UNIVERSIDADE DE SÃO PAULO
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CAROLINE MARTINS GAMBARDELA TKACZ

Evaluation of the dental arches shape influence in the anterior crowding relapse

Avaliação da influência da forma dos arcos dentários na recidiva do apinhamento anterior

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Orientador: Prof. Dr. Marcos Roberto de Freitas

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DEDICATÓRIA

Dedico este trabalho

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Professores
(...)
Porque tudo é educação
É matéria de todo o tempo
Ensinem a quem sabe de tudo
A entregar o conhecimento
Na sala de aula
É que se forma um cidadão
Na sala de aula
É que se muda uma nação
Na sala de aula
Não há idade, nem cor
Por isso aceite e respeite
O meu professor
(...)
Batam palmas para eles
Porque eles merecem
Batam palmas para eles
Batam palmas para eles e elas
Porque eles merecem!
Viva a educação!

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"So no one told me your life was gonna be this way (…)
I'll be there for you when the rain starts to pour
I'll be there for you like I've been there before
I'll be there for you 'Cause you're there for me too (…)
No one could ever know me, no one could ever see me
Seems you're only one who knows what it's like to be me
Someone to face the day with, make it though all the rest with
Someone I'll always laugh with
Even at my worst
I'm best with you, yeah!"
Allee Willis/Danny Wilde/ David Crane/Marta Kauffman/ The Rembrandts

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“A coisa mais moderna que existe nessa vida é envelhecer
(...) o tempo vai dizendo que agora é pra valer
(...) Como será que deve ser envelhecer
Eu quero é viver pra ver qual é
E dizer venha pra o que vai acontecer
(...) Eu quero pôr Rita Pavone
No ringtone do meu celular
(...) E quando eu esquecer meu próprio nome
Que me chamem de velho gagá
Pois ser eternamente adolescente nada é mais demodé
(...)Como será que deve ser envelhecer”

Música Envelhecer
Arnaldo Antunes

"Time changes everything! Nothing stays
the same... in life and orthodontics."

Richard Gerald "Wick" Alexander

RESUMO

Objetivos: Comparar as alterações das dimensões lineares e da forma da arco dentário no início, ao final do tratamento e em longo prazo em relação à severidade do apinhamento anteroinferior em indivíduos tratados com extração de 4 pré-molares. **Material e Métodos:** A amostra foi composta por 41 pacientes com má oclusão de Classe I e II tratados com extração de 4 pré-molares, divididos em 2 grupos de acordo com a severidade do apinhamento anteroinferior inicial e avaliados no pré-tratamento, pós-tratamento e pós-contenção. Grupo apinhamento suave: pacientes com Índice de irregularidade de Little inferior menor que 6mm e Grupo 2 apinhamento severo: pacientes com Índice de irregularidade de Little inferior maior que 6mm. Os modelos de gesso foram digitalizados e as imagens tridimensionais foram analisadas. O índice de irregularidade de Little, as larguras transversais e longitudinais dos arcos superior e inferior foram avaliados. A comparação intergrupos foi realizada com o teste t independente. Os valores das coordenadas x, y e z de cada marco anatômico foram obtidos e analisados com Superimposição de Procrustes, Análise de Componentes Principais e Análise de Correlação Canônica para examinar a variação entre indivíduos e grupos. **Resultados**: Os grupos em geral apresentaram comportamento semelhante entre eles para as dimensões dos arcos superior e inferior e apinhamento dentário em todas as fases. A maior variação na forma do arco dentário está relacionada à posição dos incisivos e caninos. A forma do arco mudou com o tratamento e foi mantida com pequenas variações em longo prazo. O comportamento dos arcos dentários superiores e inferiores de ambos grupos foi semelhante. **Conclusões:** Não houve diferenças entre os grupos de apinhamento suave e severo para as dimensões do arco dentário, porém o grupo leve apresentou maior porcentagem de recidiva no arco inferior. A forma original do arco dentário foi modificada com o tratamento e apresentou discreta variação durante o acompanhamento em longo prazo em ambos os grupos.

Palavras-chave: Arco Dental. **Má Oclusão. Extração Dentária.** Recidiva.

ABSTRACT

Aim: To compare changes in linear transversal dimensions and dental arch shape during at pretreatment, posttreatment and in long-term according to the severity of anterior crowding in individuals treated with 4-premolars extraction. **Material and Methods:** The sample consisted of 41subjects with Class I and II sagittal relationship treated with extraction of 4 premolars, divided into 2 groups according to the severity of the anterior crowding and evaluated in the pretreatment, posttreatment and postretention. Group Mild crowding: subjects with initial mandibular Little irregularity index (LII) less than 6mm Group Severe crowding: subjects with initial mandibular Little irregularity index of 6mm or greater. Three-dimensional images of dental casts were analyzed. Little's irregularity index, the transverse and longitudinal widths of the maxillary and mandibular arches were evaluated. Intergroup comparisons were performed with independent t tests. The anatomical landmarks were marked, the x, y, z coordinates for each landmark were collected for maxillary and mandibular arches. Generalized Procrustes Analysis, Principal Component Analysis and Canonical Variates Analysis were used to examine the variation between individuals and groups. **Results:** The groups presented similar behavior between them for maxillary and mandibular arches dimensions and dental crowding for all stages. The variables showed different behavior among the stages in both groups. The Principal Components Analysis demonstrated greatest variation in the shape was related to the displacement of the incisor and canines. The arch shape changed with treatment and was maintained, with slight variation, over the long-term follow-up. The behavior for maxillary either mandibular dental arches for both groups were similar. **Conclusion:** There were no differences between mild and severe crowding groups for dental arch dimensions, but the mild group presented greater mandibular percentage of relapse. The initial dental arch shape was modified during the treatment and showed slight variation in the long-term follow-up in both groups.

Keywords: Dental Arch. Malocclusion. Tooth Extraction. Recurrence. Longitudinal Studies.

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LIST OF ABREVIATIONS AND ACRONYMS

LII	Little's Irregularity Index
3-3 width	Intercanine width
5-5 width	Inter premolar width
6-6 width	Intermolar width
T1	Initial or pretreatment
T2	Final or posttreatment
T3	Postretention follow-up
ANOVA	analysis of variance
SD	Standard deviation
ICC	Intraclass Correlation Coefficient
SSA	Statistical shape analysis
GMM	Geometric Morphometric
GPA	Generalized Procrustes Analysis
PCA	Principal Components Analysis
CVA	Canonical Variates Analysis
CAPES	Coordination for the Improvement of Higher Education Personnel

SUMÁRIO

1 INTRODUCTION

1 INTRODUCTION

Malocclusion of the teeth and the broader spectrum of dentofacial deformity is due to an interplay between genetic and external environmental factors, although clinically abnormal, is nonetheless in a balanced state. This oral disease is not just teeth. A tooth is a variable in dental arch shape. The teeth react to other forces and factors that are highly dynamic. The forces of orofacial musculature are maintained in equilibrium and prevent the teeth moving out of position. The tongue acts as a powerful stimulus for the teeth's systematic arrangement in the arch form. The functions of teeth and alveolar bone structures have been able to position the dental arch in a balanced area. Extraction of permanent teeth in orthodontics is a reasonable method to balance tooth and jaw size and to achieve relatively stable outcomes in the treatment of malocclusions involving significant dental crowding. The possibility of instability exists when a physiological imbalance was produced. The tissues are brought into play in a way attempting to restore balance, thereby returning in a developmental direction toward the pretreatment state or some combination between. It is a protective mechanism. It is the same growth process working toward physiologic, biomechanical, and developmental equilibrium. The orthodontic relapse is mainly related to the changes produced in the dental arch form during mainly the fixed appliances stage and the incorrect positioning of the roots of the teeth in relation to their apical bases; muscle dysfunctions; imbalance of mechanical loads imposed on dental crowns when contact occurs antagonist teeth in the chewing process and after discontinuing the use of retainers. (Brader, 1972; Brodie, 1939; Cotrim-Ferreira, 2018; Enlow; Hans, 1998; Peck, 2017; Proffit, 1978) Nowadays the concept of stability is dynamic and biological, rather than purely mechanical. (AlShayea; AlMaghlouth; AlBalkhi, 2019; Swidi et al., 2018)

The use the basic conformation of the malocclusion as a reference and preserve it throughout the treatment is a requirement in orthodontics.(Little, 1990; Little, 1999) Identify exactly the ideal conformation of the patient's dental arch shape is not an objective task for orthodontists, therefore seek an arch shape that approximates the maximum individual conformation.(Arai; Will, 2011; Interlandi, 1964)

The knowledge of growth, craniofacial morphology (Brodie, 1939; Richardson, 1994), ethnic characteristics (Bayome et al., 2011; Gafni et al., 2011; Kook et al., 2004; Lavelle; Foster; Flinn, 1971; Nojima et al., 2001; Othman et al., 2012; Pinzan; Pinzan-Vercelino; Pinzan, 2010), long-term follow-up results and environmental factors should be considering in orthodontic diagnosis, prognosis and individualized treatment plan.

Usually a researcher selects ratios of distances and angles between landmarks or angles and then submitted these to univariate statistical analyses. Statistical shape analysis (SSA) is multivariate statistical procedure, that involves statistical methods for analyzing the shapes of objects. In geometrical methods allowed to work on the Cartesian landmark coordinates directly. Geometric morphometric analysis studies shape using landmark coordinates to capture the morphology rather than linear, angular or volumetric variables. It allows for effective visual representations of statistical results as actual shapes/forms or shape/form deformations. Centroid Size is the square root of the sum of squared Euclidean distances from each landmark to the centroid of that configuration. Centroid size is the measure of size that is mathematically independent of shape. In biological data, it may often be empirically correlated with shape because larger organisms often are shaped differently than smaller ones. The Centroid Size of each individual is calculated used to resize all settings and matched. Procrustes distance is the distance between the centroid size and the corresponding landmarks, that cannot be removed by scaling, translation, or rotation and is therefore useful as a measure of shape difference.(Bookstein, 1991; Cooke; Terhune, 2015; Dryden; Mardia, 1998; Klingenberg, 2016; Moraes, 2003; van de Lande; Papaioannou; Dunaway, 2019; Zelditch; Swiderski; Sheets, 2012)

In Greek mythology Procrustes also known as Damastes, he was a son of Poseidon. He was an innkeeper, who lived by the road from Eleusis to Athens. He would offer travelers a room for the night and fit them to the bed by stretching them if they were too short or chopping off their limbs if they were too tall. Procrustes continued his reign of terror until he was captured by Thesus, who "fitted" Procrustes to his own bed.

Generalized Procrustes Analysis (GPA) comprised translating, scaling, and rotating all landmark configurations until to the same centroid. This method was used to enlargement without distortion, the smallest object until both objects are of equal

size. The enlargement used gives the difference in size between both objects. In the sense to minimize the differences among landmark configurations.(Mitteroecker et al., 2013)

The mythological Procrustes changed the shape of his victims, it was an analogy because the mathematical Procrustes superimposition method did not change shape. Translation, scaling and rotation was the mathematical operation responsible for not changing the shape. (Gower, 1975; Rohlf) The analogy with the mythology character is slight and regard one configuration as the bed and the other as the person being “translated, rotated” and possibility “rescaled” so as to fit as close as possible to the bed. The word "Procrustean" is thus used to describe situations where different lengths or sizes are fitted to an arbitrary standard.

Statistical shape analyses and geometric morphometric has been applied in various knowledge areas as computer science, medical imaging analysis, archaeology, geology, agriculture, genetics, zoology, anthropology, orthodontics and others. In orthodontics specifically to assess tooth shape, (Al-Shahrani et al., 2014) relationship between dental arches and different types of malocclusion, (Miller et al., 2016; Palomo et al., 2005; Papagiannis; Halazonetis, 2016; Pugliese et al., 2019) open bite, (Lagana et al., 2019; Lione et al., 2020) profile, (Kouli et al., 2019) including crowding severity. (Kim et al., 2017; Lestrel; Takahashi; Kanazawa, 2004)

2 ARTICLES

2 ARTICLES*

2.1 ARTICLE 1 - Dental arch dimensions changes and anterior dental crowding relapse in patients treated with extractions: long-term follow-up study

2.2 ARTICLE 2 - Geometric morphometric analyses of dental arches changes in the long-term posttreatment follow-up

* These 2 articles that compose this thesis were written according to the American Journal of Orthodontics and Dentofacial Orthopedics instructions and guideline for article submission.

2.1 ARTICLE 1 - Dental arch dimensions changes and anterior dental crowding relapse in patients treated with extractions: long-term follow-up study

Abstract

Aim: to compare the long-term dental arch dimensions changes and crowding behavior in subjects with mild to several initial crowding treated with 4 premolars extraction.

Material & Methods: The sample comprised 41 subjects with Class I and Class II malocclusions treated with 4-premolars extraction, divided into two groups according to initial mandibular anterior crowding severity. Group Mild: 16 subjects (9 females; 7 males) with initial Little irregularity index (LII) less than 6mm (mean=3.31mm, SD=2.10), with means initial, final and postretention ages of 13.45 (SD=1.57), 15.98 (SD=1.97) and 54.93 years (SD=3.78). Treatment, retention and long-term follow-up times were 2.53 (SD=0.72), 1.80 (SD=0.73) and 38.95 years (SD=2.88). Group Severe: 25 subjects (17 females; 8 males) with Little irregularity index of 6mm or greater (9.95mm, SD=2.65), with means initial, final and postretention ages of 13.25 (SD=2.20), 15.40 (SD=2.25) and 52.85 years (SD=6.23). Treatment, retention and long-term follow-up times were 2.15 (SD=0.43), 2.48 (SD=1.27) and 37.45 years (SD=5.23). The maxillary and mandibular Little irregularity index, transversal and longitudinal widths were assessed in digital dental casts at pretreatment, posttreatment and long-term postretention, using the Ortho Analyzer 3D software. Intergroup comparisons were performed with independent t tests. Intragroup comparisons were performed with repeated measures analysis of variance followed by Tukey tests. **Results:** The groups presented similar behavior between them for maxillary and mandibular arches dimensions and dental crowding for all stages. The variables showed different behavior among the stages in both groups. **Conclusions:** There were no differences between mild and severe crowding groups regarding arch dimensions and crowding relapse in the long-term posttreatment follow-up.

Keywords: Malocclusion; Tooth Extraction; Relapse; Longitudinal Studies.

INTRODUCTION

Dental crowding can be defined as a disparity in the relationship between tooth dimensions and jaw size which results in imbrication and rotation of teeth. It can be primary with genetic etiology or tertiary crowding that occurs during adolescent and post adolescent period and it is related with late facial growth.[1,2] Therefore, it refers to an intra-arch problem and can be present in different inter-arch conditions.[3] There is anthropological evidence that dental crowding is increasing in modern societies.[4] Retention is the stage that attempts to maintain teeth in their corrected positions after active teeth movement.[5] The prolonged retention time may be an important factor for stability.[6] The retainer did not prevent a certain amount of unwanted occlusal changes but has a role in maintaining the alignment of the mandibular anterior teeth.[7]

Transversal arch dimensions and effective apical base lengths are important factors related to the amount of dental crowding,[8-10] and broken of contact points for anterior teeth malalignment.[11] There was no relationship between crowding and tooth size,[8] presence of third molars,[12,13] neither incisor-crown-morphology index.[14]

The changes of anterior alignment after orthodontic treatment is a common orthodontic patient's chief complaint in private practice. It is the trend for teeth to move to unwanted positions, which can be expressed as percentage.[1,15]

Relapse can be defined as any unfavorable change in teeth position after orthodontic treatment. Therefore, it is unpredictable and should be presumed that every patient has the potential for long-term changes.[6,9,16,17]

The etiology of posttreatment relapse is multifactorial and not completely understood. It is related to an unfavorable facial growth pattern; to the soft tissue response after the release of orthodontic forces; muscular balance.[18,19] Besides that, the relapse could also be associated with intercanine width increase, changes in the shape of dental arch,[20] amount of mandibular bone structure (Cortical thickness and alveolar bone),[21] periodontal and occlusal factors, oral and soft tissue pressures, lack of patient compliance in the use of the retainers.[22,23] These changes may also be the result of normal age-related effects, physiological changes in the dentoalveolar processes continues to happen throughout adult life.[24] There was no relationship between crowding and presence of third molars.[25]

There are no characteristics, variables and kind of treatment that are valuable in predicting the long-term results.[9,17,26-28] A small amount of overcorrection in the finishing stage is an established method to minimize the relapse.[18] Furthermore,

recently studies in the retention and stability field showed that there are new promising techniques that could enhance postretention stability.[29-31]

Based on that, this study aimed to compare the long-term incisor alignment and dental arch dimensions changes between two groups divided by mandibular Little irregularity index severity in subjects treated with 4-premolar extraction.

MATERIAL AND METHODS

Material

This longitudinal, retrospective cohort study[32] was approved by the Ethics Committee on Human Research of _____, under number _____ and written consents were obtained from all subjects.

To detect a minimum difference of 2 mm with a standard deviation of 1.9 mm in mandibular Little irregularity index at follow-up,[33] considering an 80% of test power at a significance level of 5%, the sample size calculation demonstrated that 15 subjects were necessary in each group.

The sample was selected according to the following inclusion criteria: Class I or any severity of Class II malocclusion at the beginning of the treatment, complete orthodontic treatment with fixed edgewise appliances; treatment protocol with extraction of 4 premolars; presence of full permanent dentition until first molars erupted, no tooth agenesis or anomalies; maxillary removable appliance, and mandibular fixed canine-to-canine retainers worn for at least 1 year; without retention at the time of the follow-up records; pretreatment (T1), posttreatment (T2), dental casts available for the study; at least 25 years posttreatment at the new follow-up (T3).

The exclusion criteria applied at T3 was history of new orthodontic treatment, any tooth loss, except the third molars. The eligible patients received a letter or a message at the social medias that included information about the study and an invitation to a new follow-up examination.

The sample comprised 41 treated subjects by graduate students in the 1970s and 1980s from the files of Orthodontic Department at Bauru Dental School. The sample was divided into 2 groups according to the mandibular Little irregularity value at pretreatment

Group 1 – Mild crowding: 16 subjects (9 females and 7 males) perfect alignment, minimal or mild mandibular anterior crowding at the start the treatment, initial Little irregularity index less than 6 mm (mean 3.31mm, SD=2.10), with means an

initial final and postretention ages of 13.45 years (SD 1.57), 15.98 (SD=1.97) and 54.93 years (SD=3.78) respectively. Treatment, retention and long-term follow-up times were 2.53 (SD =0.72), 1.80 (SD =0.73) and 38.95 years (SD=2.88).

Group 2 – Severe crowding: 25 subjects (17 females and 8 males) with moderate to severe mandibular anterior crowding at the start the treatment, initial Little irregularity index greater than 6 mm (mean 9.95mm, SD=2.65), with means an initial, final and postretention ages of 13.25 years (SD=2.20), 15.40 (SD=2.25) and 52.85 years (SD=6.23) respectively. Treatment, retention and long-term follow-up times were 2.15 (SD=0.43), 2.48 (SD=1.27) and 37.45 years (SD=5.23).

Orthodontic mechanics of both groups was similar and included fixed edgewise appliance 0.022 x 0.028-in slot; extra-oral headgear was used as anchorage to maintain Class I and to correct the Class II molar relationship; the anterior teeth were retracted with a rectangular archwire and elastic chains; Class II elastics were used when necessary.

The long-term follow-up examinations were performed by 2 orthodontic graduate students (CMGT and PPCS) from October 2017 to October 2019 at Bauru Dental School.

Methods

The dental casts were scanned with the 3Shape R700 3D scanner (3Shape A/S, Copenhagen, Denmark). The image was saved in STL format, compatible with software for 3D images. The images from the dental casts were acquired with the ScanIt software (3Shape A/S, Copenhagen, Denmark). All measurements were performed by one operator (CMGT) in Ortho Analyzer 3D software (3Shape A/S, Copenhagen, Denmark).

Measurements were performed in maxillary and mandibular arches, and included:

- **Little irregularity index**: The quantitative method of assessing anterior irregularity. The sum of the five linear displacements of the anatomic contact points of the six anterior teeth[34] (Fig. 1).
- **Intercanine width (mm):** distance between the cusp tips of the permanent canines.

- **Interpremolar width (mm):** distance between the buccal cusp tips of the first premolars or second premolars; At T1 this measure of all patients was performed between the second premolars, at T2 and T3 this measure was performed between the premolar that was not extracted.
- **Intermolar width (mm):** distance between the mesiobuccal cusp tips of the first molars;
- **Arch length (mm):** the distance from the contact point of the central incisors to a line connecting the mesial contact points of the first molar from one side to the other;
- **Arch perimeter (mm):** The sum of the segments from mesial of the first molar contact point to the distal contact point of the canine and from this point to the contact point of the central incisors on both sides (Fig. 2).

Error of the method

In order to determine the error involved in the method as well as the reliability of the results, 30% of the sample were randomly selected and remeasured. The random errors were calculated according to Dahlberg's formula. The systematic errors were evaluated with dependent t tests, at $P<0.05$.

Statistical analysis

Normal distribution was verified by the Kolmogorov-Smirnov test. Intergroup comparability of the ages, treatment, follow-up and retention times was performed with independent t tests, and gender and initial malocclusion distribution was compared with chi-square test. The repeated measures ANOVA and Tukey tests were used for the intragroup comparison among the stages. Intergroup comparisons were performed with independent t tests.

Statistical analysis was performed by Statistica software (Statistica for Windows, version 10.0, Statsoft, Tulsa, Okla, USA) and the results were considered significant at $P<0.05$.

RESULTS

The random errors ranged from 0.13mm (maxillary interpremolar width at T1) to 1.13mm (mandibular arch length at T2) and are within the acceptable range.[35,36] Other 4 variables showed statistically significant systematic errors (Table I).

The groups were comparable regarding ages, follow-up time evaluation, retention time and gender distribution. However, the mild group had more subjects with Class II initial malocclusion and the severe group had more subjects with Class I. The mild crowding group showed longer treatment time than the severe group (Table II).

Maxillary irregularity for mild group was corrected during treatment and remained stable at the long-term. Interpremolar width and arch length decreased with treatment and continued to decrease in the postretention stage. The intermolar width continued to decrease in the long-term. The maxillary arch perimeter for mild crowding group decreased during treatment and presented stability at the long-term follow-up. The mandibular LII for mild group was corrected with treatment and relapsed to the baseline values at the long-term. The mandibular intercanine width was maintained during treatment and decreased over the adulthood. The mandibular interpremolar and intermolar widths decreased during treatment and remained stable at the long-term. Arch length and perimeter decreased during treatment and continued to decrease in the long-term (Table III).

The maxillary crowding of the severe group was corrected during treatment and relapsed over the long-term, but not returning close to baseline values. The maxillary intercanine and interpremolar widths remained unchanged during treatment and slightly decreased in the long-term follow-up. The maxillary and mandibular intermolar width and maxillary arch length decreased during treatment and remained a stable at the long-term follow-up. The maxillary arch perimeter decreased during treatment and continued to decrease at the long-term. Mandibular LII was corrected with treatment and relapsed over the long-term, but not returning close to pretreatment values. Mandibular intercanine width increased during treatment and returned to pretreatment values at the long-term follow-up. The mandibular interpremolar width, arch length and arch perimeter decreased during treatment and continued to decrease in the long-term follow-up (Table IV).

Mandibular LII was greater in the severe group. The groups were comparable at pretreatment with exception of mandibular interpremolar width that was statistically significant greater in the mild group (Table V).

The mandibular arch length was greater in the severe crowding group at postretention (Tables VI and VII).

The mild group presented smaller changes than the severe group for mandibular LII during treatment and the severe group presented smaller changes for interpremolar width than mild group during treatment.

Maxillary and mandibular crowding relapse and changes in arch dimensions in the long-term were similar between the groups (Table VIII).

DISCUSSION

This sample comprised 41 subjects treated with four premolars extraction and includes 35 who were treated with four first premolar extractions, and 6 treated with maxillary first and mandibular second premolar extractions. The results regarding crowding relapse were not influenced by these types of therapy.[37] The median value of 6mm for mandibular LII at pretreatment has been chosen to allocate the subjects in groups,[10,38] this criterion was used to fulfill the sample size calculation.

The treatments of this sample were carried out in the 1970s and 1980s, when the diagnosis was based only on cephalometric analyzes. Therefore, the treatment plan with 4-premolar extraction and anchorage with headgear protocol was very usual then, even in cases with mild crowding. The mild crowding group showed longer treatment time than the severe group. This could be justified because the mild group had more subjects with Class II malocclusion and the severe group had more Class I subjects. Other studies supported that treatment times for Class I with mild and severe crowding treated with four first-premolar extractions are similar,[39] that explains the time required to correct the anteroposterior relationship with headgear or elastics.[40] The follow-up time was similar between the groups (Table II).

In this study, the maxillary long-term alignment can be considered acceptable, however, cannot be considered successful in maintaining mandibular alignment in the long-term. It was previously suggested that the maxillary anterior crowding relapsed in the short term and remained stable in the long-term postretention. Mandibular anterior crowding significantly decreased with treatment, showed a significant relapse in the short term, and continued to significantly increase in the long-term postretention stage.[41] The retainers were used only for a short period and removed in the short-term follow-up. Hence, it may be induced the LII results. This sample agrees with previous studies which a short period of time the use of mandibular retainers does not seem to

prevent long-term relapse, after the retention time these changes can be considered natural and physiologic. These long-term changes cannot be distinguished from normal aging processes that can happens in subjects untreated or treated orthodontically. Nowadays, the patient is advised to use the retainers for a long period of time.[1,15,19,24,29,42-45]

The mandibular intercanine width was maintained during treatment and decreased over the adulthood in the mild group (Table III). The mandibular intercanine width increased during treatment and return to pretreatment values after long-term follow-up in the severe group (Table IV). The results of severe group from this sample agrees with a meta-analyses[46] stated that regardless diagnostic classification and kind of treatment, mandibular intercanine width tends to increase during treatment and decreased the same amount in postretention. Similar findings were reported by others studies that the mandibular intercanine width not increased during treatment,[45] remained stable in short-term follow-up but decreased in long-term follow-up,[29] and even though the later decrease in intercanine widths with age were more pronounced in the mandibular than in the maxillary arch.[24]

The results of the two groups of this investigation are supported by the literature when reported that arch widths and length decreased after retention whereas mandibular incisor crowding increased.[9,17,26,27] The changes during treatment were related to retraction, the mechanical therapy applied for all subjects. No intervention was performed in the period between the end of the treatment and the long-term follow-up. A classical article[15] prompt for attention that the differences between the rapid relapse and the slow relapse. The occlusal stability or outcome of orthodontic treatment, which means that relapse and late changes are often misinterpreted. The task to decide whether has relapse or posttreatment changes is a highly subjective judgement. It can be speculated that the long-term changes can be classified as physiological rather be related to the relapse. The groups were comparable between then with the exception of mandibular interpremolar width at pretreatment and mandibular arch length at postretention (Tables V and VIII). The two groups at posttreatment did not show differences. It can be confirmed that both groups were treated by the same way (Table VI).

The percentage of mandibular LII relapse[47] was calculated and represent 112.82% for mild group and 43.50% for severe group. It is a high value for a treatment performed with premolars extraction (Table VI). Another follow-up study presented

78.6% of relapsed in mandibular LII.[29] This study values are the highest, however the period of time between end of treatment and recall for the new follow-up of the present study is also longer than other results already published.[37]

The present study showed a high percentage of relapse. Although, none of the patients presented mandibular perfect alignment at postretention. The mild group presented 56.25% (9 subjects) and the severe group presented 56% (14 subjects) with satisfactory mandibular anterior alignment or minimal irregularity (1 to 3 mm) at the postretention stage. Six subjects in each group presented moderate irregularity 4mm to 6 mm at postretention, that represents 37.5% of the mild group and 24% of the severe group. The mild group presented 6.25% (1 subject) and the severe group presented 16% (four subjects) with severe irregularity. No one in the mild group and only one subject that represented 4% of the severe group had a very severe irregularity at postretention almost 35 years after removal of retainers. Nevertheless, this values were higher than the 30% of success and smaller than the 20% of severe crowding.[17]

Study limitations

One limitation of this study is that was not possible to know if all patients who were treated at that time in the graduate clinic and those who were currently evaluated and comprised this sample were concerned or uncomfortable with their present crowding. It is reasonable that in this interval of almost forty years the subjects who might be bothered with the crowding performed a new orthodontic treatment. It could be speculated that the amount of crowding found in the subjects of this study is due to this, in other words, subjects who possible had a higher relapse in the LII, looked for a new orthodontic treatment and were not eligible to the present study' sample.

Clinical implications

The life expectancy of the population is increasing, not only teenagers but adults are starting orthodontic treatments and getting benefits with the results. The challenge of the orthodontist is generating quality of life for the patient. The knowledge of long-term results is evidence-based information for the prognosis of future treatments. Follow the oral health of patients with regularity, instruct them appropriately regarding the importance of using retainers, the care of their retainers and oral hygiene, these instructions are clinician's responsibility.[9,23,27,28,48-50]

CONCLUSION

- The transversal and longitudinal arch dimensions decreased while the crowding increased at the long-term follow-up;
- The amount of crowding relapse was similar between the groups, but the percentage of mandibular crowding relapse was significantly higher in the mild group than in the severe group;
- The mandibular alignment obtained with treatment with 4-premolar extraction was not stable in the long-term.

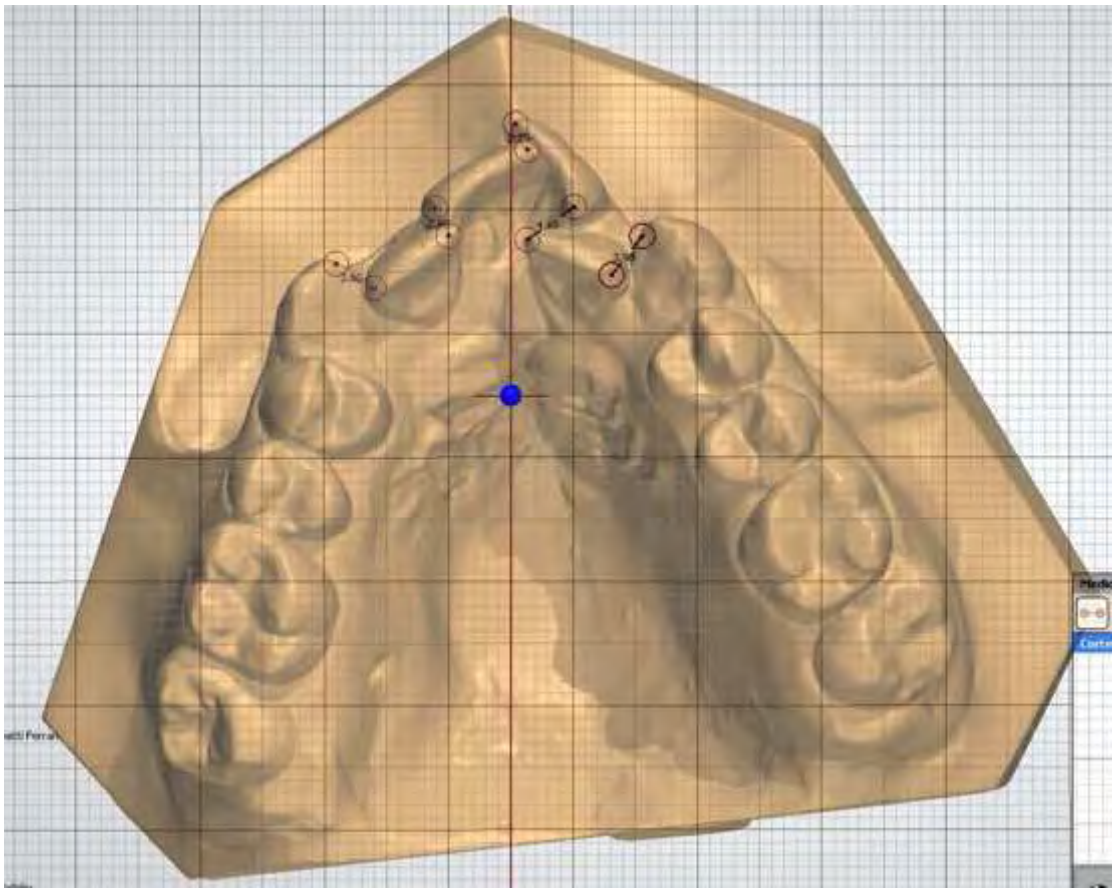

Fig 1. 1A: Measurement of Maxillary Little's Irregularity index

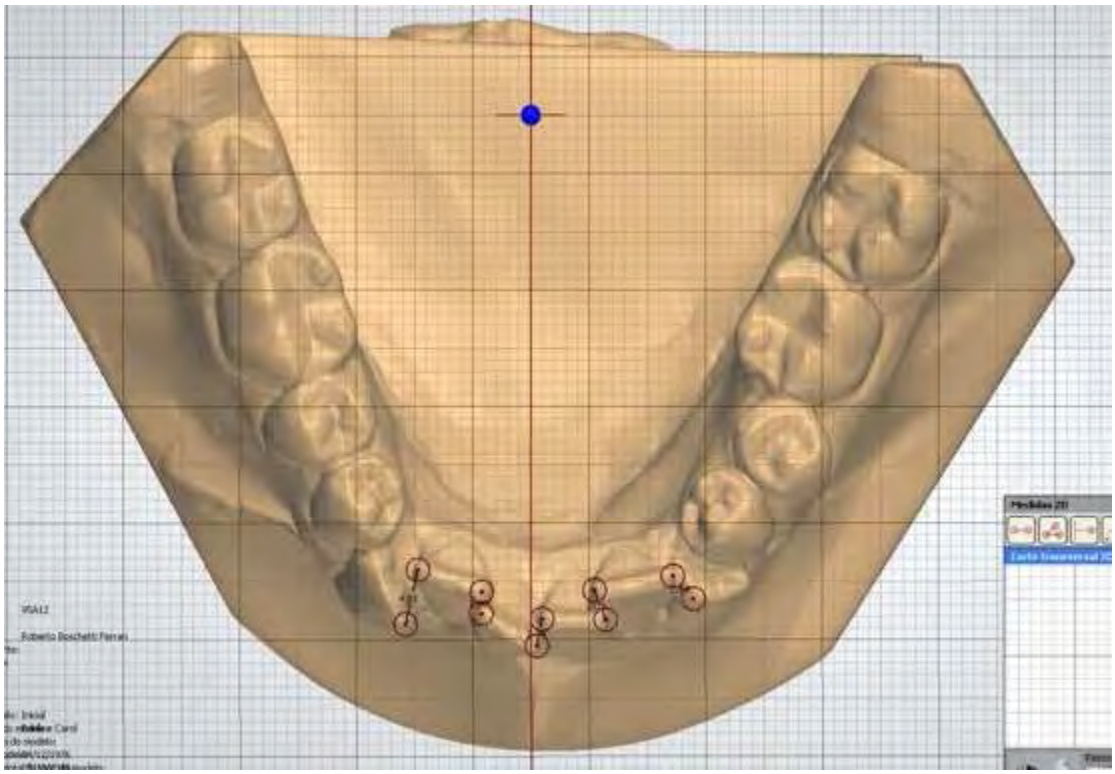

Fig 1. 1B: Measurement of Mandibular Little's Irregularity index

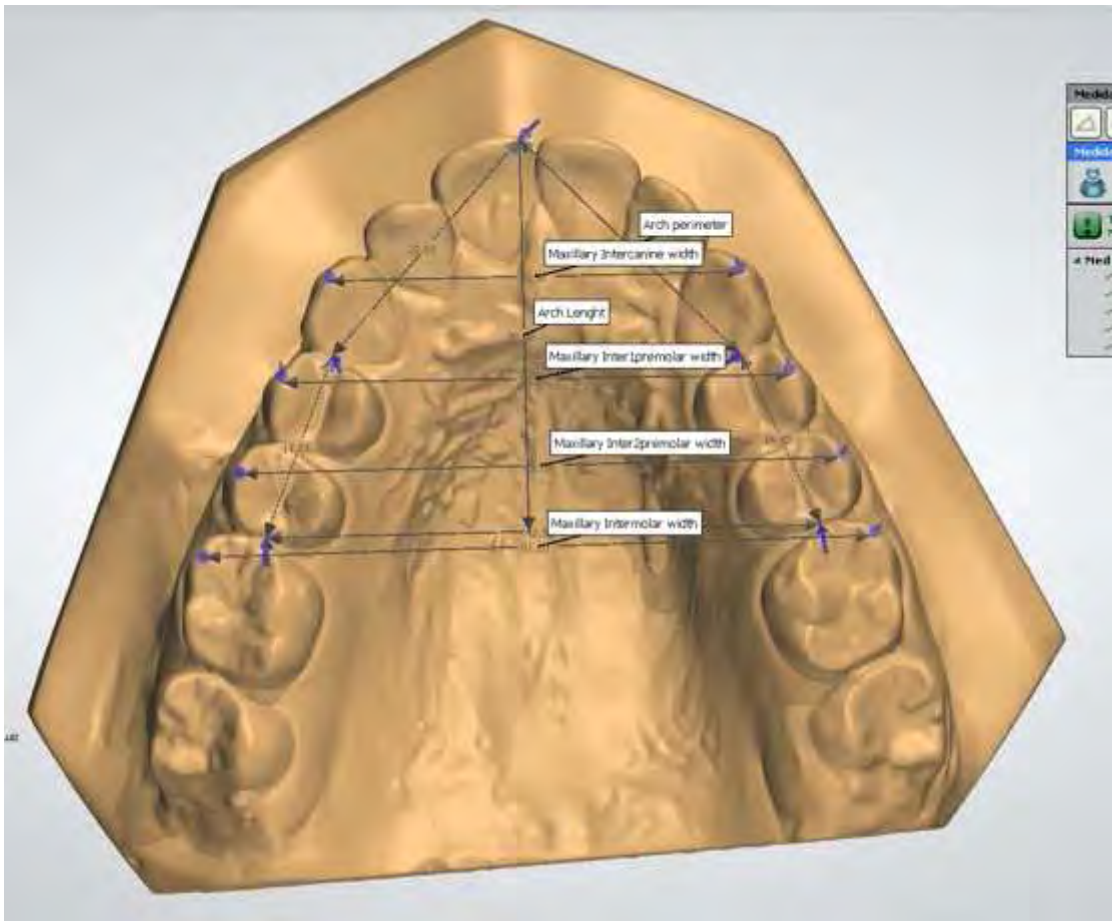

Fig 1. 2A: Measurements of Maxillary Transversal and longitudinal widths

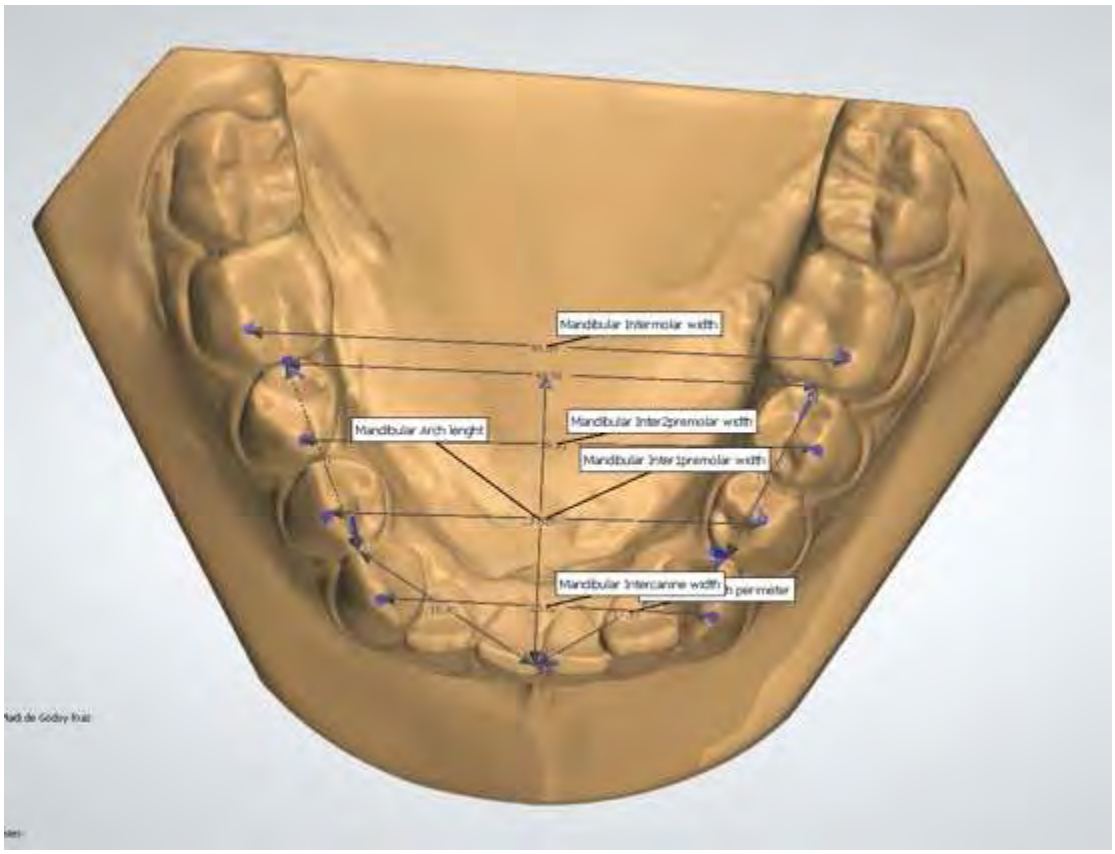

Fig 1. 2B: Measurements of Mandibular Transversal and longitudinal widths

Table I: Intra-investigator evaluation of random and systematic errors (n=41)

	1st. Measurement Mean (sd)	2nd. Measurement Mean (sd)	Dahlberg	P
Maxillary dental casts measurements at T1				
Little's Irregularity Index	7.79 (3.74)	7.63 (3.03)	0.81	0.982
3-3 width	34.42 (2.32)	33.72 (2.26)	0.81	0.513
5-5 width	44.19 (2.39)	43.79 (2.32)	0.13	0.564
6-6 width	49.20 (2.29)	48.89 (2.18)	0.20	0.183
Arch length	28.01 (2.64)	27.59 (2.40)	0.48	**0.004***
Arch perimeter	71.58 (5.50)	72.10 (3.39)	**1.00**	0.051
Mandibular dental casts measurements at T1				
Little's Irregularity Index	7.36(4.07)	7.47(4.18)	0.48	0.802
3-3 width	26.04 (2.16)	25.43 (1.62)	0.24	**0.021***
5-5 width	38.07 (2.82)	37.53 (3.08)	0.15	0.094
6-6 width	43.35 (2.30)	43.50 (2.76)	0.62	0.139
Arch length	22.87 (2.27)	22.44 (1.58)	0.89	0.482
Arch perimeter	63.15 (4.23)	62.38 (3,33)	**1.06**	0.490
Maxillary dental casts measurements at T2				
Little's Irregularity Index	0.21 (0.53)	0.59 (0.72)	0.25	0.196
3-3 width	35.09 (1.72)	34.98 (1.80)	0.22	0.085
5-5 width	43.06 (1.81)	42.80 (1.13)	0.10	0.486
6-6 width	47.98 (2.11)	48.14 (1.63)	0.28	**0.027***
Arch length	22.33 (3.12)	21.35 (1.81)	0.43	0.211
Arch perimeter	62.55 (2.83)	61.68 (2.40)	0.85	0.562
Mandibular dental casts measurements at T2				
Little's Irregularity Index	0.52 (0.87)	0.78 (1.15)	0.40	0.949
3-3 width	26.99 (1.36)	26.59 (1.78)	0.49	0.270
5-5 width	35.68 (1.69)	35.32 (1.36)	0.44	0.073
6-6 width	40.40 (2.08)	40.75 (1.60)	0.80	0.061
Arch length	18.08 (2.16)	17.54 (1,77)	**1.13**	0.493
Arch perimeter	52.91 (3.04)	51.70 (3.52)	0.92	0.359
Maxillary dental casts measurements at T3				
Little's Irregularity Index	2.25 (2.27)	3.92 (2.90)	0.70	0.061
3-3 width	34.07 (2.37)	33.03 (2.23)	0.26	0.461
5-5 width	41.78 (2.30)	41.29 (1.86)	0.23	**0.015***
6-6 width	47.53 (2.64)	46.86 (2.95)	0.77	0.661
Arch length	20.76 (1.96)	20.19 (2.45)	0.22	0.587
Arch perimeter	59.84 (3.62)	58.24 (3,36)	0.44	0.196
Mandibular dental casts measurements at T3				
Little's Irregularity Index	4.23 (2.73)	5.12 (3.44)	0.33	0.166
3-3 width	24.91 (2.50)	24.36 (1.15)	**1.08**	0.705
5-5 width	34.22 (2.20)	33.28 (1.62)	0.84	0.363
6-6 width	41.10 (2.75)	41.13 (1.80)	0.95	0.994
Arch length	16.40 (1.98)	15.86 (2.00)	0.50	0.178
Arch perimeter	49.91 (3.29)	48.33 (3.02)	0.76	0.216

* Statistically significant at P<0.05

Table II: Results of intergroup comparability of the ages, treatment, follow-up and retention times, gender and initial malocclusion distribution (independent t test and chi-square test).

Variables	GROUP 1 Mild crowding (N=16)		GROUP 2 Severe Crowding (N=25)		P
	Mean	SD	Mean	SD	
Initial age (T1)	13.45	1.57	13.25	2.20	0.756
Final age (T2)	15.98	1.97	15.40	2.25	0.409
Follow-up age (T3)	54.93	3.78	52.85	6.23	0.239
Treatment Time (T2-T1)	2.53	0.72	2.15	0.43	**0.046***
Follow-up time (T3-T2)	38.95	2.88	37.45	5.23	0.302
Retention time	1.80	0.73	2.48	1.27	0.062
Gender distribution	9 (21.95%) female 7 (17.07%) male		17 (41,46%) female 8 (19.51%) male		0.447[Chi]
Initial Malocclusion	12 (29.26%) Class II 4 (9.76%) Class I		5 (12.20%) Class II 20 (48.78%) Class I		**0.000*** [chi]

* Statistically significant at p< 0.05

[chi] Chi-square

Table III: Result of Repeated measures ANOVA and Tukey tests for comparison among the times for the mild crowding group (N=16)

Variables (mm)	T1	T2	T3	P
	Mean (SD)	Mean (SD)	Mean (SD)	
Maxillary dental casts measurements				
Little Irregularity Index	6.84 (2.98) ^{A}	0.37 (0.68) ^{B}	1.55 (1.95) ^{B}	**0.000***
3-3 width	34.37 (2.38)	34.93 (1.76)	33.02 (4.02)	0.136
5-5 width	44.85 (2.58) ^{A}	43.46 (1.64) ^{B}	41.96 (2.41) ^{C}	**0.000***
6-6 width	49.39 (2.63) ^{A}	48.28 (1.43) ^{AB}	47.51 (2.40) ^{B}	**0.029***
Arch length	27.89 (2.72) ^{A}	22.71 (3.51) ^{B}	20.11 (2.32) ^{C}	**0.000***
Arch perimeter	70.67 (5.98) ^{A}	61.91 (3.06) ^{B}	58.86 (3.72) ^{B}	**0.000***
Mandibular dental casts measurements				
Little Irregularity Index	3.31 (2.10) ^{A}	0.58 (0.97) ^{B}	3.67 (2.11) ^{A}	**0.000***
3-3 width	26.54 (2.02) ^{A}	26.74 (1.33) ^{A}	24.23 (2.70) ^{B}	**0.008***
5-5 width	39.44 (3.17) ^{A}	35.40 (1.92) ^{B}	34.48 (2.48) ^{B}	**0.000***
6-6 width	44.05 (2.02) ^{A}	40.78 (1.43) ^{B}	41.78 (2.91) ^{B}	**0.000***
Arch length	23.11 (1.87) ^{A}	17.87 (1.93) ^{B}	15.58 (1.76) ^{C}	**0.000***
Arch perimeter	62.21 (5.53) ^{A}	52.76 (3.03) ^{B}	49.04 (3.11) ^{C}	**0.000***

* Statistically significant at $p<0.05$

Different letters in a row indicate the presence of a statistically significant difference between the groups

Table IV**:** Result of Repeated measures ANOVA and Tukey tests for comparison among the times for the severe crowding group (N=25)

Variables (mm)	**T1**	**T2**	**T3**	**P**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	
Maxillary dental casts measurements				
Little Irregularity Index	8.41 (4.10) ^{A}	0.12 (0.41) ^{B}	2.71 (2.38) ^{C}	**0.000***
3-3 width	34.26 (2.23) ^{A}	34.87 (1.86) ^{A}	34.02 (2.10) ^{B}	**0.040***
5-5 width	43.68 (2.24) ^{A}	42.72 (1.97) ^{A}	41.55 (2.31) ^{B}	**0.000***
6-6 width	49.09 (2.11) ^{A}	47.79 (2.45) ^{B}	47.37 (2.76) ^{B}	**0.000***
Arch length	28.09 (2.65) ^{A}	22.09 (2.91) ^{B}	21.18 (1.62) ^{B}	**0.000***
Arch perimeter	72.17 (5.30) ^{A}	62.96 (2.67) ^{B}	60.47 (3.49) ^{C}	**0.000***
Mandibular dental casts measurements				
Little Irregularity Index	9.95 (2.65) ^{A}	0.48 (0.82) ^{B}	4.60 (3.05) ^{C}	**0.000***
3-3 width	25.74 (2.24) ^{A}	27.15 (1.38) ^{B}	25.36 (2.32) ^{A}	**0.000***
5-5 width	37.18 (2.16) ^{A}	35.51 (1.73) ^{B}	34.06 (2.04) ^{C}	**0.000***
6-6 width	42.72 (2.37) ^{A}	40.17 (2.53) ^{B}	40.38 (2.89) ^{B}	**0.000***
Arch length	22.72 (2.52) ^{A}	18.23 (2.33) ^{B}	16.93 (1.98) ^{C}	**0.000***
Arch perimeter	63.77 (3.12) ^{A}	53.61 (2.27) ^{B}	50.47 (3.35) ^{C}	**0.000***

* Statistically significant at $p< 0.05$

Different letters in a row indicate the presence of a statistically significant difference between the groups

Table V: Result of Intergroup comparability at pretreatment (T1) (independent t tests).

Variables (mm)	GROUP Mild crowding (N=16)		GROUP Severe Crowding (N=25)		P
	Mean	SD	Mean	SD	
T1					
Maxillary dental casts measurements					
Little Irregularity Index	6.84	2.98	8.41	4.10	0.195
3-3 width	34.37	2.38	34.26	2.23	0.876
5-5 width	44.85	2.58	43.68	2.24	0.132
6-6 width	49.39	2.63	49.09	2.11	0.689
Arch length	27.89	2.72	28.09	2.65	0.822
Arch perimeter	70.67	5.98	72.17	5.30	0.404
Mandibular dental casts measurements					
Little Irregularity Index	3.31	2.10	9.95	2.65	**0.000***
3-3 width	26.54	2.02	25.74	2.24	0.254
5-5 width	39.44	3.17	37.18	2.16	**0.010***
6-6 width	44.05	2.02	42.72	2.37	0.071
Arch length	23.11	1.87	22.72	2.52	0.596
Arch perimeter	62.21	5.53	63.77	3.12	0.256

* Statistically significant at p< 0.05

Table VI: Result of Intergroup at posttreatment (T2) (independent t tests).

Variables (mm)	GROUP Mild crowding (N=16)		GROUP Severe Crowding (N=25)		P
	Mean	**SD**	**Mean**	**SD**	
T2					
Maxillary dental casts measurements					
Little Irregularity Index	0.37	0.68	0.12	0.41	0.154
3-3 width	34.93	1.76	34.87	1.86	0.922
5-5 width	43.46	1.64	42.72	1.97	0.216
6-6 width	48.28	1.43	47.79	2.45	0.473
Arch length	22.71	3.51	22.09	2.91	0.537
Arch perimeter	61.91	3.06	62.96	2.67	0.254
Mandibular dental casts measurements					
Little Irregularity Index	0.58	0.97	0.48	0.82	0.720
3-3 width	26.74	1.33	27.15	1.38	0.345
5-5 width	35.40	1.92	35.51	1.73	0.846
6-6 width	40.78	1.43	40.17	2.53	0.379
Arch length	17.87	1.93	18.23	2.33	0.608
Arch perimeter	52.76	3.03	53.61	2.27	0.311

* Statistically significant at $p < 0.05$

Table VII: Result of Intergroup at postretention (T3) (independent t tests).

Variables (mm)	GROUP Mild crowding (N=16)		GROUP Severe Crowding (N=25)		P
	Mean	SD	Mean	SD	
T3					
Maxillary dental casts measurements					
Little Irregularity Index	1.55	1.95	2.71	2.38	0.111
3-3 width	33.02	4.02	34.02	2.10	0.303
5-5 width	41.96	2.41	41.55	2.31	0.591
6-6 width	47.51	2.40	47.37	2.76	0.877
Arch length	20.11	2.32	21.18	1.62	0.089
Arch perimeter	58.86	3.72	60.47	3.49	0.170
Mandibular dental casts measurements					
Little Irregularity Index	3.67	2.11	4.60	3.05	0.292
3-3 width	24.23	2.70	25.36	2.32	0.160
5-5 width	34.48	2.48	34.06	2.04	0.551
6-6 width	41.78	2.91	40.38	2.89	0.140
Arch length	15.58	1.76	16.93	1.98	**0.032***
Arch perimeter	49.04	3.11	50.47	3.35	0.180

* Statistically significant at $p < 0.05$

Table VIII: Dental arches dimensions changes over the time in the treatment time (T2-T1) and long-term follow-up time (T3-T2) (independent t tests).

Variables (mm)	GROUP Mild Crowding (N=16)	GROUP Severe Crowding (N=25)	P	GROUP Mild Crowding (N=16)	GROUP Severe Crowding (N=25)	P
	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	
	Treatment changes T2-T1			Long-term follow-up changes T3-T2		
Maxillary dental casts measurements						
Little Irregularity Index	-6.48 (2.97)	-8.29 (4.01)	0.129	1.18 (2.18)	2.59 (2.35)	0.062
Percentage of relapse	---	---	---	18.20%	31.24%	0.177
3-3 width	0.56 (2.00)	0.62 (2.18)	0.934	-1.90 (3.73)	-0.85 (1.53)	0.214
5-5 width	-1.39 (1.61)	-0.96 (2.24)	0.514	-1.50 (1.71)	-1.16 (1.71)	0.541
6-6 width	-1.11 (2.02)	-1.30 (2.05)	0.770	-0.65 (1.80)	-0.34 (1.40)	0.560
Arch length	-5.18 (4.33)	-6.00 (3.13)	0.484	-2.60 (3.59)	-0.90 (2.44)	0.078
Arch perimeter	-8.75 (6.80)	-9.21 (4.71)	0.801	-3.05 (2.04)	-2.49 (3.81)	0.596
Mandibular dental casts measurements						
Little Irregularity Index	-2.73 (2.18)	-9.47 (2.49)	**0.000***	3.08 (2.35)	4.12 (2.75)	0.222
Percentage of relapse	---	---	---	112.82%	43.59%	**0.000***
3-3 width	0.20 (1.79)	1.42 (2.25)	0.076	-2.51 (2.72)	-1.79 (2.01)	0.339
5-5 width	-4.04 (3.27)	-1.66 (1.92)	**0.006***	-0.91 (2.11)	-1.46 (2.05)	0.420
6-6 width	-3.27 (2.21)	-2.55 (2.33)	0.337	1.00 (2.25)	0.22 (2.78)	0.355
Arch length	-5.25 (2.21)	-4.49 (2.23)	0.295	-2.29 (1.55)	-1.30 (2.32)	0.141
Arch perimeter	-9.45 (5.44)	-10.16 (2.71)	0.583	-3.72 (2.53)	-3.14 (2.66)	0.495

* Statistically significant at p<0.05

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2.2 ARTICLE 2 - Geometric morphometric analyses of dental arches changes in the long-term posttreatment follow-up

Abstract

Objective: To evaluate the dental arch shape changes during the treatment and in long-term follow-up in subjects with slight or moderate to several initial dental crowding treated with 4 premolars extraction using geometric morphometric tools. **Material and Methods:** The sample comprised 32 patients with Class I and Class II malocclusions treated with 4 premolar extraction divided in 2 groups according to the Little irregularity index. Group 1 Mild: 15 subjects (8 female and 7 males) with initial Little irregularity index lesser than 6 mm (mean 3.45 mm SD=2.17) with mean initial, final and postretention age of 13.52 years (SD 1.54), 16.05 (SD=1.87) and 55.15 years (SD=3.54). Treatment, retention and long-term follow-up times were 2.53 (SD=0.67), 1.69 (SD=0.63) and 39.09 years (SD=2.86) respectively. Group 2 Severe: 17 subjects (11 female and 6 males) with moderate to severe mandibular anterior crowding at the start the treatment, Little irregularity index greater than 6 mm (mean 10.29 mm SD=2.54) with means an initial, final and postretention age of 13.43 years (SD=2.51), 15.48 (SD=2.62) and 54.41 (SD=5.05). Treatment, retention and long-term follow-up times were 2.05 (SD=0.35), 2.39 (SD=1.32) and 38.92 years (SD=3.85). The images from the digital dental casts at Pretreatment, posttreatment and postretention were analyzed with Generalized Procrustes Analysis, Principal Components Analysis and Canonical Variates Analysis to examine the variation among individuals and groups at pretreatment, posttreatment and postretention. **Results:** The Principal Components Analysis demonstrated greatest variation in the arch shape at pretreatment was related to the displacement of the incisor and canines. At posttreatment, the variations were due to the 4-premolar extraction and anterior retraction. The greatest variation among the subjects after almost forty years was related to incisor position relapse. The arch shape changed with treatment and was maintained, with slight variation, over the long-term follow-up. The Canonical Variates Analysis illustrated the behavior for maxillary and mandibular dental arches for both groups were similar. **Conclusions:** The initial dental arch shape was modified during treatment and showed slight variation in the long-term follow-up in both groups.

Keywords: Dental Arch. Malocclusion. Tooth Extraction.

INTRODUCTION

Dental arch is the curve formed by the teeth in their position in the jaw and the morphology has been related to the size of the basal bone and the alveolar process,[1-3] the activity of the oral musculature[4-7] and ethnicity.[8-13] It is an important factor in diagnosis and treatment planning in orthodontics.[14]

The dental crowding is a disparity in the relationship between tooth size and jaw size.[15] It shows notoriety in orthodontic practice due to its negative implications for smile aesthetics and a great demand for treatment. The dental alignment is the successful result of crowding treatment. Relapse is defined as a return toward initial conditions. Follow-up studies after orthodontic treatment evaluated the stability of the occlusion and in cases of instability, the long-term result is often described as relapse.[16] Use of retainers is the best way to avoid it.[17,18]

There was a dogma that mandibular arch cannot be permanently altered by therapy, therefore, maintaining the patients' original malocclusion arch dimensions and form during the treatment would be an alternative to enhance stability, an exception to the rule of inviolability of mandibular arch form, but the clinicians cannot expect all of our patients to be exceptions. Avoid enlargement of the lower arch unless mandated by facial profile concerns, or to harmonize the occlusion with maxillary palatal expansion accomplished for cross-bite corrections or unusual narrowness.[19-23]

Shape is all the geometrical information that remains when location, scale and rotational effects are filtered out from an object. It was unaffected by changes in the position, the orientation and the size. Size-and-Shape is all the geometrical information that remains when location and rotational effects are filtered out from an object. Hence, size-and-shape also can be considered as form. Size can be defined as that it can be removed from a configuration.[24,25]

A Brazilian sample presented maxillary and mandibular ovoid arch shape before and after the treatment. The relationship between the mandibular basal and dental arch shape and the crowding still not clarified.[10] Preservation of the balance between muscle, bone, teeth and the maintenance of the original arch shape and mandibular intercanine width in clinical orthodontics have been essential for long-term occlusal stability.[26-30] Based on that this article aimed to evaluate the long-term variation of dental arch shape in patients with mild and severe crowding, treated orthodontically with 4-premolar extractions.

MATERIAL AND METHODS

Material

This longitudinal, retrospective cohort study[31] was approved by the Ethics Committee on Human Research of _____, under number _____ and written consents were obtained from all subjects.

To detect a mean difference of 2 mm, with a standard deviation of 1,9 mm in mandibular Little's irregularity index[22] at follow-up, considering an 80% of test power at a significance level of 5%, the sample size calculation demonstrated that 15 subjects were necessary in each group.

The sample was comprised 32 subjects treated by graduate students in the 1970s and 1980s from the files of Orthodontic clinic at Bauru Dental School. **Group 1 Mild Crowding**: 15 subjects (8 female and 7 males) with perfect alignment, minimal or mild mandibular anterior crowding at the start the treatment, Little irregularity index less than 6 mm (mean 3.45 mm SD=2.17) with means an initial, final and postretention age of 13.52 years (SD 1.54), 16.05 (SD=1.87) and 55.15 years (SD=3.54). Treatment, retention and long-term follow-up times were 2.53 (SD=0.67), 1.69 (SD=0.63) and 39.09 years (SD=2.86). **Group 2 Severe Crowding:** 17 subjects (11 female and 6 males) with moderate to severe mandibular anterior crowding at the start the treatment, Little irregularity index of 6 mm or greater (mean 10.29mm, SD=2.54) with means an initial, final and postretention age of 13.43 years (SD=2.51), 15.48 (SD=2.62) and 54.41 years (SD=5.05). Treatment, retention and long-term follow-up times were 2.05 (SD=0.35), 2.39 (SD=1.32) and 38.92 years (SD=3.85).

Orthodontic mechanics of both groups was similar and included fixed edgewise appliance 0.022 x 0.028-in slot; extraoral headgear was used as anchorage to maintain Class I and to correct the Class II molar relationship; the anterior teeth were retracted with a rectangular archwire and elastic chains; Class II elastics were used when necessary.

The selected subjects should present the following inclusion criteria: with Class I and any severity of Class II malocclusion at the beginning of the treatment, complete orthodontic treatment with fixed edgewise appliances (0.022 x 0.028-in slot); treatment protocol with extraction of four premolars; presence of full permanent dentition until first molars erupted, no tooth agenesis or anomalies; maxillary removable appliance, and mandibular fixed canine-to-canine retainers worn for at least 1 year; pretreatment (T1), posttreatment (T2), dental casts available for the study; at least 25 years

postretention at the new follow-up (T3). The eligible patients received a call, letter or a message at the social medias that included information about the study and an invitation to a new follow-up examination. The exclusion criteria applied at T3 was history of new orthodontic treatment, any tooth loss, except the third molars. The long-term follow-up examinations were performed by 2 orthodontic graduate students (CMGT and PPCS) from October 2017 to October 2019 at Bauru Dental School.

Methods

The dental casts were digitized with the 3Shape R700 3D scanner. The images from the dental casts were acquired with the ScanIt software (3Shape A/S, Copenhagen, Denmark) and the image was saved in (.stl) format, compatible with specific software for three-dimensional images.

The mandibular Little irregularity index (LII) was the quantitative method of assessing anterior irregularity. The sum of the five linear displacements of the anatomic contact points of the six anterior teeth.[32] were performed by one operator (CMGT) in Ortho Analyzer 3D software (3Shape A/S, Copenhagen, Denmark). This measure was used to allocate the subjects in each group (Fig. 1 and Table II).

Three-dimensional dental casts images were imported into the software Stratovan Checkpoint (Stratovan Corporation, Davis, California, USA). Incisor edge midpoint, canines, second premolars cusp tips and molar buccal cusp tips have been chosen as reference for the arches' registration, then twelve anatomical landmarks were marked for maxillary and mandibular arches.[11,33] The 1st premolar was not included (Fig. 2). The x, y, z coordinates for each landmark were collected and exported in a text format file. The z axis represented the third dimension. The raw landmarks coordinates data were arranged and imported into the software MorphoJ (Klingenberg Lab, Manchester, UK).[34]

The landmark configurations' superimposition has been done and Generalized Procrustes Analysis (GPA)[35,36] was applied to describe the shape of dental arches. A mean shape dental arch was determined after translation, rotation and scaling. Ordination methods were employed to summarize variation in shape space. The principal components analysis (PCA) was used to describe the variation among individuals and Canonical Variates Analysis (CVA) was used to comparison the groups.

It constructs variables that can be used to examine variation among individuals within a sample.[37] The PCA was first performed within each stage and afterwards with complete data for each group and jaw, to evaluate intragroup variation in shape. The CVA was done with mild and severe group in the same dataset.

Error of the method

In order to determine the error involved in the method as well as the reliability of the results, 30% of the sample were randomly selected and remeasured after 15 days. for the initial maxillary and mandibular x axis values. Intraexaminer reproducibility was evaluated using Intraclass Correlation Coefficient (ICC) for landmarks coordinate values (Table I).

Statistical analyses

Chi-square tests was used to compare gender and initial malocclusion distribution. Independent t-test was used to compare ages, treatment, follow-up and retention time, repeated measures ANOVA was used to compare LII (Table II). The chi-square, t-test and ANOVA was performed by Statistica software (Statistica for Windows, version 10, Statsoft, Tulsa, Okla, USA). The Intraclass Correlation Coefficient (ICC) was calculated in a Microsoft Excel spreadsheet.

RESULTS

To determine the reliability of the method, 10 dental casts were randomly selected, and the raw coordinate data collected again by the same operator after 30 days. The Intraclass Correlation Coefficient (ICC) showed good to excellent degree of reliability for repeated landmark placement, the values range from 0.533 to 1.02 for the maxillary and mandibular x coordinates (Table I).

The groups were comparable regarding ages, follow-up time evaluation, retention time and gender distribution. However, the mild group had more subjects with Class II initial malocclusion and the severe group had more subjects with Class I. The mild crowding group showed treatment time greater than the severe group. The ratio of subjects with each sagittal relationship in each group corroborates the treatment time being different between groups. The long-term follow-up time did not present difference between groups (Table II).

The Little Irregularity Index was corrected with treatment for both groups. The mandibular LII returned to the baseline values at the long-term in the mild group and in the severe group presented slight relapse in alignment over the long-term. The maxillary alignment can be considered acceptable at the long-term in the mild group and also presented slight relapse in alignment over the long-term (Table III).

The landmarks for maxilla and mandible in mild and severe groups surrendered 14 and 16 PC's respectively, each principal component described the shape variation.

The first PC described the greatest variance, it represented 40.82% for maxillary arch (Fig. 2.3A) and 34.11% for mandibular arch at pretreatment (Fig. 2.3D); 40.65% and 55.05% of the variance at the posttreatment for maxilla and mandible (Fig. 2.3B and 2.3E) respectively, 53.86% and 58.35% of the variance at postretention (Fig. 2.3C and Fig. 2.3F) for mild crowding group (Table IV).

The first PC described 40.59% of the total variance for maxillary arch (Fig. 2.4A) and 34.53% for mandibular arch in severe crowding group at pretreatment (Fig. 2.4D), 48.35% for maxillary (Fig. 2.4B) and 58.96% for mandibular (Fig. 2.4E) at posttreatment and 45.58% for maxillary (Fig 2.4C) and 38.64% for mandibular (Fig. 2.4F) in long-term follow-up (Table V).

The figures display wireframe graphics of the first principal component, axis 1 vs 3 that represented the dental cast in an occlusal view. There is another option of visualization for the graphic of shape changes based on the Procrustes superimposition entitled lollipop but the wireframe graphic the easiest to interpret. Light blue line represents the reference (the consensus) and the dark blue represented the shape variation associated with the value of the analyzed axis, in this case the first.[36,38]

Figures 2.3 and 2.4 (A to F) represents the mild and severe intragroup comparisons at each stage.

Figures 2.3A and 2.3D showed the variation of maxillary and mandibular dental arches for mild group at pretreatment. The greatest variation in the shape was related to the malposition of the maxilla left canine and mandibular right second premolar.

Figures 2.3B and 3E demonstrated variations in the dental arch shapes of the maxillary and mandibular for mild crowding group. It was outcome of treatment carried out with premolars extraction and anterior retraction.

Figures 2.3C and 3F showed the greatest variation of maxillary and mandibular dental arch shape among the subjects followed by 39.09 years after the end of

treatment (Table IV). It was related to incisors position. There was no variation in position of maxillary canines and mandibular premolars among individuals.

Figure 2.3G and H illustrated the comparison among pretreatment, posttreatment and postretention for maxillary and mandibular arches in the mild group.

The dots represent each subject. There is a separation between blue dots that represent pretreatment and red and green dots those represent posttreatment and postretention, respectively. The scatter plot showed that there was a change in the arch shape associated with treatment with 4-premolar extraction and that these changes were maintained with slight variation over the long-term.

Figures 2.4A and 2.4D showed the variation of maxillary and mandibular dental arches shapes for severe crowding group at pretreatment. It may be noted the large displacement of the incisors and canines.

Figures 2.4B and 2.4E showed the variation of maxillary and mandibular dental shape arch between the subjects after treatment.

Figures 2.4C and 2.4F showed the variation of maxillary and mandibular dental arches shapes among the subjects in adult life followed by 38.92 years (Table V). There is a variation in the position of the left upper central incisor.

The points arrangement in the scatter plots for both maxillary and mandibular arches was similar. The PC's indicated some overlap for posttreatment and postretention and a separation of pretreatment. The changes obtained with the treatment were maintained with slight variation in the long-term follow-up (Figure 2.4G and H).

The first and the second Canonical Variates scatter plots illustrated the separation of pretreatment and the other two stages. Furthermore, posttreatment cluster with the postretention for maxillary either mandibular dental arch shape for mild and severe crowding groups (Figures 2.5).

DISCUSSION

The present study aimed to evaluate the variation of dental arch shape in patients with crowding orthodontically treated with 4-premolars extraction and followed after almost forty years.

Variations can be observed in arch shape among subjects at all stages (Figures 2.3, 2.4 A to F and Tables IV, V). The variation observed at pretreatment referred to

crowded position of incisor and canines.[39] It can be stated that the greatest dental arch shape variations at posttreatment occurred due to correct the crowding and the sagittal relationship, no intervention was performed in the period between the end of the treatment and the long-term follow-up. However, there is a possibility of the slight changes that occurred in this period was may be due to relapse associated with physiological changes[40] (Figures 2.3, 2.4 G and H).

The time interval of the present study is longer than that recently published which also analyzed the dental arch shape in three stages and concluded that most adolescent changes of dental arch take place between ages 12 and 15 years, whereas dental arch form was relatively stable during age 15–18 years. Additionally suggested that if treatment is completed at around age 15, the dentoalveolar complex will be relatively stable post orthodontic treatment and chances of relapse due to growth and development is minimal.[13] The final ages in that study were 16.05 (SD 1.87) for mild and 15.48 (SD 2.62) for severe groups.

Regardless of the crowding severity the changes in the arch shape achieved with the treatment were maintained in the long-term (Table III, Figure 2.5). Success in the results reached during treatment is expected in a long-term. Preserve or maintain the balance among lip, cheek, tongue, teeth and jaw is an important factor in success of the treatment, in other words, the stability of the results achieved with the therapy. Moreover, the elimination of etiological factors, although it is difficult must be considered to achieve stability of the new position of the teeth.[41] Dental arch shape changes are possible when the teeth positions do not change the muscles balance.[4,14,42]

The results of this study showed a variability in the arch shape at each stage and period evaluated. It has been suggested that there was not a single arch shape for subjects with different crowding severities and agrees with the literature on this variation. Therefore, arch form is an important factor to consider in orthodontic treatment plan. An objective assess of the patient's initial arch shape at time of diagnosis and treatment is important for the rational choice among archwires commercially available that best fit to patient. The literature reports that the prefabricated archwires use is currently widespread. Moreover, there was none specific archwire for each malocclusion. However, individualization of archwire shape is required.[22,26,27,39,43-47] There are several kinds of templates to facilitate customization

of the archwires of the patient during treatment.[28] To contour the archwires according to the initial malocclusion during treatment can be associated with stability.[48]

The present study has used geometric morphometric tools as methodology, to analyze the variations in dental arches. GPA was an established method to superimpose the data and produced similar results. A previously long-term study also reported changes in arch form after 15.7 years, the mandibular arch tends to become more rectangular due the incisor has flattened. To obtained this results the authors measured an angle in photographic of the dental casts and tracing the cephalograms and did not use statistical shape analysis. They did not relate the method used to superimpose the pictures.[49] The method used in the current study was widely used in orthodontics for several comparisons.[33,39,43,50-53]

Another study that related arch shape and crowding severity evaluated the differences in arch shapes of crown tip and root apex between the control and crowding groups using CBCT data and Procrustes analysis conclude that the disparity of root apex arch form shape between the groups evaluated is hard to recognize. Thus, even if a tooth crown shows severe displacement that results in tooth crowding, that is the root apices of crowded teeth were not in a crowded position.[54] There is an evidence that WALA ridge or other anatomic landmarks of the basal bone can be a rational tool to predict the ideal dental arch and individualization of the archwire.[2,3,55]

Clinical implications

The knowledge about the dental arch shapes changes is an important factor for a prognosis, diagnosis and stability of orthodontic treatment planning.

CONCLUSIONS

Treatment with 4-premolar extractions caused great changes in dental arch shape and slight variations were seen after almost forty years follow-up in both groups with different crowding severities.

Figure 2.1 Measurement of maxillary and mandibular Little's Irregularity index

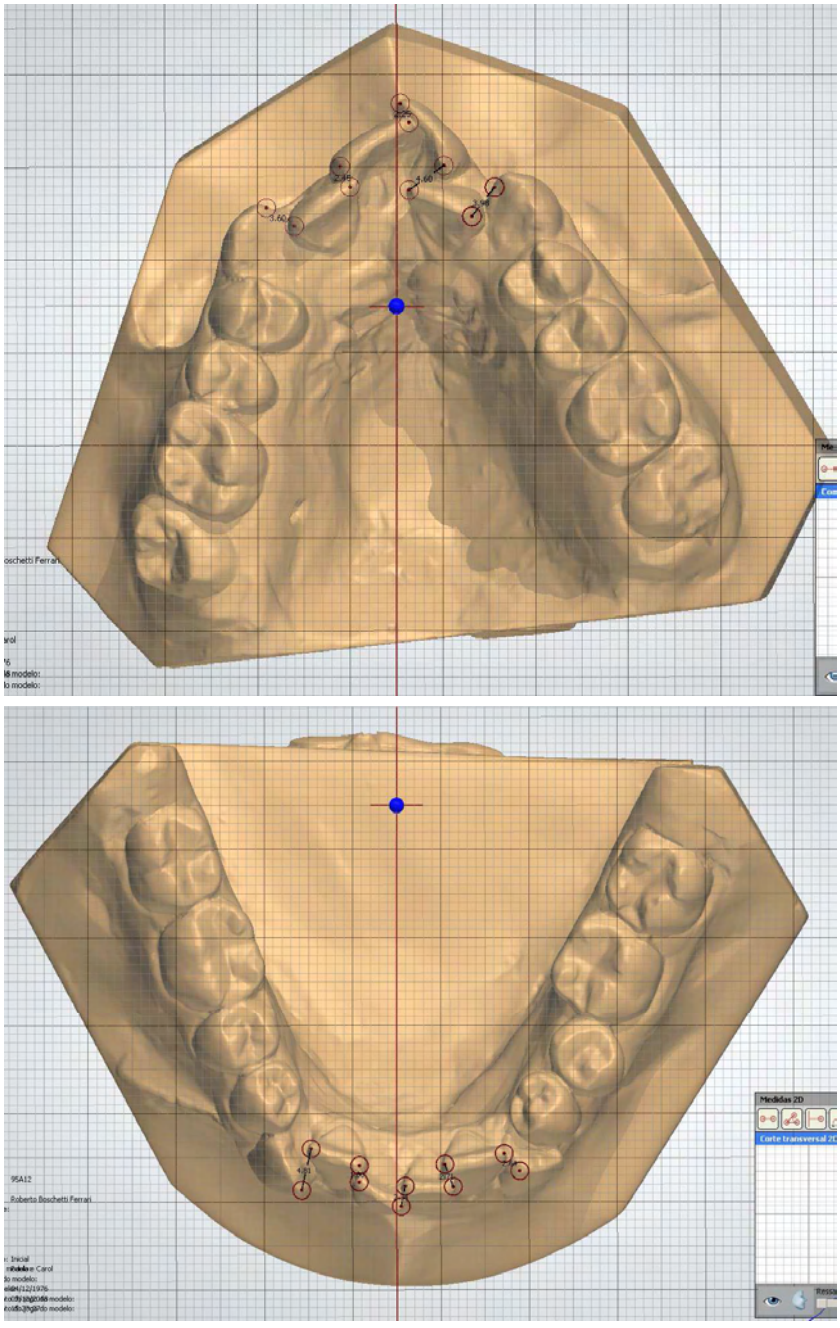

Figure 2.2 The locations of 12 landmarks in maxillary and mandibular dental casts

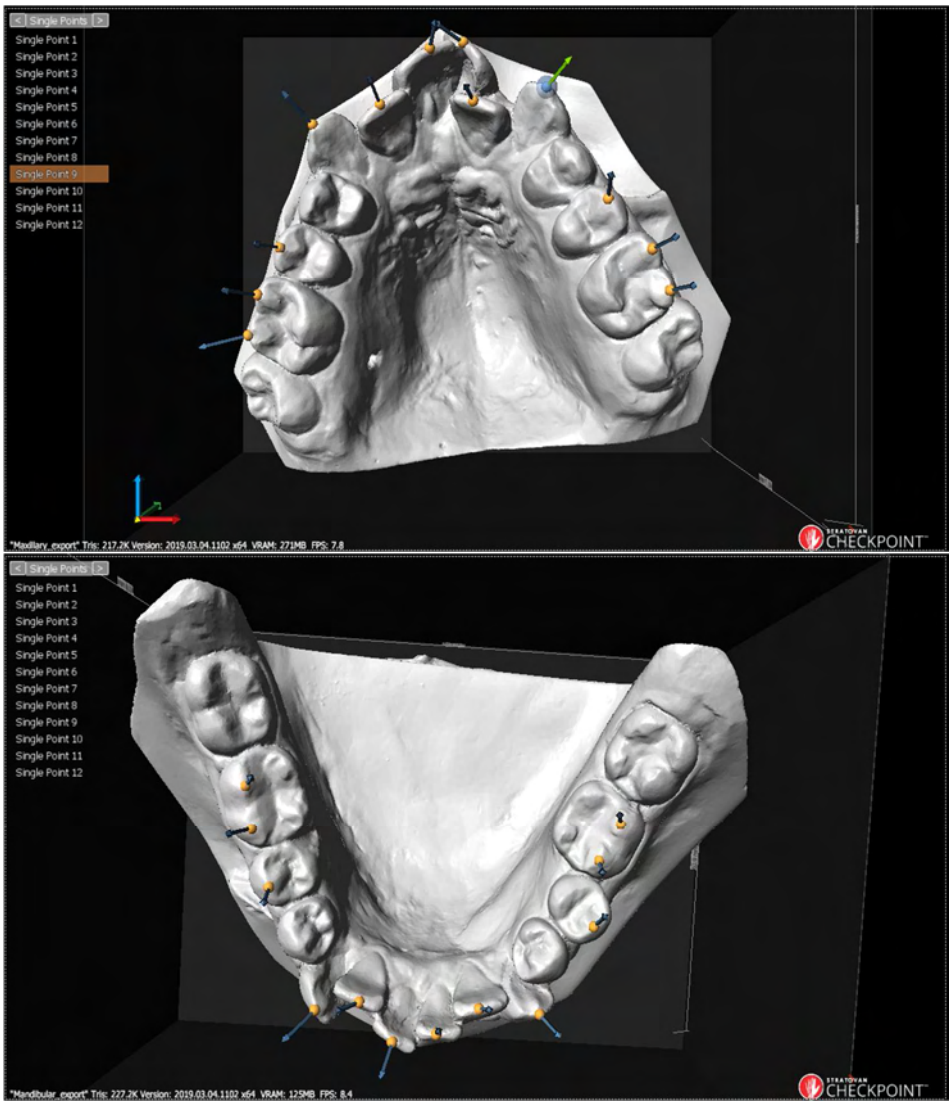

Figure 2.3A First PC shape changes for 15 subjects of maxillary mild crowding group at pretreatment

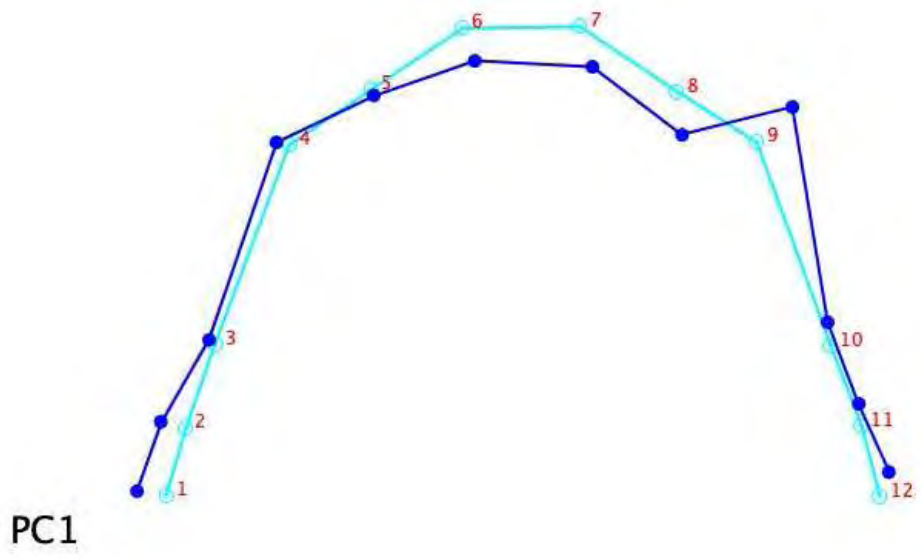

Figure 2.3B First PC shape changes for 15 subjects of maxillary mild crowding group at posttreatment

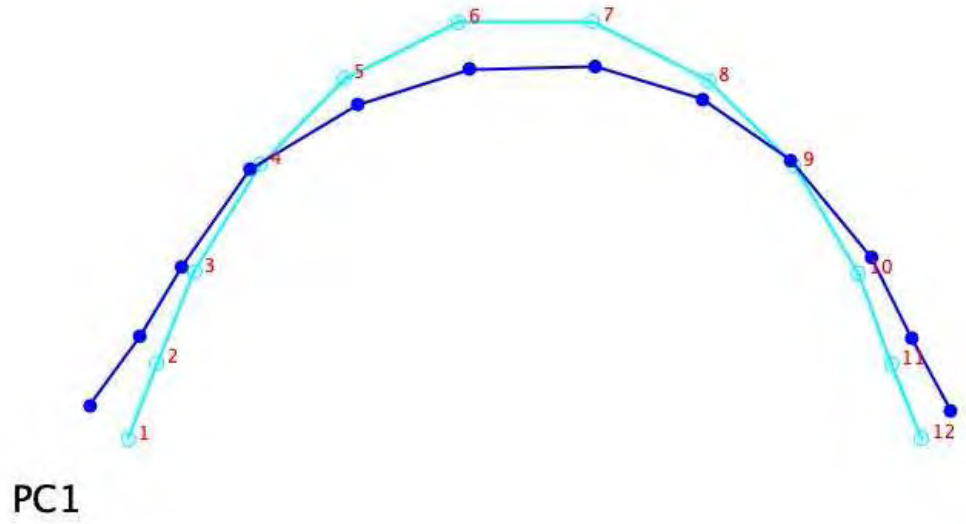

Fig 2.3C First PC shape changes for 15 subjects of maxillary mild crowding at postretention

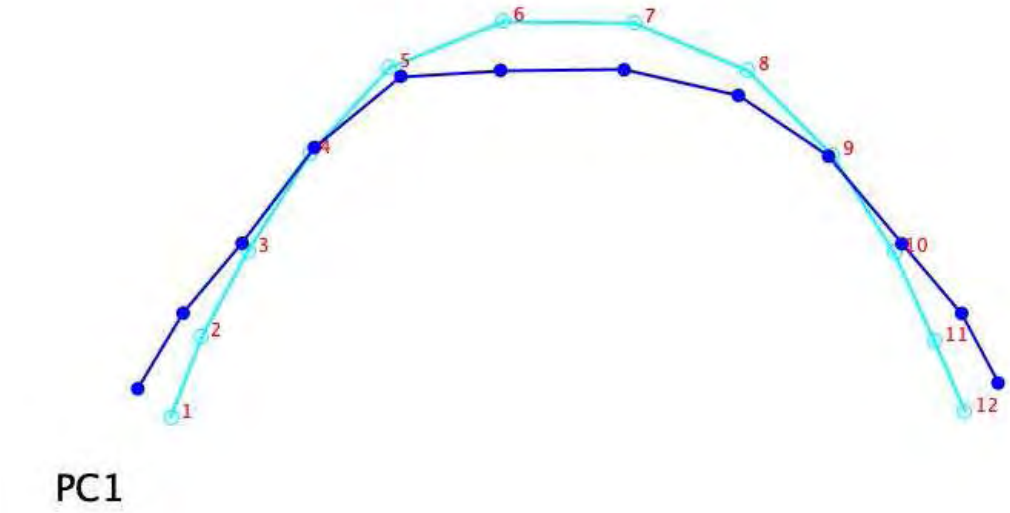

Figure 2.3D First PC shape changes for 15 subjects of mandibular mild crowding at pretreatment

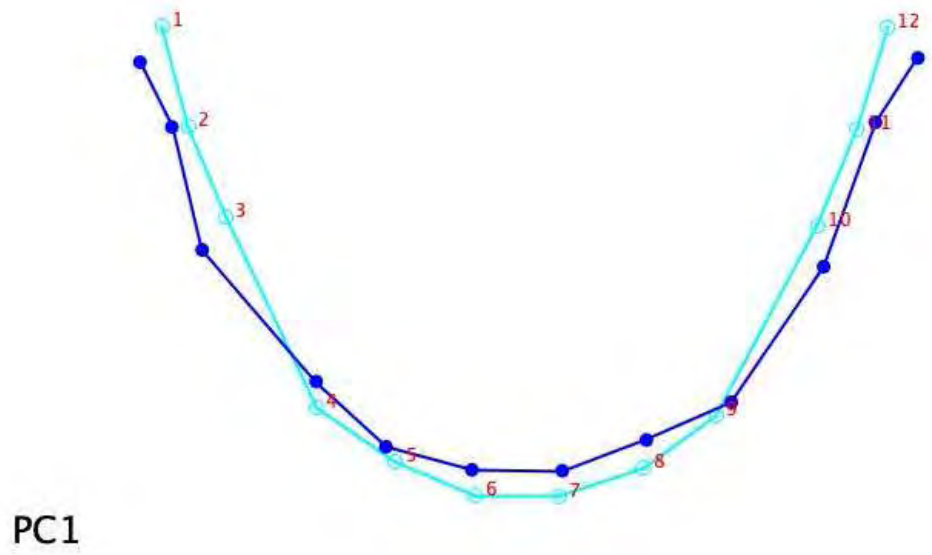

Figure 2.3E First PC shape changes for 15 subjects of mandibular mild crowding group at posttreatment

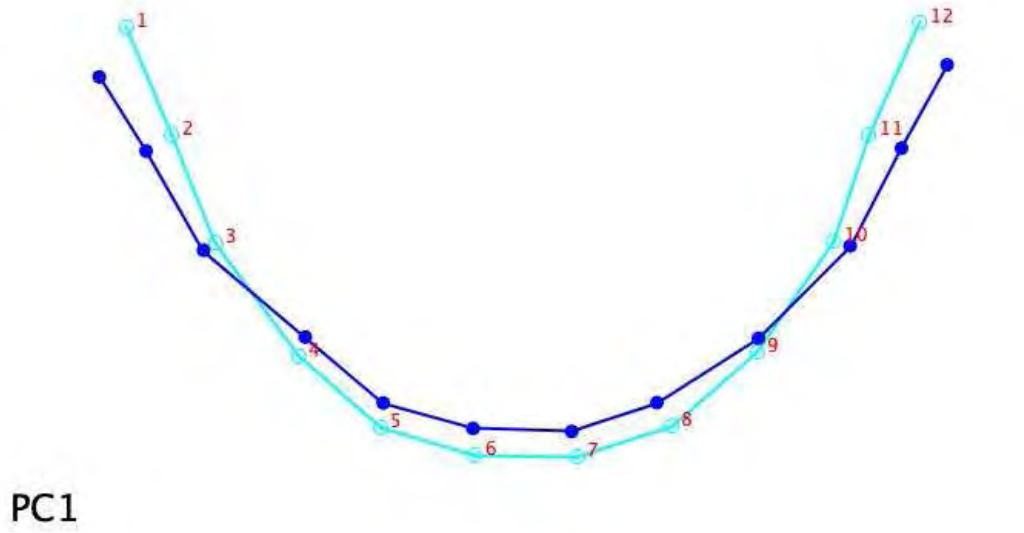

Figure 2.3F First PC shape changes for 15 subjects of mandibular mild crowding group at postretention

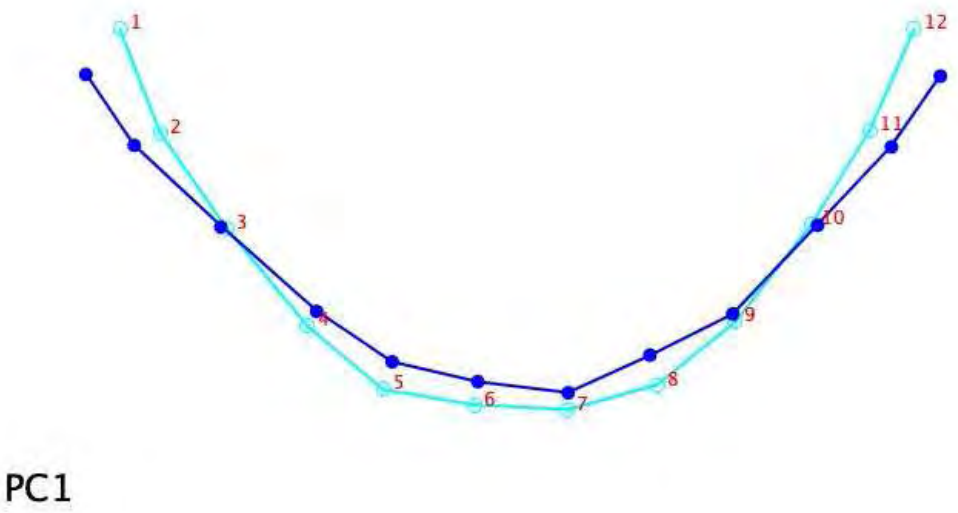

Figure 2.3G First and Second PC scores for maxillary mild crowding group at pretreatment (blue dots), posttreatment (red dots) and postretention (green dots)

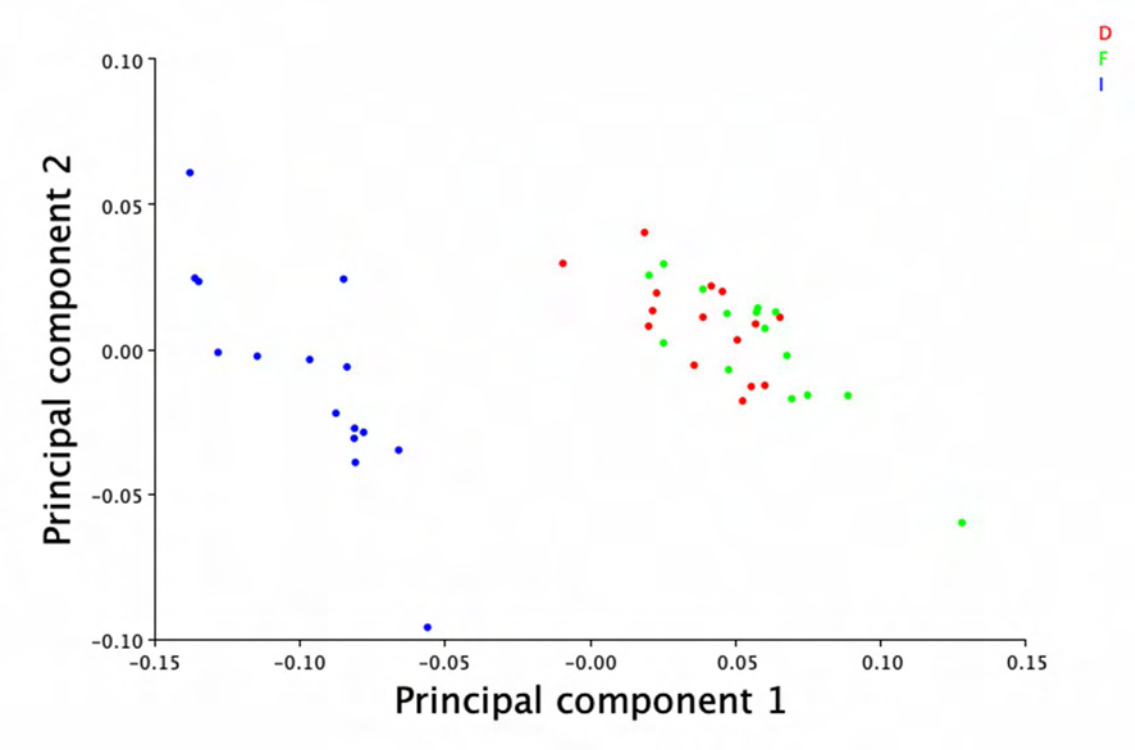

Figure 2.3H First and Second PC scores for mandibular mild crowding group at pretreatment (blue dots), posttreatment (red dots) and postretention (green dots)

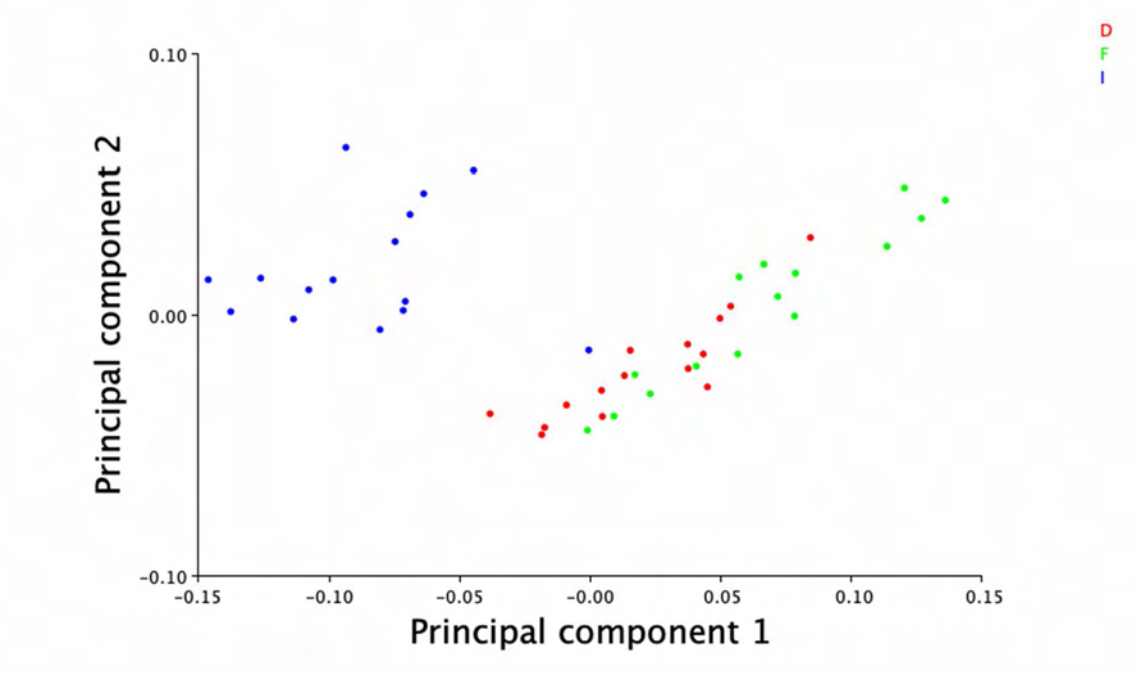

Figure 2.4A First PC shape changes for 17 subjects of maxillary severe crowding group at pretreatment

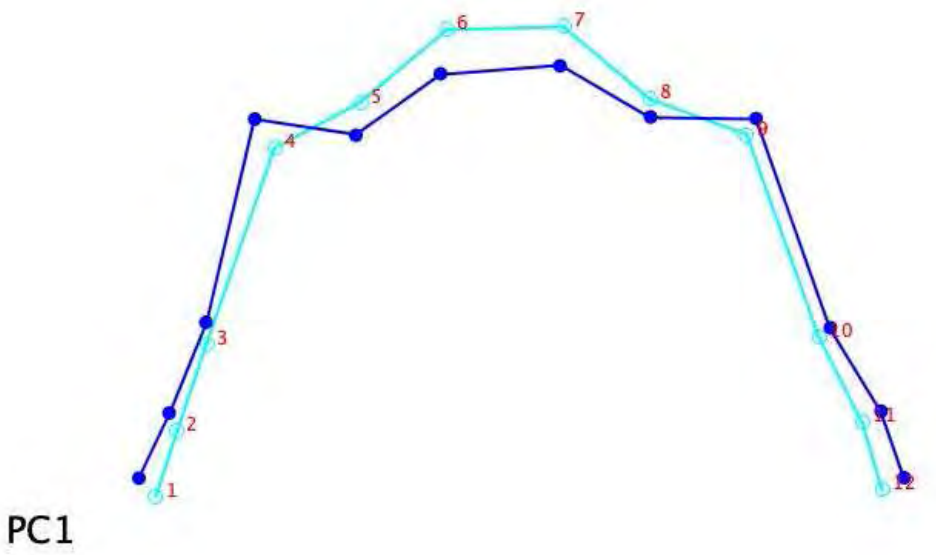

Figure 2.4B First PC shape changes for 17 subjects of maxillary severe crowding group at posttreatment

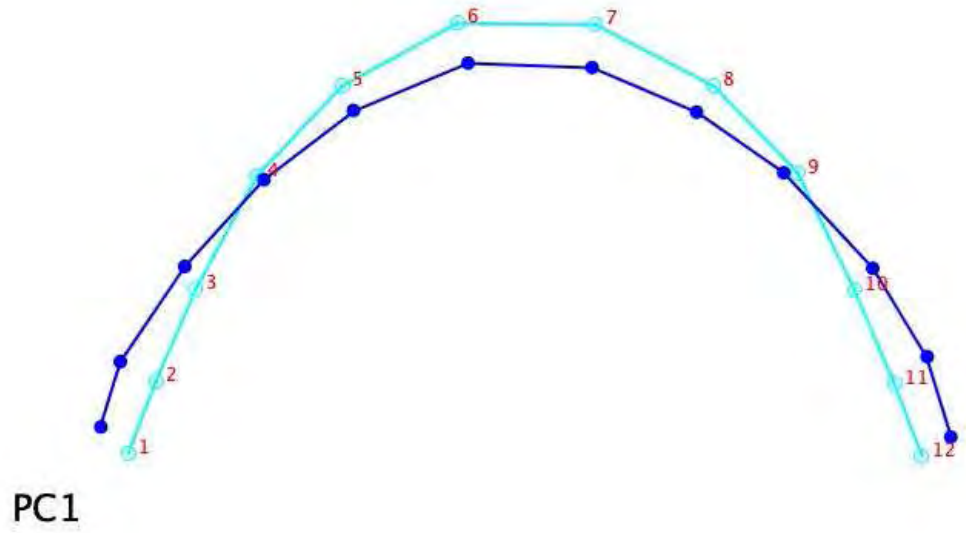

Figure 2.4C First PC shape changes for 17 subjects of maxillary severe crowding group at postretention

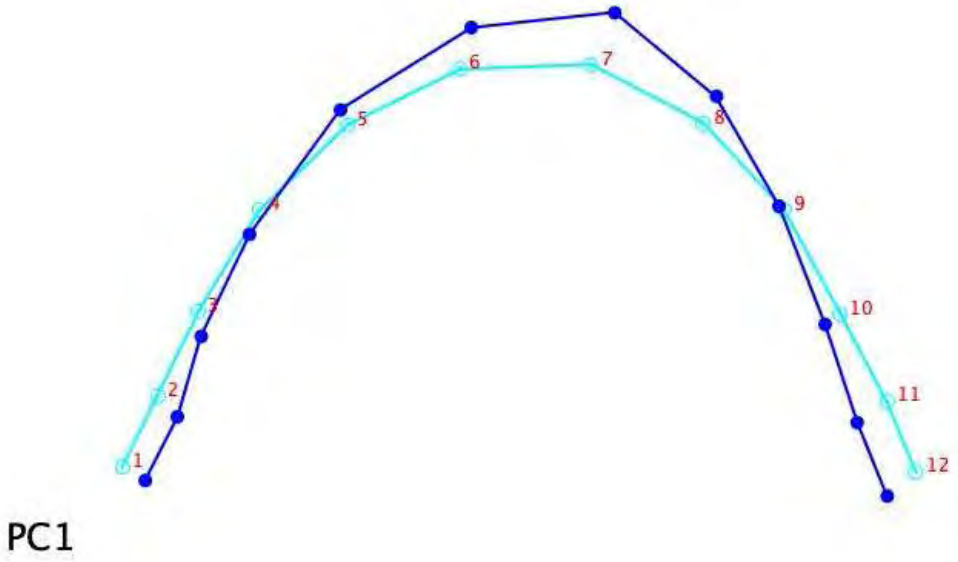

Figure 2.4D First PC shape changes for 17 subjects of mandibular severe crowding group at pretreatment

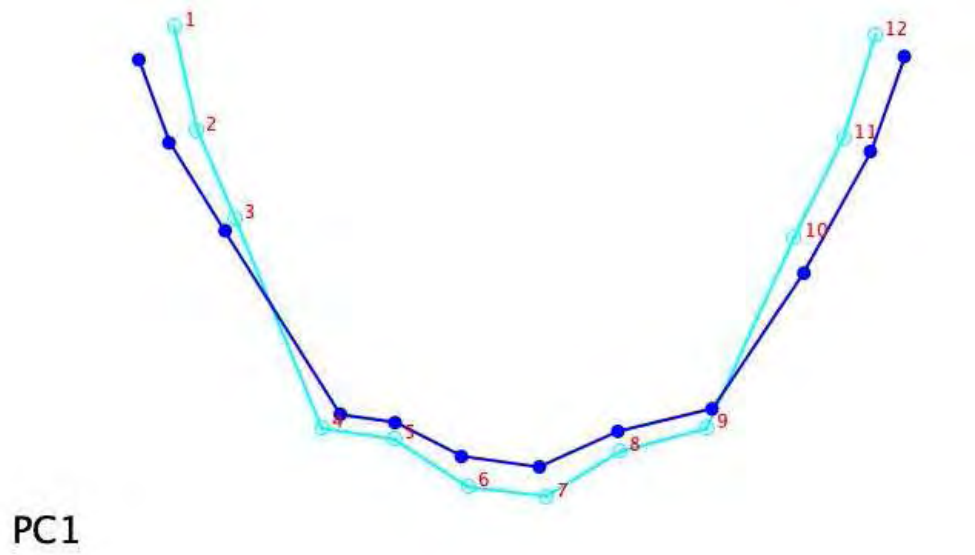

Figure 2.4E First PC shape changes for 17 subjects of mandibular severe crowding group at posttreatment

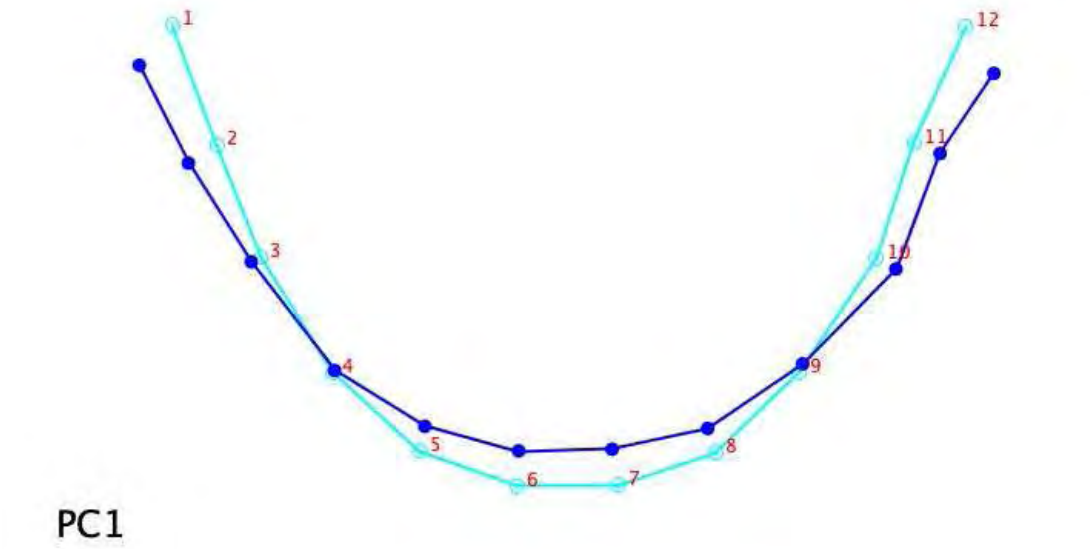

Figure 2.4F First PC shape changes for 17 subjects of mandibular severe crowding group at postretention

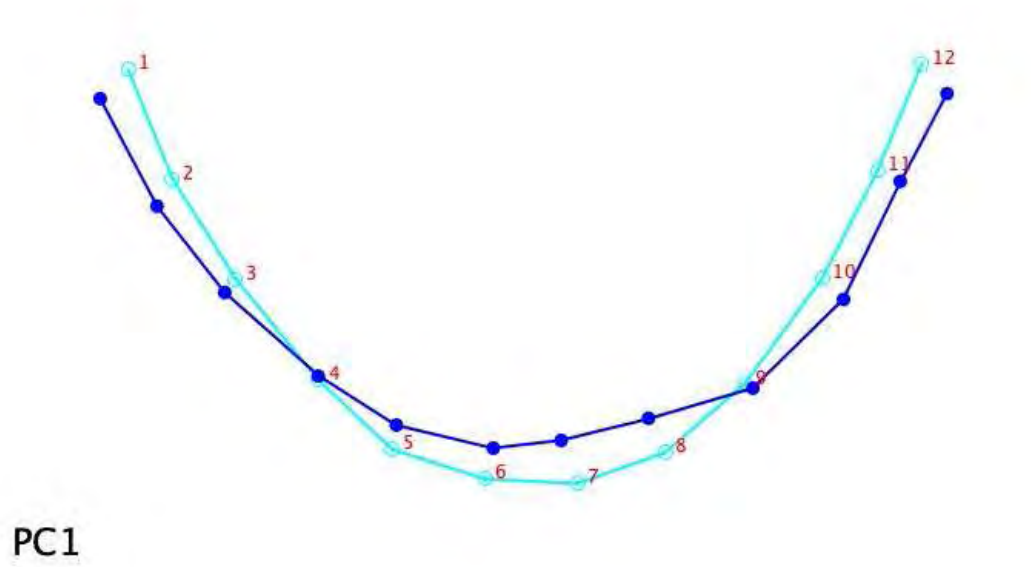

Figure 2.4G First and Second PC scores for maxillary severe crowding group at pretreatment (blue dots), posttreatment (red dots) and postretention (green dots)

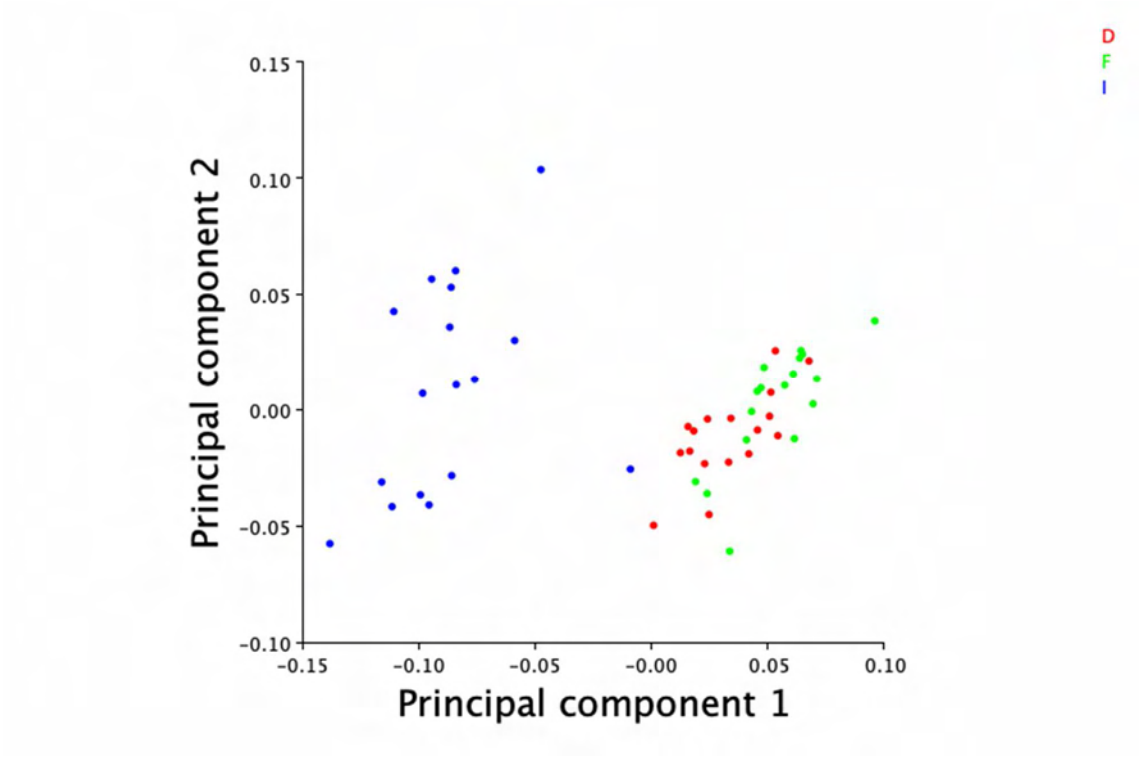

Figure 2.4H First and Second PC scores for mandibular severe crowding group at pretreatment (blue dots), posttreatment (red dots) and postretention (green dots)

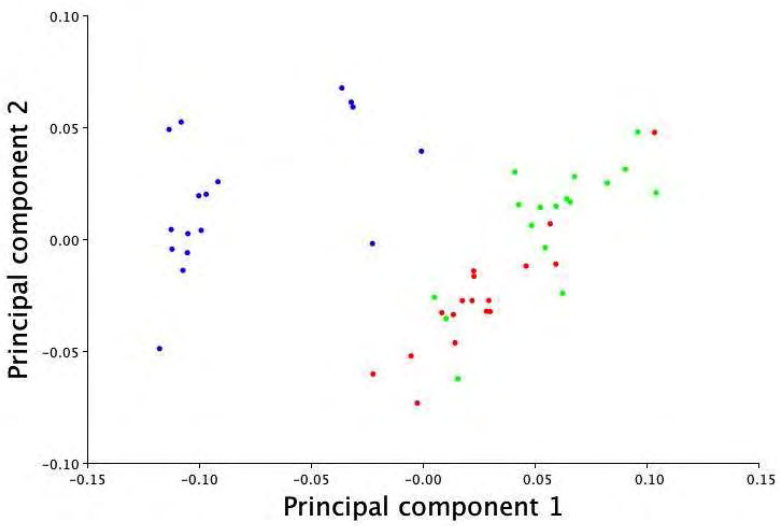

Figure 2.5A First and Second CV scores for mild maxillary crowding group at pretreatment (dark blue dots), posttreatment (red dots) and postretention (pink dots) and severe maxillary crowding at pretreatment (light blue dots), posttreatment (orange dots) and postretention (purple dots)

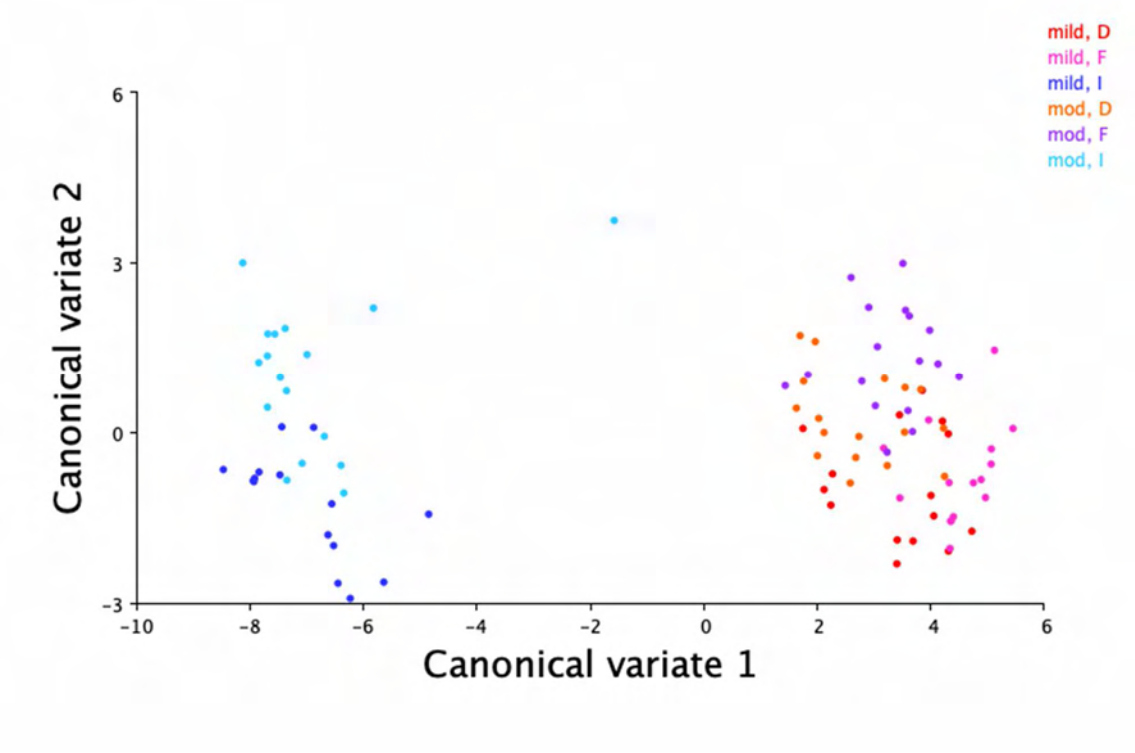

Figure 2.5B: First and Second CV scores for mild mandibular crowding group at pretreatment (dark blue dots), posttreatment (red dots) and postretention (pink dots) and severe mandibular crowding group at pretreatment (light blue dots), posttreatment (orange dots) and postretention (purple dots)

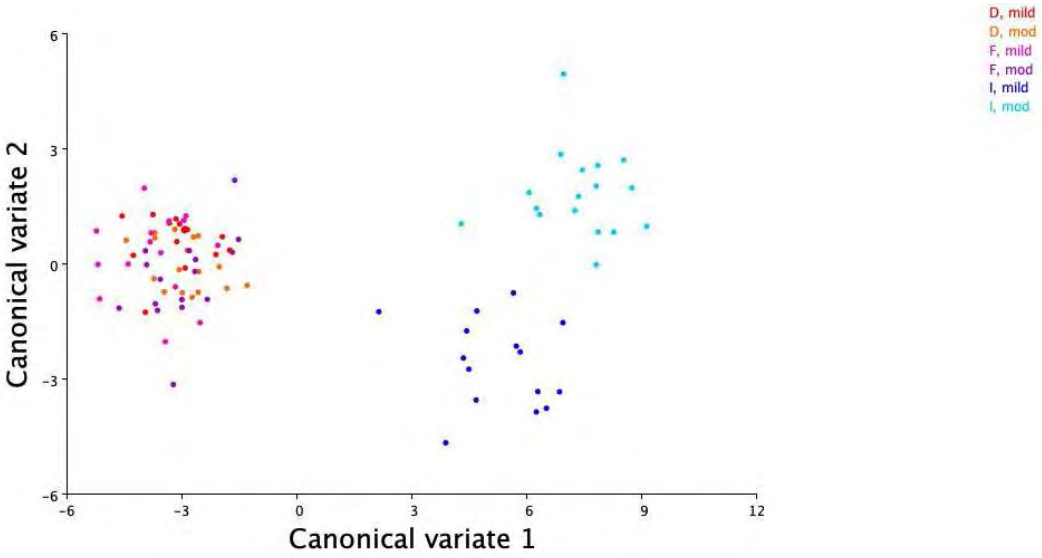

Table I: Intraclass Correlation Coefficient results for Intra-investigator errors evaluation (n=32)

POINT	1.st Measurement Mean (SD)	2.nd Measurement Mean (SD)	ICC
Maxillary dental casts measurements			
1: Distobuccal cusp tip of right 1st molar	-2.61 (1.47)	-2.60 (1.44)	0.854
2: Mesiobuccal cusp tip of right 1st molar	-2.47 (1.43)	-2.48 (1.27)	0.963
3: Buccal cusp tip of right premolar	-2.26 (1.38)	-2.28 (1.60)	0.973
4: Cusp tip of right canine	-1.76 (1.38)	-1.75 (1.94)	0.963
5: Midpoint of incisal edge of the right lateral incisor	-2.67 (3.09)	-1.99 (2.21)	0.533
6: Midpoint of incisal edge of the right central incisor	-4.60 (1.98)	-5.62 (2.34)	1.101
7: Midpoint of incisal edge of the left central incisor	4.14 (2.58)	3.69 (2.91)	0.730
8: Midpoint of incisal edge of the left lateral incisor	4.55 (3.61)	5.92 (3.52)	0.965
9: Cusp tip of left canine	1.65 (2.55)	1.51 (2.40)	0.867
10: Buccal cusp tip of left premolar	2.20 (1.74)	2.13 (1.88)	0.952
11: Mesiobuccal cusp tip of left 1st molar	2.48 (1.61)	2.43 (2.09)	0.969
12: Distobuccal cusp tip of left 1st molar	2.63 (1.62)	2.63 (2.02)	0.994
Mandibular dental casts measurements			
1: Distobuccal cusp tip of right 1st molar	-2.34 (1.29)	-2.30 (1.41)	0.985
2: Mesiobuccal cusp tip of right 1st molar	2.19 (1.20)	-2.20 (1.24)	0.999
3: Buccal cusp tip of right premolar	-1.94 (1.73)	-1.94 (2.23)	1.013
4: Cusp tip of right canine	-1.61 (1.26)	-1.42 (1.75)	1.062
5: Midpoint of incisal edge of the right lateral incisor	-6.58 (3.00)	-5.63 (3.86)	0.832
6: Midpoint of incisal edge of the right central incisor	-3.51 (2.46)	-4.46 (2.13)	0.797
7: Midpoint of incisal edge of the left central incisor	2.34 (2.89)	1.94 (2.74)	0.594
8: Midpoint of incisal edge of the left lateral incisor	6.03 (2.34)	6.20 (2.03)	0.745
9: Cusp tip of left canine	2.74 (3.03)	1.89 (2.24)	1.021
10: Buccal cusp tip of left premolar	1.85 (1.75)	1.79 (1.75)	0.798
11: Mesiobuccal cusp tip of left 1st molar	2.15 (1.37)	2.16 (1.98)	1.105
12: Distobuccal cusp tip of left 1st molar	2.36 (1.24)	2.44 (1.72)	0.856

Table II: Results of intergroup comparability of the ages, treatment, follow-up and retention times, gender and initial malocclusion distribution (independent t test and Chi-square test).

Variables	**GROUP Mild crowding (N=15)**		**GROUP Severe Crowding (N=17)**		**P**
	Mean	**SD**	**Mean**	**SD**	
Initial age (T1)	13.52	1.54	13.43	2.51	0.906
Final age (T2)	16.05	1.87	15.48	2.62	0.490
Follow-up age (T3)	55.15	3.54	54.41	5.05	0.642
Treatment Time (T2-T1)	2.53	0.67	2.05	0.35	**0.017***
Follow-up time (T3-T2)	39.09	2.86	38.92	3.85	0.894
Retention time	1.69	0.63	2.39	1.32	0.074
Gender	8 (53.33%) female 7 (46.67%) male		11 (64.70%) female 6 (35.30%) male		0.605^{Chi}
Initial Malocclusion	10 (66.67%) Class II 5 (33.33%) Class I		4 (23.53%) Class II 13 (76.47%) Class I		**0.019*^{Chi}**

* Statistically significant at P<0.05

Table III: Repeated Measures ANOVA and Tukey tests for Little Irregularity Index comparison among the times for both groups.

	GROUP Mild crowding (N=15)				**GROUP Severe Crowding (N=17)**			
	T1	T2	T3	p	T1	T2	T3	p
	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)	
Maxillary LII	6.86 (3.09)^{A}	0.31 (0.67)^{B}	1.74 (2.03)^{B}	**0.000***	9.58 (4.00)^{A}	0.08 (0.36)^{B}	2.41 (2.61)^{C}	**0.000***
Mandibular LII	3.54 (2.17)^{A}	0.69 (0.98)^{B}	3.93 (2.12)^{A}	**0.000***	10.29 (2.54)^{A}	0.47 (0.73)^{B}	4.45 (3.36)^{C}	**0.000***

* Statistically significant at P<0.05

Table IV: Percent variance in shape described by the principal components analyses among subjects for the mild crowding group

Maxillary						
	T1		T2		T3	
	% Variance	% Cumulative	% Variance	% Cumulative	% Variance	% Cumulative
PC 1	40.82	40.82	40.65	40.65	53.86	53.86
PC 2	24.50	65.32	13.63	54.29	16.18	70.04
PC 3	8.65	73.97	11.87	66.17	6.76	76.80
PC 4	7.70	81.68	9.84	76.01	5.37	82.18
PC 5	5.57	87.26	7.48	83.49	4.21	86.39
PC 6	3.96	91.22	4.57	88.06	3.53	89.92
PC 7	2.22	93.44	3.25	91.32	2.39	92.32
PC 8	2.18	95.62	2.81	94.12	1.95	94.27
PC 9	1.60	97.23	2.06	96.19	1.56	95.84
Mandibular						
	T1		T2		T3	
	% Variance	% Cumulative	% Variance	% Cumulative	% Variance	% Cumulative
PC 1	34.11	34.11	55.05	55.05	58,35	58.35
PC 2	17.18	51.30	13.67	68.72	10.10	68.46
PC 3	15.87	67.18	8.73	83.38	7.51	75.97
PC 4	10.18	77.36	5.92	86.91	6.92	82.90
PC 5	5.73	83.09	3.53	89.94	3.95	86.86
PC 6	3.98	87.07	3.02	92.45	3.34	90.20
PC 7	2.72	90.92	2.51	94.27	2.61	92.81
PC 8	1.92	93.64	1.81	95.83	2.20	95.02
PC 9	1.31	95.57	1.56	97.14	1.90	96.93

Table V: Percent variance in shape described by the principal components analyses among subjects for the severe crowding group

Maxillary						
	T1		T2		T3	
	% Variance	% Cumulative	% Variance	% Cumulative	% Variance	% Cumulative
PC 1	40.59	40.59	48.35	48.35	45.58	45.58
PC 2	20.73	61.33	11.27	59.62	11.34	56.92
PC 3	14.35	75.69	8.72	68.34	10.53	67.46
PC 4	9.80	85.49	7.42	75.76	6.20	73.66
PC 5	4.55	90.04	3.13	81.27	5.87	79.53
PC 6	2.22	92.27	4.42	85.69	4.40	83.93
PC 7	1.98	94.26	3.13	88.82	3.97	87.91
PC 8	1.31	95.57	2.77	91.59	3.13	91.05
PC 9	1.20	96.78	2.10	93.69	2.289	93.34
Mandibular						
	T1		T2		T3	
	% Variance	% Cumulative	% Variance	% Cumulative	% Variance	% Cumulative
PC 1	34.53	34.53	58.96	58.96	38.64	38.64
PC 2	19.60	54.13	12.71	71.67	16.39	55.04
PC 3	11.81	65.94	5.829	77.50	11.07	66.11
PC 4	9.35	75.29	4.778	82.28	8.28	74.40
PC 5	6.75	82.05	4.32	86.60	6.68	81.08
PC 6	5.27	87.32	3.37	89.97	4.61	85.69
PC 7	4.58	91.91	2.54	92.52	3.49	89.18
PC 8	2.37	94.29	1.82	94.34	2.60	91.79
PC 9	1.53	95.82	1.43	95.78	2.27	94.06

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3 DISCUSSION

3 DISCUSSION

To monitor the crowding status of a particular population that received a specific treatment and their outcomes throughout life was the main aim of these articles. One of the most difficult tasks is to determine the causes of disease, to develop methods of prevention. This Current research involves a recall of patients who were treated when our supervisors were still students. At this time some patients accepted the invitation to return to clinic of orthodontics of Bauru Dental school almost forty years after the end of treatment and others declined to participated. Thus, the nonrandomized observational, longitudinal, retrospective cohort study methods have been chosen to the design. Observational studies are used to examine causal factors, to monitor or describe the health status of a population, the relationship between exposure and the outcome measure of interest. The disease effect and possible cause do not exist in isolation but in a complex interplay of factors. The existing situation is observed and try to understand what is happening. The longitudinal study examines the changes in health status over time. A cohort study is one in which a group of subjects was selected to represent the population of interest and followed over time. It can be prospective or retrospective. The second design has been chosen for the present research. It looks at events from some timepoint in the past up to the present time and collect this past exposure information on participants through recorded information. The subjects are disease-free at the outset of the study and at distinct points in time, data are collected relating to health outcomes and exposure to risk factors. It may be either fixed, where the study subjects do not vary over time and dropouts are not replaced, or dynamic, where new subjects enter the study in accordance with eligibility criteria. All types of study design have Advantages and Disadvantages. The Disadvantage of Longitudinal studies is time-consuming and often result in loss to follow-up. The advantage of cohort studies is that the information is available immediately, can be used to study more than one outcome. The better study is that answering the research question. (Bland, 2015; Levin, 2005; Levin, 2006; Pandis et al., 2014)

It was suggested that the term relapse should be reserved to describe changes that result from inappropriate treatment and recovery as the most appropriate term to describe posttreatment changes, therefore a biologic concept and not simply. Normal

physiologic changes, developmental or maturational changes maybe appropriate terms. (Horowitz; Hixon, 1969) The treatments that comprised this samples were well conducted.

The interest in studying the dental arch shape began more than century ago and is still currently discussed (Lombardo; Coppola; Siciliani, 2015; Williams, 1917). There has been no standard form of dental arch and there is some difficulty in selecting a nomenclature to describe, to sort or to analyze the types of dental arches (Felton et al., 1987; Nouri et al., 2016). The lack of good method in the field of dental arches shape studies and description of variation among a population was reported and the statistical shape analysis were introduced.(Sampson, 1981) Geometric morphometric is a recent method in orthodontics, but describes the three-dimensional shape of orthodontic interest.(Huanca Ghislanzoni et al., 2017) The software Stratovan Checkpoint and MorphoJ has been chosen, but geometric morphometric analyses can be performed in others statistical packages such as Landmark, tpsDig, Morphologika, Viewbox 4 (dHAL Software, Kifissia, Greece) (Papagiannis; Halazonetis, 2016), Matlab, R, SAS.(Viscosi; Cardini, 2011) Two recent orthodontic works using these methods and the Viewbox software demonstrate how many PCs were significantly significant.(Kouli et al., 2019; Lagana et al., 2019) Another orthodontic articles (Miller et al., 2016; Papagiannis; Halazonetis, 2016) explored the variation in the dental arch shape also used geometric morphometric, however a covariation entitled two blocks partial least square analysis was used to examine the interrelationships of maxillary and mandibular dental arches also for the symmetrical and asymmetrical shape components of the sample were performed. Discriminant functions was used to evaluate the relationship between dental arches and crowding.(Lestrel; Takahashi; Kanazawa, 2004)

Future studies with this same sample should explore:

This investigation did not assess the patient's complaint at postretention. Who will complain about the maturational physiological changes? Who will seek the orthodontist again for a new treatment many years after the end of treatment and without using retainers?

- Assess quality of life of these subjects during adulthood;
- Assess the face attractiveness through photography, not by profile;
- Assess the relationship between dental arches shape and masticatory muscles' function perhaps an interaction with some discipline of postgraduate speech therapy.

4 FINAL CONSIDERATIONS

4 FINAL CONSIDERATIONS

Adults who were orthodontically treated while teenagers had some degree of physiological changes. These results will improve diagnostic and prognosis in orthodontics. Furthermore, the life expectancy is increasing, and adults are becoming more demanding with the appearance. The general dentist and orthodontist must be aware of this demand and also that orthodontic treatment can improve better quality of life.

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APPENDIXES

APPENDIXES

APPENDIX A – Declaration of exclusive use of the article 1 in thesis.

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN THESIS

We hereby declare that we are aware of the article "Dental arch dimensions changes and anterior dental crowding relapse in patients treated with extractions: long-term follow-up study " will be included in thesis of the graduate student Caroline Martins Gambardela Tkacz and may not be used in other works of Graduate Programs at the Bauru Dental School, University of São Paulo.

Bauru, March 18th of 2020.

Caroline Martins Gambardela Tkacz

Karina Maria Salvatore de Freitas

Marcos Roberto de Freitas

APPENDIX B - Declaration of exclusive use of the article 2 in thesis.

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN THESIS

We hereby declare that we are aware of the article "Geometric morphometric analyses of dental arches changes in the long-term posttreatment follow-up" will be included in thesis of the graduate student Caroline Martins Gambardela Tkacz and may not be used in other works of Graduate Programs at the Bauru Dental School, University of São Paulo.

Bauru, March 18th of 2020.

Caroline Martins Gambardela Tkacz

Karina Maria Salvatore de Freitas

Marcos Roberto de Freitas

ANNEXES

ANNEXES

ANNEX A – Research Institutional Board approval, protocol number 71649217.5.0000.5417

USP - FACULDADE DE ODONTOLOGIA DE BAURU DA USP

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: AVALIAÇÃO DA INFLUÊNCIA DA FORMA DOS ARCOS DENTÁRIOS NA RECIDIVA DO APINHAMENTO ANTERIOR

Pesquisador: Caroline Martins Gambardela Tkacz

Área Temática:

Versão: 3

CAAE: 71649217.5.0000.5417

Instituição Proponente: Universidade de Sao Paulo

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.834.688

Apresentação do Projeto:

Os pesquisadores solicitam uma emenda para alteração do título "Avaliação da influencia da forma dos arcos dentarios na estabilidade do apinhamento anterior" para " Avaliação da influencia da forma dos arcos dentarios na recidiva do apinhamento anterior". A metodologia não foi alterada.

Objetivo da Pesquisa:

Nao se aplica

Avaliação dos Riscos e Benefícios:

não se aplica

Comentários e Considerações sobre a Pesquisa:

Os pesquisadores solicitam alteração do título apenas, sem alteração na metodologia. N inicial de 90 participantes.

Considerações sobre os Termos de apresentação obrigatória:

Idem acima.

Conclusões ou Pendências e Lista de Inadequações:

Aprovado.

Considerações Finais a critério do CEP:

A emenda apresentada pelo(a) pesquisador(a) foi considerada APROVADA na reunião ordinária do

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CEP de 05/02/2020, com base nas normas éticas da Resolução CNS 466/12. Ao término da pesquisa o CEP-FOB/USP exige a 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_1499074_E1.pdf	16/01/2020 16:51:26		Aceito
Outros	Ementa.pdf	16/01/2020 16:49:55	Caroline Martins Gambardela Tkacz	Aceito
Folha de Rosto	Folhaderosto2020.pdf	16/01/2020 16:49:30	Caroline Martins Gambardela Tkacz	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLECarol2.pdf	01/09/2017 16:11:22	Caroline Martins Gambardela Tkacz	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	CEPaquiscencia.pdf	01/09/2017 16:09:46	Caroline Martins Gambardela Tkacz	Aceito
Outros	CEPquestionario2.pdf	01/09/2017 16:02:12	Caroline Martins Gambardela Tkacz	Aceito
Projeto Detalhado / Brochura Investigador	ProjetoTeseCEP2.pdf	01/09/2017 15:20:01	Caroline Martins Gambardela Tkacz	Aceito
Declaração de Pesquisadores	CEPCompromisso.pdf	20/07/2017 11:53:21	Caroline Martins Gambardela Tkacz	Aceito
Declaração de Instituição e Infraestrutura	CEParquivo.pdf	20/07/2017 11:15:58	Caroline Martins Gambardela Tkacz	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

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Continuação do Parecer: 3.834.888

BAURU, 12 de Fevereiro de 2020

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

Endereço: DOUTOR OCTAVIO PINHEIRO BRISOLLA 75 QUADRA 9
Bairro: VILA NOVA CIDADE UNIVERSITARIA **CEP:** 17.012-901
UF: SP **Município:** BAURU
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ANNEX B – Invitation letter

Prezado Sr(a). _____,

O(A) senhor(a) foi paciente da clínica de ortodontia da Faculdade de Odontologia de Bauru - USP há mais de trinta anos, está lembrado(a)?

Primeiramente, gostaríamos de agradecê-lo(a) pela sua contribuição para o desenvolvimento da Odontologia brasileira e, informamos que seu o tratamento foi de extrema importância.

O nosso objetivo atual é avalia-lo(a) novamente e verificar como está sua saúde bucal de forma geral. Somos cirurgiãs – dentistas e alunas de doutorado em Ortodontia na Faculdade de Odontologia de Bauru - Universidade de São Paulo e, com as informações obtidas em nossa consulta, além de informá-lo e orientá-lo(a) sobre eventuais problemas, pretendemos realizar uma nova pesquisa sobre as mudanças apresentadas pelos seus dentes durante este tempo sob a orientação do Prof. Dr. Marcos Roberto de Freitas e da Prof. Dra. Karina Maria Salvatore de Freitas. Será realizada uma avaliação clínica com profissionais especializados SEM NENHUM CUSTO. Estaremos à disposição, também, para orientações ou dúvidas que ele apresente.

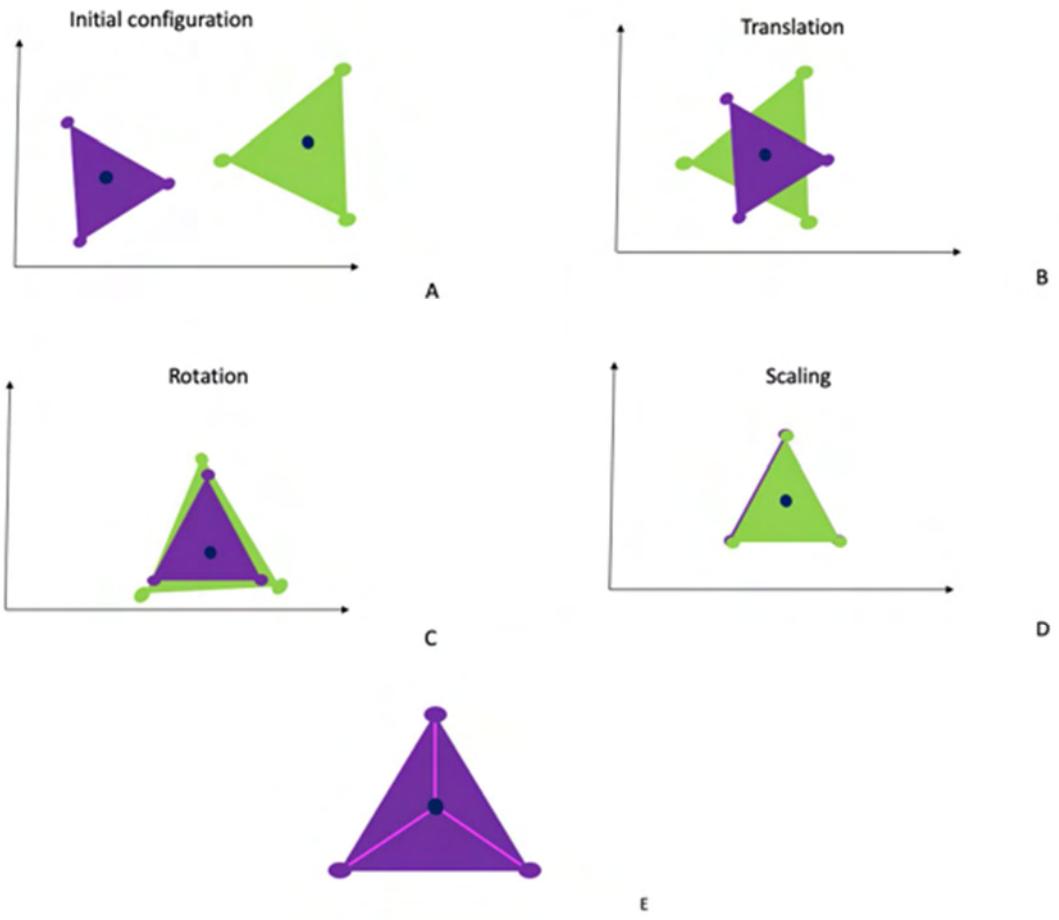
Localizamos os dados nos arquivos da disciplina e o seu contato atualizado com o auxílio da internet.
Gostaríamos de entrar em contato e esclarecer melhor o apresentado aqui nesta carta, portanto estamos escrevendo para que o senhor entre em contato conosco assim que possível. Aceitamos contato via e-mail, telefone, mensagem, Whats app, Facebook ou carta. O importante é nos comunicarmos para marcarmos a sua avaliação. Todos os contatos encontram-se no verso desta carta.

Esperamos o seu contato e estamos à disposição para maiores esclarecimentos.

Atenciosamente e até breve,

Dra. Caroline Martins Gambardela Tkacz & Dra. Paula Patrícia Cotrin da Silva

ANNEX C – Illustration of Procrustes superimposition or Generalized Procrustes Analysis (A to D) and centroid size: the square root of the sum of squared Euclidean distances from each landmark to the centroid of that configuration, the measure of size that is mathematically independent of shape. (E)



ANNEX D – Guidelines for AJO-DO submissions: Original Article

ELSEVIER

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Official Journal of the American Association of Orthodontists, its constituent societies, the American Board of Orthodontics, and the College of Diplomates of the American Board of Orthodontics

AUTHOR INFORMATION PACK

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ISSN: 0889-5406

DESCRIPTION

Published for more than 100 years, the *American Journal of Orthodontics and Dentofacial Orthopedics* remains the leading **orthodontic** resource. It is the official publication of the American Association of Orthodontists, its constituent societies, the American Board of Orthodontics and the College of Diplomates of the American Board of Orthodontics. Each month its readers have access to original peer-reviewed articles that examine all phases of **orthodontic treatment**. Illustrated throughout, the publication includes tables, photos (many in full color), and statistical data. Coverage includes successful diagnostic procedures, imaging techniques, bracket and archwire materials, extraction and impaction concerns, orthognathic surgery, TMJ disorders, removable appliances, and adult therapy.

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