraction.^{11,16,19-27} Even though no isolated determinant factor was appointed as direct cause to hinder space closure during the treatment or to compromise its stability after closing, it is fact that the reopening could occur and it can vary from fractions of one to several millimeters.¹¹

Thus, once observed, since the early days of Orthodontics, the high prevalence of open spaces at the end of treatment,^{14,28-30}, as well as, the tendency of relapse to the initial dental positions,^{13,16,24,31-37} it is essential to evaluate the actual prevalence of space closures at the end of treatment and of relapse when extractions are performed. Therefore, the aim of this study was to evaluate and quantify extraction space remaining rate and its behavior at the end of treatment, and at the short- and long-term posttreatment stages, in orthodontic patients treated with extractions.

MATERIAL AND METHODS

This study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo, Brazil (protocol number 71638917.2.0000.5417).

Sample characteristics and inclusion criteria

To assess the behavior of the sites where the extractions were performed, Dental casts of patients treated in the Department of Orthodontics of Bauru Dental School, University of São Paulo, with dental extractions, during 40 years, independent of the initial malocclusion or extraction treatment protocol,³⁸ were selected using inclusion and exclusion criteria.^{16,39} The maxillary retention protocol of all patients consisted of a removable Hawley plate used continuously, except during meals, for 6 months and only during sleeping for an additional six months. The mandibular <u>retainer</u> consisted of a bonded canine-to-canine lingual wire used during a mean period of 3 years.³⁸

In order to make the study sample homogenous and to provide trustfully results, the sample was selected following the inclusion criteria: (1) absence of craniofacial anomalies,⁴⁰ (2) complete initial diagnoses, (3) tooth extraction only for orthodontic reasons,⁶ (4) final, 1 year and 5 year posttreatment dental casts,¹⁶ (5) complete permanent dentition at the pretreatment stage,¹⁶ (6) absence of supernumerary tooth, (7) absence of periodontal surgery in the extraction area, (8) absence of spaces that were not due to orthodontic extractions in the final stage,¹⁴ and, (9) in short- and long-term, absence of extractions after orthodontic treatment. To avoid bias risk, when patients with any anomaly or missing data could be added to the sample, exclusion criteria was followed, which was: (1) broken casts, (2) incomplete initial file, (3) extractions independent of the orthodontic treatment, (4) anodontia, (5) agenesis and (6) low quality casts.

Dental casts

The dental casts corresponded to three stages: final, 1- and 5-year posttreatment.

Dental casts' evaluation

Measurement of space dimension

The amounts of remaining and reopened extraction spaces were measured with a 0.01-mm precision digital caliper (MTX, Matrix Tools for ExistenceTM). The extraction spaces were measured in all quadrants, starting from 0.1mm.^{39,41-44} The spaces were measured from distal face of the extraction space mesial adjacent tooth to the mesial face of the extraction space distal tooth of the same quadrant.³⁹

Error study

Two months after the first measurement, dental casts of 618 patients at the end of treatment were remeasured by the same operator (M.V.V.). Random errors were calculated according to Dahlberg's formula,⁴⁵ S² = $\Sigma d^2/2n$, where S² is the error

variance, and *d* is the difference between 2 determinations of the same variable, and the systematic errors were estimated with dependent *t* tests,⁴⁶ with significance set at *P* < 0.05.

Statistical analysis

Remaining or reopened space analysis

The descriptive analyses were used to present the behaviors of the spaces at the final, shot- and long-term. They demonstrated the percentages of closed, reopened and late closed spaces, per patients and per quadrants.

Variation of the space among three stages

To evaluate space behavior across the time among the three stages, the sample was divided in three groups, as follows: 'End of treatment' (T0, dental casts made immediately after debonding), 'Short-term' (T1, dental casts made after 1 year after debonding) and 'Long-Term' (T2, dental casts made after 5 years after debonding).

Normality tests were not necessary to the Class I and II groups,⁴⁷⁻⁴⁹ and, to the Class III group, Kolmogorov-Smirnov tests were performed to assess normal distribution of the data. All quadrants had a normal distribution. Then, Analysis of Variance (ANOVA) was performed to evaluate dimensional dimensional space variation among the three groups.

RESULTS

The random errors ranged from 0.01 to 0.02 and were considered acceptable and within normal ranges.³⁹ No significant systematic errors were found (Table I).

The descriptive analysis of this study was performed through amounts of patients, and percentages of patients and quadrants, and its results were organized into tables, from II to VII.

Almost all of the patients had dental casts at the end of treatment. The amounts of patients with dental casts decreased according to the number of stages required (Table II).

Class II malocclusion was the most prevalent, followed by Class I and III, respectively (Table III).

Patients with no closed extraction space at the end of treatment were as prevalent as those with all spaces closed. Almost the whole sample presented one of these two situations at T0 (Table IV).

The longitudinal evaluation, in percentages of patients and quadrants, evidenced that the sample presented a tendency of late space closure in short- (T0-T1) and long-term (T1-T2) of the spaces which were open at the end of treatment (Tables V and VI). Space relapse affected a small part of the sample in each period, with more prevalence in the short period. Only a decimal part of the quadrants persisted with open spaces in the long-term, and they were distributed in about one third of all the patients.

In the long-term stage (T2), Class I and Class III patients with persistent open spaces in the three stages presented significantly smaller spaces than at the end of treatment (T0, Table VII). Class II patients presented significantly smaller spaces in the Long-term stage than in the other two stages.

DISCUSSION

Sample description and statistical methods

The sample collection was performed in an Orthodontic department of a university, which means that all the treatments occurred under the supervision of experienced professors. Therefore, equal or similar treatment philosophies were performed and the strictness applied to obtain good results was the same. Moreover, no difference in the overall quality of orthodontic treatments performed in university programs and private practices was found previously.⁵⁰

There is no scientific evidence that growth or sex could affect space closure behavior during or after extraction treatments, which allows to group patients with different ages and sexes treated with extractions. Furthermore, final dentition stage (complete permanent dentition), the retention methods and period of use were the same. Besides, since no effort was made to select well or poorly finished cases, it can be assumed that the results are faithful to what routinely happens in general orthodontic daily practice.

The mechanics used the standard fixed edgewise or preadjusted appliances (Roth prescription), included 0.022 x 0.028-in conventional brackets, associated with extraoral headgear and lip bumpers to reinforce anchorage for upper and lower teeth,

when necessary. Since no effort was made to select patients with maximum or minimum anchorage reinforcement needs, it can be assumed that the evaluated patients had mean anchorage reinforcement needs.⁵¹⁻⁵³

There were 1506 patients with dental casts at the end of treatment, but smaller quantity of them had casts in posttreatment stages (Table II). This fact is comprehensive and expected because is commonly difficult in patients to return for follow-up.

Malocclusion classification was based in molar anteroposterior relationships, according to Angle.^{31,54} In Table III, it is possible to verify that more than the half of the sample (63.13%) presented initially Class II malocclusion, what converges to what was found for previous studies which evaluated the malocclusion prevalence of individuals seeking for or in need of orthodontic treatment.⁵⁵⁻⁵⁷ The lowest malocclusion prevalence was of Class III (3.88%). It runs with the findings of several studies that detected rates ranging from 2.5% to 5.7%.⁵⁷⁻⁶⁴

It was not necessary to verify data normality in studies which sample is bigger than 30 patients per group because the violation of the normality assumption should not cause greater problems. In this situation, parametric tests can be used and that is why they were applied in this study.⁴⁷⁻⁴⁹

Extraction spaces at the end of treatment (T0)

The orthodontic literature has no previous study with such a large sample related to this specific topic. Even less showing the behavior of closed and not completely closed spaces at the end of treatment, at the short- and long-term. Therefore, to be clear and easy to understand, the general longitudinal results were presented in percentages of patients and of quadrants (Tables IV, V and VI).

This study found that less than a half of patients (42.16%) presented all quadrants closed at the end of treatment (T0, Table IV). It is crucial that the orthodontists read this result as a red flag. In general, the six keys of normal occlusion¹⁸ should be one of the goals to the orthodontic treatment. Particularly in this case, the evaluation of the key five, the proximal contact.

Orthodontic treatment outcomes can be influenced by many factors which do not depend on the professional ability.⁶⁵⁻⁶⁸ However, although to reach a high-level finishing is not an easy mission, it is indispensable that the in-office goals be achieved during the treatment. Space closure is one of these goals since tight contacts are one

of the ideal six keys.¹⁸ Interproximal contacts have already shown a tendency to improve over time in normal occlusion.⁶⁹ This suggests that there would be good long-term perspective of stability when spaces were closed even with the aging of the patients. Nonetheless, studies reporting open spaces at the end of treatment and relating the difficult to obtain only cases with closed spaces to the samples are common and frequent in the literature.^{13,16,30,39,70} There are basically three intraoral methods to close extraction spaces: coil springs, reciprocal dental movement with elastics and unilateral movement with absolute anchorage.⁷¹⁻⁷³ All these methods were only subject on the attention and dedication of the orthodontist.

Previous studies shown variated closure rates at the end of treatment, ranging from 20% to more than 70%.^{13,14,29} The different percentages seems to be related to the extracted teeth, amounts of space to close and employed mechanics.^{11,14,74}

Although there is no work reporting the space behavior in Class III treatment in the literature, similar results of it was obtained by the present study were found already previously in Class I and Class II studies.^{29,39}

The low closing rate found in this study is still better than which was reported by previous study, that found closed spaces at the final of the treatment only in 31.4% of patients.¹⁴ However it can be due the different orthodontic systems applied, bonded brackets and banded teeth, respectively. The banded system leaves proximal spaces after bands removing, which does not allow complete closure after de-banding.¹⁴

Better closure rates were found in two studies in the literature,^{13,39} with more than 70% of closed spaces at the end of treatment. However, one of them³⁹ evaluated only patients treated with premolar extractions in a sample with two restrict groups, bilateral Class I and complete bilateral Class II malocclusions. Both malocclusions are very common in orthodontic routine.^{5,75,76} They have classic and well-delineated extraction treatment protocols to be followed, what can increase the chances of success in orthodontic outcomes achievement in many cases. The present study comprised any tooth extraction, including molars. Surely, the larger dimension of the extraction space and the few mechanical options to apply in these cases can have affected the treatment results. The second study¹³ evaluated patients with teeth still in irruption adjacent of the spaces, what is favorable to the closure by spontaneous mesial migration of them in their irruption trajectory.

It is possible to observe that there were similar rates of patients with all quadrants closed and with no quadrant closed, 42.16% and 45.62%, respectively

(Table III). However, the other possibilities, one, two and three closed quadrants, ranged between low percentages, from 1.39% (two closed quadrants) to 7.57% (three closed quadrants). These values can suggest that, perhaps, most patients could present a determinant tendency to close the spaces, or, on the contrary, to resist to the closure mechanics. This tendency could derive from several factors,^{14,16,27,77} which were not assessed in this study.

Longitudinal behavior of extraction spaces

Space reopening

As important as the occlusal, functional and esthetic orthodontic goals, it is the stability of the treatment outcomes.¹⁸ According to Angle,⁷⁸ the relapse would affect cases in which normal occlusion was not achieved during the treatment. However, several studies have demonstrated that the tendency to malocclusion relapse is present even in treatments well finished.^{35,74,79,80} This relapse tendency includes extraction space closure.^{8,11,15,16,19,22,24,28,81}

As expected, longitudinal evaluation of extraction space behavior in this study (Tables V, VI and VII) also found the occurrence of relapse in the short-term period (T0-T1). There was space relapse of at least one quadrant in 9.76% patients with all quadrants closed at the end of treatment (T0). This relapse represents 10.16% of closed quadrants at T0.

Considering the relapse rate in the first year after treatment, this result is divergent from which was found in previous study,¹⁶ which found 13.71% of reopened spaces in one year post-treatment stage. This difference can be explained by the different extractions performed in both samples. The mentioned study only evaluated premolar extraction spaces, following classic extraction treatment protocols to treat Class I and Class II malocclusions.^{5,76} The present study had no limitation according to the extraction protocol, involving any orthodontic extraction performed. The possibility of extract any tooth provides the possibility to extract which one is in the worst position or almost out of the dental arch. In general, space closure is facilitated in these situations because of the small amounts of movement required, what can lead to more stable results.^{16,33,36,82}

In the present study, it can be observed (Tables V, VI and VII) that relapse occurred also in the long-term period (T1-T2). Quadrants that were closed at T0 and T1 stages presented 5.67% of relapse at T2. This percentage reflects 3.9% of the

patients. This rate is smaller than what occurred in the short-term period (T0-T1, 4.49% of quadrants and 5.86% of patients). The lower rate in the long-term period suggests that relapse can occur continuously even after retention period, but the most of changes tends to happen during the first year after debonding. This result converges with previous studies which found that the most orthodontic relapse occurs in the first two years after treatment.^{16,36,74,83}

On the scarce literature related to this topic, there is a previous study³⁹ whose results are almost equal to the present. At a long-term evaluation, the authors found 7.62% of reopened spaces. This result is not hardly different of what was found in the present study, which was 10.16% of relapse, adding up the short- (T0-T1) and long-term (T1-T2) periods reopening rates.

Nonetheless, considering the period of reopening, a previous study¹⁶ found divergent results. The authors found reopened spaces only in the short-term period (1 year after debonding). As mentioned before, since a long time ago,⁸⁴ several studies have found that most of relapse occurs in the short-term period.^{16,36,74,83} However, it does not just occur at this period. Then, it is reasonable to consider that the huge sample size of the present study collaborated to find these infrequent late changes.

Late closure

Late closure consists in the consequence of the natural tendency that the spaces present of decrease over time until proximal contact be established. This closure depends of the amounts of remaining space. Smaller spaces present a tendency to close faster than great amounts.^{8,15,39}

Although the few amount of studies related to this specific topic in literature, it is convention that extraction spaces tends to decrease over the years.^{13,15,16,28,39,85} However, there is no previous study evaluating the extraction behavior beyond of the classic treatment protocols, offering pure percentages of patients and quadrants, and the millimetric variation of the spaces.

The results of this study showed that the tendency of late closure is greater than that of the space remaining open (Tables V, VI and VII). Among all of the open quadrants at the end of treatment (T0), only 6.83% persisted open during the three stages. Fifteen percent of the remaining spaces closed during the short-term period (T0-T1). Posteriorly, it was found additional 4.3% of late closure in the long-term period

(T1-T2). One more time, the results of the present study demonstrate that the most of the changes occurs during the first years after treatment, but does not stop there.

These results are according to previous study³⁹ which found 16.7% of late closed quadrants in the long-term evaluation. This result is not hardly different of what was found in the present study at the point that the sum of late closure in short-(15.62%) and long-term (4.3%) stages was 19.92%. This small difference can be explained because, as told before, previous studies demonstrated that there is more closing potential in smaller spaces than in the large ones.^{8,15,39} Then, in the present study, the possibility of pure assessment of quadrants beyond the classic protocols involves unusual extractions. These extractions could require less movement of the other teeth and/or provide smaller spaces to be closed. Thus, these factors can lead to a favorable tendency of late closure and its comprehensive higher rate in the present study.^{8,15,39}

On the other hand, there are divergent results in the literature. Previous study¹⁵ found an increase of about 17% in the amounts of closed spaces after two year of treatment. This percentage is different than which was found in the present study (Table VI). However, the period evaluated in the study was longer and the authors of the mentioned study considered as open spaces only those which presented more than 0.5mm of dimension. Both factors can have made their results seem more favorable to late closure than reality.

At this point, there is a very relevant question: how do extraction spaces that have been finished open close at the long-term? On the 50's, a long-term study,²⁸ reported that the teeth movement in the late closure occurs through angulation of the teeth which are adjacent of the space, especially in the mandibular arch. This effect was also observed in the present study. Although it was not part of the study objectives, while assessing the dental casts, it was possible to observe that late closure occurs through axial angulation in mandibular arch and through tooth rotation in maxillary arch. This information can be clinically applied at the point that some patients present a wish of remove their appliances as soon as the esthetical results are achieved. But, whether premature debonding is performed before lower space closure, it can result in future axial angulation of space adjacent teeth and its unevenness, affecting chew, intercuspation and compromising treatment stability.¹⁷

Extraction space dimension

Despite the consistent discussion of the qualitative behavior of the extraction spaces, it is interesting and relevant to know in what quantitative dimensional proportions space changes occur.^{11,13,15,70,74}

In general, even the spaces which were not closed until the long-term stage (T2) presented a tendency to dimensional reduction. At the end of treatment, patients of both malocclusions presented almost equal values of space dimension, 0.26mm and 0.25mm, in Class I and II, respectively. These values suggest that both malocclusions answer similarly to closure mechanics. Therefore, it is plausible to consider that space closure it is not influenced by the use anchorage reinforcement devices, external or intermaxillary elastics.

At the short-term, the sample presented a significantly reduction in space dimension to about 70% of the space present at the end of treatment. Although there is no previous study about dimensional space behavior in the short-term, these results converge to what was expected, according to the tendency of space reduction over time.^{13,15,16,28,39,85}

The mean space presented in Class I and II malocclusions in the long-term was 1.25mm. This result converges to the only previous study in the literature,³⁹ which found almost the same dimension (1.05mm) in the long-term evaluation of the same malocclusions.

Class III malocclusion also presented the tendency of significantly space reduction over time. However, this group presented a greater space size at the end of treatment (1.32mm). As explained before, several patients present a wish of remove their appliances as soon as the esthetical results are achieved. One of the most unpleasant features of Class III malocclusion for the patients is the anterior crossbite, which is often corrected before the complete space closure. Thus, it plausible to speculate that the greater space at this stage in relation to the other two malocclusions is due the possible more significant amounts of prematurely finished treatments, without the full closure of extraction spaces.

As well as occurred in Class I and Class II treated cases, extraction spaces presented a tendency of decrease at the long-term period. Although the constant decrease of its dimension, it was observed that most reduction in extraction space occurred in the short-term. This tendency, which was similar to the other two evaluated malocclusions, is according to the previous studies that have assessed space behavior in the course of time.^{13,15,16,39,85}²⁸ Further comparisons with other studies were not possible because there is no study evaluating extraction space behavior in Class III treatment at any stage.

CLINICAL IMPLICATIONS

The amount of unclosed spaces at the end of treatment is worrisome, but it reflects what happens in the orthodontic routine. Moreover, most patients with all quadrants closed at the end of treatment tend to stay stable. Therefore, excellence in finishing should precede the concern with stability.

Nonetheless, the tendency to relapse is a fact. Thus, achieving excellent results is not enough. It is necessary to know how the treatment outcomes behave. Know the general prevalence of closed quadrants at the end of treatment, as well as, the real chances of relapse and late closure of extraction spaces consists in the best way to conduce a predictable and controlled extraction treatment. Besides, the achieved data is a safe parameter to be used in particular performance evaluation.

CONCLUSIONS

- The percentage of patients with 1-4 quadrants with unclosed spaces at the end of treatment was substantially large, 57.83%;
- Despite of the late space closure tendency, several spaces may remain open at the long-term;
- More than 60% of closed quadrants at the end of treatment were stable in the long-term;
- There was significant reduction in extraction space dimension in the long-term.

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Variables	1st measurement		2nd meas	urement	Dahlbarg	в
variables	Mean	SD	Mean	SD	Daniberg	Г
ExtUppRig	0.29	0.4	0.30	0.38	0.02	0.955
ExtUppLeft	0.34	0.6	0.34	0.52	0.01	1.000
ExtLowRig	0.41	0.29	0.40	0.28	0.01	0.938
ExtLowLeft	0.38	0.31	0.37	0.32	0.00	0.944

Table I - Random and systematic errors of the measurements (Dahlberg's formula and t dependent test)

Sample subgroups	N (patients)
Patients treated with extractions	1950
Patients according to inclusion/exclusion criteria	1546
Patients with dental casts at T0	1506
Patients with dental casts at T0 + T1	313
Patients with dental casts at T0 + T2	342
Patients with dental casts at T1 + T2	279
Patients with dental casts at T0 + T1 + T2	256

Table II – Sample selection

Molar Relationship	N (patients)
Class II	976 (63.13%)
Class I	510 (32.99%)
Class III	60 (3.88%)
Total	1546 (100%)

Table III _	Sampla	distribution	according	to the	initial	malocolusion
	Sample	usubulon	according		muai	maiocciusion

45.62% (687)

Space behavior (at T0)N (N=1506)Patients with all quadrants closed at T042.16% (634)Patients with just 3 closed quadrants at T07.57% (114)Patients with just 2 closed quadrants at T01.39% (22)Patients with just 1 quadrant closed at T03.26% (49)

Patients with no closed quadrant at T0

Table IV – Transversal space behavior at the end of treatment (T0), per percentage of patients

Table V – Longitudinal space benavior, per percentage of patients					
General space behavior (T0~T2)	N (256)				
Patients with 1-4 open quadrants at T0, but all closed at T1	21.48% (55)				
Patients with 1-4 open quadrants at T0, all closed at T1 and T0	17.97% (46)				
Patients with 1-4 open quadrants at T0, all closed at T1, but at least 1 relapse at T2	3.51% (9)				
Patients with 1-4 open quadrants at T0 and T1, but all closed at T2	14.84% (38)				
Patients with persistently open quadrants at T0, T1 and T2	37.89% (97)				
Patients with all quadrants closed at T0, but at least 1 relapse at T1	5.86% (15)				
Patients with all quadrants closed at T0 and T1, but at least 1 relapse at T2	3.9% (10)				
Patients with all quadrants closed at T0, at least 1 relapse at T1, but all closed at T2	5.86% (15)				
Patients with all quadrants closed at all stages	28.91% (74)				

Table V – Longitudinal space behavior, per percentage of patients

	•
General space behavior (T0~T2)	N (1024 per stage)
Open quadrants at T0 and persistently open at T1	16.61% (129)
Persistently open quadrants at T0, T1 and T2	6.83% (70)
Closed quadrants at T0 and persistently closed at T1	63.28% (648)
Persistently closed quadrants at T0, T1 and T2	61,72% (632)
Late closure	
Open quadrants at T0, but closed at T1	15.62% (160)
Open quadrants at T0 and T1, but closed at T2	4.3% (44)
Space relapse	
Closed quadrants at T0, but reopened at T1	4.49% (46)
Closed quadrants at T1, but reopened at T2	5.67% (58)

Table VI – Longitudinal space behavior, per percentage of quadrants

Table VII – Longitudinal behavior of the size of the persistently open extraction space at the end of treatment, short- and long-term stages, per malocclusion (ANOVA, followed by Tukey tests)

Malocclusion\Stage	End of treatment (T0)		Short-term (T1)		Long-term (T2)		Р
Class I (spaces in mm)	Mean	SD	Mean	SD	Mean	SD	0 000*
N = 99	0.26 ^A	0.43	0.17 ^B	0.37	0.12 ^B	0.33	0.000*
Class II (spaces in mm)	Mean	SD	Mean	SD	Mean	SD	0 000*
N = 144	0.25 ^A	0.43	0.19 ^B	0.42	0.13 ^C	0.37	0.000
Class III (spaces in mm)	Mean	SD	Mean	SD	Mean	SD	0 000*
N= 13	1.32 ^A	0.50	0.52 ^B	0.76	0.47 ^B	0.69	0.000^
Total (spaces in mm)	Mean	SD	Mean	SD	Mean	SD	0.000*
N = 256	0.25 ^A	0.43	0.18 ^B	0.40	0.13 ^C	0.35	0,000

Different letters represent statistically significant differences.

*Statistically significant at *P* < 0.05.

DISCUSSION

3 DISCUSSION

Orthodontists should base their practical routine on strong evidences. Few studies have been studied extraction space closure and relapse rates with well delineated methodology and adequate samples. (GARIB et al., 2016; JANSON; VALARELLI; et al., 2017)

Insufficient information of extraction space behavior, its prevalence, behavior and causes is present in literature. (CHIQUETO et al., 2011; CROSSMAN; REED, 1978; GARIB et al., 2016; JANSON; VALARELLI; et al., 2017; OFTEDAL, B.; WISTH, J., 1982; OFTEDAL, B.; WISTH, P. J., 1982; USISKIN; WEBB, 1971; WISTH; OFTEDAL, 1982) No systematic review was performed about this specific topic. The most quantitative data of extraction spaces can only be found as additional data of qualitative studies. Based on this, conclusions with scientific strength are still not enough.

Literature analysis evidences that orthodontic extraction spaces are often occasional findings on stability studies. (EDWARDS, 1971; GARIB et al., 2016; JANSON; VALARELLI; et al., 2017) The concern about relapse seems to obfuscate that, before worrying about the stability of treatment, orthodontists should be concerned about the occlusal final success of it. The six keys of normal occlusion should be always the main goal of orthodontic treatment. (ANDREWS, 1972)

Considering the whole literature, only two recently published studies made a significant effort to evaluate extraction space closure behavior after treatment. (GARIB et al., 2016; JANSON; VALARELLI; et al., 2017) However both studies have different designs, consequently to the different aims of each one. The first published of them presents qualitative data about space relapse and the possibility of reopening, but the evaluation was performed only from closed spaces. (GARIB et al., 2016) Moreover the qualitative results do not allow to visualize the clinical impact of the space presence. The last published studied offers a long-term evaluation of extraction behavior, presenting qualitative and quantitative data. (JANSON; VALARELLI; et al., 2017) Measurements were performed in a similar way to that used in the present study. However, the is no data about short-term stage. This does not allow complete visualization of the chronology of the changes, separating short- and long-term effects.

Therefore, it became necessary to further investigate the theme and heal the obscurities present in the literature. This study aimed to evaluate and quantify extraction space remaining rate and its behavior at the end of treatment, short- and long-term stages, in orthodontic patients treated with extractions. Additionally, Class I, Class II and Class III patients were compared among the three stages regarding the dimension of spaces in order to better comprehension of clinical impact of the open spaces. This design seemed enough elaborate for this.

The achieved results demonstrate that the importance of pay attention in treatment finishing should be greater than the concern with stability. More than a half of the patients presented 1-4 quadrants open at the end of treatment. Less than 10% of quadrants persisted open at the three stages. Most of relapse and late closure occurred in the first year after treatment, but do not stop there. About 5% of quadrants closed at T0 presented relapse at T1. Less than 3% of quadrants closed at T1 presented relapse at T2. Space dimension decreased significantly in the long-term evaluation of the three malocclusions.

These results converge to previous studies which affirm that the most changes occur in the first years after debonding. (GARIB et al., 2016; HARRIS; VADEN, 1994; VADEN; HARRIS; GARDNER, 1997; ZACHRISSON, 1997) As well as, corroborates to previous studies which found a tendency of decrease of the space dimension over time. (COOKSON, 1971; CROSSMAN; REED, 1978; GARIB et al., 2016; JANSON; VALARELLI; et al., 2017; OFTEDAL, B.; WISTH, P. J., 1982; STACKLER, 1957)

The results of the Class III group could not be further compared because there is no previous study in the literature of extraction space behavior in Class III patients. However, the present one can be used as parameter for comparisons with studies that may arise.

Therefore, based in the results of this large longitudinal evaluation of the orthodontic extraction spaces, it can be pointed out that the stability is not the greater deficiency on extraction therapy, since the most of quadrants remained open at the end of treatment, as well as, the first years after debonding are the most important to observe space behavior changes, but these changes do not stop in the long-term, what means that long-term follow-up is advisable.

CONCLUSION
4 CONCLUSIONS

- The percentage of patients with 1-4 quadrants with unclosed spaces at the end of treatment was very large, 57.83%;
- Despite of the late space closure tendency, several spaces may remain open in the long-term;
- More than 60% of closed quadrants at the end of treatment were stable in the long-term;
- There was significant reduction in extraction space dimension in the longterm.

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Appendix

APPENDIX A - DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN DISSERTATION/THESIS

We hereby declare that we are aware of the article "LONGITUDINAL EVALUATION OF EXTRACTION SPACE CLOSURE, AT THE FINAL, SHORT AND LONG-TERM STAGES, IN SEVERAL MALOCCLUSIONS, TREATED IN THE LAST 44 YEARS" will be included in Dissertation of the student Marcelo Vinicius Valerio and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

	Bauru, November 30th, 2018.
<u>Marcelo Vinicius Valerio</u> Author	Signature
Guilherme Janson	Signature
Author	Signature
Author	Signature



ANNEX A. Ethics Committee approval, protocol number 71638917.2.0000.5417 (front).



ANNEX A. Ethics Committee approval, protocol number 71638917.2.0000.5417 (verso).



Continuação do Parecer: 2.566.826

apresentação de relatório final. Os relatórios parciais deverão estar de acordo com o cronograma e/ou parecer emitido pelo CEP. Alterações na metodologia, título, inclusão ou exclusão de autores, cronograma e quaisquer outras mudanças que sejam significativas deverão ser previamente comunicadas a este CEP sob risco de não aprovação do relatório final. Quando da apresentação deste, deverão ser incluídos todos os TCLEs e/ou termos de doação assinados e rubricados, se pertinentes.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_P ROJETO_920370.pdf	13/03/2018 19:29:57		Aceito
Outros	solicitacao_de_apreciacao2.pdf	13/03/2018 19:29:24	Marcelo Valerio	Aceito
Projeto Detalhado / Brochura Investigador	marceloviniciusvalerio2.pdf	13/03/2018 19:28:16	Marcelo Valerio	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE2.pdf	13/03/2018 19:27:44	Marcelo Valerio	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.pdf	20/11/2017 15:58:45	Marcelo Valerio	Aceito
Outros	SOLICITACAO_APRECIACAO.pdf	25/09/2017 11:46:14	Ana Lúcia Pompéia Fraga de Almeida	Aceito
Outros	TERMO_AQUIESCENCIA.pdf	25/09/2017 10:53:03	Marcelo Valerio	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	DISPENSA_TCLE.pdf	25/09/2017 10:50:09	Marcelo Valerio	Aceito
Projeto Detalhado / Brochura Investigador	projetomarceloviniciusvalerio.pdf	26/05/2017 00:33:56	Marcelo Valerio	Aceito
Outros	usodasdependencias.pdf	26/05/2017 00:31:34	Marcelo Valerio	Aceito
Outros	compromisso.pdf	26/05/2017 00:30:24	Marcelo Valerio	Aceito
Folha de Rosto	marceloviniciusvalerio.pdf	26/05/2017 00:28:45	Marcelo Valerio	Aceito

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Página 02 de 03

ANNEX A. Ethics Committee approval, protocol number 71638917.2.0000.5417 (front).



Continuação do Parecer: 2.566.826

Situação do Parecer: Aprovado

Necessita Apreciação da CONEP: Não

BAURU, 27 de Março de 2018

Assinado por: Ana Lúcia Pompéia Fraga de Almeida (Coordenador)

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Página 03 de 03

ANNEX B. Patient's informed consent exoneration (front)



Universidade de São Paulo Faculdade de Odontologia de Bauru

Departamento Odontopediatria, Ortodontia e Saúde Coletiva Disciplina de Ortodontia

DISPENSA DE TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO E TERMO DE ASSENTIMENTO

Solicitamos ao Comitê de Ética em Pesquisa, FOB-USP, a dispensa do Termo de Consentimento Livre e Esclarecido e Termo de Assentimento, do projeto de pesquisa "Avaliação longitudinal do comportamento do espaço da extração ao final, em médio e longo prazos, e sua associação com o protocolo adotado, em pacientes tratados nos últimos 40 anos, com diversas maloclusões", de autoria de Marcelo Vinicius Valerio sob a orientação do Prof. Dr. Guilherme Janson.

Tal solicitação justifica-se pelo fato da amostra ser retrospectiva. Os prontuários estão sob os cuidados da disciplina de Ortodontia do Departamento de Odontopediatria, Ortodontia e Saúde Coletiva. Estes prontuários são do acervo desde 1973, constituindo uma dificuldade o contato com os pacientes devido ao tempo decorrido desde o tratamento feito até a data presente. Vale ressaltar que os pacientes, quando atendidos da clínica de Ortodontia, assinam a "AUTORIZAÇÃO PARA DIAGNÓSTICO E/OU EXECUÇÃO DE TRATAMENTO ORTDÔNTICO" (modelo anexo) a qual aprova tanto a execução do tratamento quanto seu uso para "quaisquer fins de ensino e de divulgação em jornais e/ou revistas científicas do país e do exterior", desta forma aprova-se também o uso dos dados do seu prontuário para o ensino em pesquisas científicas.

A dispensa do termo de Assentimento se deve ao fato de os pacientes da amostra, no momento da execução do exame, serem tanto menor de 18 anos quanto adultos, não sendo diferenciado para a pesquisa, como critério de inclusão ou exclusão. Tais pacientes também foram autorizados pelo responsável no documento "AUTORIZAÇÃO PARA DIAGNÓSTICO E/OU EXECUÇÃO DE TRATAMENTO ORTDÔNTICO". Os nomes e dados pessoais dos pacientes não serão divulgados em nenhum momento, mantendo desta forma o sigilo profissional (Artigo 9º do Código de Ética Odontológico) e a privacidade dos participantes da pesquisa durante todas as fases e assumimos o compromisso de cumprir as exigências contidas na Resolução CNS Nº 466, de 12.12.12.

Bauru, 25 de/setembro de 2017.

10 ricu Marcelo Vinicius/Valerio Pesquisador

Al. Dr. Octávio Pinheiro Brisolla, 9-75 – Bauru-SP – CEP 17012-901 – C.P. 73 e-mail: veragato@fob.usp.br – Fone (0xx14) 3235-8217 – Fax (0xx14) 3223-4679 http://www.fob.usp.br

ANNEX B. Patient's informed consent exoneration (verso)

UNIVERSIDADE DE SÃO PAULO FACULDADE DE ODONTOLOGIA DE BAURU CLÍNICA DE ORTODONTIA

AUTORIZAÇÃO PARA DIAGNÓSTICO E/OU EXECUÇÃO DE TRATAMENTO ORTODÔNTICO

Por este instrumento de autorização por mim assinado, dou pleno consentimento à FACULDADE DE ODONTOLOGIA DE BAURU-USP para, por intermédio de seus professores, assistentes e alunos devidamente autorizados, fazer diagnóstico, planejamento e tratamento em minha pessoa ou meu filho menor de idade , de acordo com os conhecimentos enguadrados no campo dessa especialidade.

Concordo também, que todas radiografias, fotografias, modelos, desenhos, históricos de antecedentes familiares, resultados de exames clínico e de laboratório e quaisquer outras informações concernentes ao planejamento de diagnóstico e/ou tratamento, constituem propriedade exclusiva desta FACULDADE, à qual dou plenos direitos de retenção, uso para quaisquer fins de ensino e de divulgação em jornais e/ou revistas científicas do país e do exterior.

Bauru, _____ de ______ de 19 ____.

Assinatura do paciente ou responsável

R.G. №:

Nome: _____

Endereço: _____

Telefone: