UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ODONTOLOGIA DE BAURU

BRUNO DA SILVA VIEIRA

Cone-beam computed tomography evaluation of upper airway, dental arches dimensions and buccolingual inclination through of cases treated with Damon System

Avaliação das vias aéreas superiores, dimensões dos arcos e inclinações vestibulolinguais através de Tomografia Computadorizada Cone Beam em casos tratados com o Sistema Damon

BAURU
2017

BRUNO DA SILVA VIEIRA

Cone-beam computed tomography evaluation of upper airway, dental arches dimensions and buccolingual inclination through of cases treated with Damon System

Avaliação das vias aéreas superiores, dimensões dos arcos dentários e inclinações vestibulolinguais através de Tomografia Computadorizada Cone Beam em casos tratados com o Sistema Damon

Tese constituída por artigos apresentada à Faculdade de Odontologia de Bauru da Universidade de São Paulo para obtenção do título de Doutor em Ciências no Programa de Ciências Odontológicas Aplicadas, na área de concentração Ortodontia.

Orientador: Prof.º Dr.º Marcos Roberto de Freitas.

Versão Corrigida

BAURU

2017

Vieira, Bruno da Silva

V673c Cone-beam computed tomography evaluation of upper airway, dental arches dimensions and buccolingual inclination through of cases treated with Damon System / Bruno da Silva Vieira – Bauru, 2017.

123p. : il. ; 31cm.

Tese. (Doutorado) -- Faculdade de Odontologia de Bauru. Universidade de São Paulo.

Orientador: Prof. Dr. Marcos Roberto de Freitas

Nota: A versão original desta tese encontra-se disponível no Serviço de Biblioteca e Documentação da Faculdade de Odontologia de Bauru – FOB/USP.

,

Comitê de Ética da FOB-USP
1.567.403
Data: 30/05/2016

FOLHA DE APROVAÇÃO

DEDICATÓRIA

A realização de um sonho envolve sentimentos ambíguos como perseverança, incertezas, dedicação, medo, felicidade, tristeza, tornando-se uma tarefa extremamente difícil. Entretanto, o carinho e a confiança de pessoas muito especiais me inspirou a continuar, independente da dificuldade a ser encontrada pelo caminho. Sendo assim, é com muito amor e com eterno sentimento de gratidão que dedico esta tese:

Aos meus amados **Pais** por todo amor e dedicação, que por muitas vezes abdicaram dos seus sonhos para ver um sorriso estampado em meu rosto, pelo investimento contínuo na minha formação pessoal e profissional, por iluminarem sempre a minha caminhada sendo os mais nobres exemplos que Deus colocou em minha vida.

A minha amada mãe **Eunice** que sempre dedicou sua vida para cuidar, amar, educar e garantir nosso bem-estar em todos os caminhos que percorremos e ainda há de percorrer. Um amor que me proporcionou força em diversos momentos e que por mais que eu tente, jamais poderei recompensá-la. *Te amo infinitamente*.

Ao meu paizão **Edison** que sempre acreditou, me incentivou, uma pessoa que sempre foi meu espelho e referência de ser humano, de cárater, de bondade e que proporcionou todo o alicerce para que eu conseguisse chegar até aqui. Essa vitória é nossa pai ou melhor, *PAIZÃO! Te amo eternamente.*

A minha querida afilhada **Ana Júlia** que trouxe para minha vida os sentimentos mais belos e puros através do seu sorriso, carinho, amor, ternura acompanhados da responsabilidade de um dia poder ser um exemplo na sua vida.

Ao meu irmão **Thiago** que me acompanhou por todas as fases da minha vida pessoal e profissional, pelo carinho prontamente disponível, pelas preocupações com minhas viagens constantes e por iluminar a minha vida nos momentos difíceis.

Amo imensamente cada um de vocês!!!!

AGRADECIMENTOS

Agradeço especialmente,

À **Deus**, por proporcionar saúde e sabedoria e estar presente em momentos de tristeza, dificuldade, realizações e felicidade. Obrigado senhor por sua bondade infinita que vem me conduzindo nessa jornada, pelos aprendizados e bênçãos em toda a minha vida.

Aos meus amados **Pais** por serem minha fonte de inspiração, zelo e amor incondicional. Obrigado por me preparar para a vida em um ambiente familiar pautado por valores, como caráter, honestidade, generosidade e sempre estarem presentes ao meu lado em todos os momentos.

Ao meu irmão **Thiago** pela amizade, carinho, incentivo e todas as brincadeiras que acalentaram meu coração e me trouxe renovação para continuar em busca desse sonho.

A minha sobrinha e afilhada **Ana Júlia** que através do seus sorriso, carinho e amor mostrou-me o sentido real da palavra felicidade.

A minha noiva **Ludmila,** pelo seu amor incondicional e cumplicidade que me ajudaram a superar inúmeros obstáculos que surgiram ao longo do curso e pacientemente esteve presente em todos os momentos de inquietude, stress e incertezas, sendo o meu porto seguro. Conte sempre comigo!

Ao **Sr. Garcia** e **D. Paulina** pelo carinho e acolhimento fraterno ao longo desses três anos de curso, sempre proporcionando momentos de alegria com suas presenças, colaborando para que minha estadia em Bauru fosse muito mais fácil e tranquila. Meu muito obrigado!

À minha **família**, pelos momentos divertidos e por sempre participar das minhas conquistas.

Aos queridos amigos **Thomas** e **Junia** que sempre vibraram com minhas vitórias e torcem por minhas conquistas. Pessoas especiais que muitas vezes me ouviram, me orientaram, me acolheram em suas vidas e que sempre estarão no meu coração.

À professora **Leniana Neves** pela oportunidade que mudou minha vida profissional, por acreditar sempre em meu potencial, pelos ensinamentos de Ortodontia, pela admiração pessoal e acadêmica, pelas orientações que fizeram com que eu chegasse até esse momento de realização desse sonho, mas principalmente pela amizade e confiança construída ao longo de todos esses anos. Muito obrigado!

Ao professor **Rodrigo Cançado** pela amizade, confiança e parceria desses anos, pelos ensinamentos de Ortodontia, pelos conselhos e orientações que foram importantíssimos para o meu crescimento profissional e pessoal. A admiração pela sua competência e dedicação com que atua na especialidade, foram fontes de inspiração que me proporcionaram alcançar mais esse objetivo. Muito obrigado!

Agradeço ao meu orientador...

Professor **Marcos Roberto de Freitas** pela oportunidade e confiança no desenvolvimento desse trabalho científico. A sua atenção, empenho e dedicação, me ajudou a crescer não só profissionalmente, mas também pessoalmente. A sua disposição em ensinar, seu carinho e bondade são alguns dos motivos que o torna esse grande professor. Serei eternamente grato pela honra de ter sido seu orientado.

Agradeço ainda....

Ao estimado professor **Guilherme Janson** por quem sempre tive uma admiração e respeito pelo profissionalismo e dedicação que exerce a Ortodontia, pelos ensinamentos e histórias durante os seminários, pelas cobranças com o objetivo de tirar o melhor de mim e pelas orientações no desenvolvimento de artigos científicos.

À querida professora **Daniela Garib** que me recebeu na Faculdade de Odontologia de Bauru de braços abertos, com todo o carinho e respeito, pelas orientações no desenvolvimento dessa pesquisa e pela admiração profissional e pessoal.

Ao estimado professor **José Fernando Castanha Henriques** pelos ensinamentos nas monitorias dos cursos de Especialização em Ortodontia, por compartilhar seu conhecimento e experiência na Ortodontia e sempre valorizar a Faculdade de Odontologia de Bauru nos congressos e eventos da especialidade.

Ao grande professor **Arnaldo Pinzan** pela consideração e respeito que sempre teve por mim, pelas suas histórias e experiências na Ortodontia compartilhadas e sempre com seu bom humor transmitindo o conhecimento não só profissional como de vida.

Ao estimado professor **Renato Rodrigues de Almeida** pela admiração e respeito por toda sua história desenvolvida na Ortodontia, pelos ensinamentos na prevenção e interceptação das más oclusões durante as clínicas integradas, por sempre estar disposto a ensinar, sendo um exemplo de dedicação e amor a Ortodontia.

À **banca examinadora** da minha tese de Doutorado; Dr. Guilherme Janson, Drª Célia Pinzan e Drª. Liliana Maltagliati por aceitarem o convite de participação e por contribuírem significantemente para o aprimoramento deste trabalho por meio de suas valiosas sugestões e críticas.

Aos **avaliadores suplentes** da minha tese de Doutorado, Drª. Ana Claudia Conti, Dr. Danilo Pinelli Valarelli, Drª Renata Sathler Zanda e Dr. Danilo Furquim Siqueira pela gentileza de se disporem a avaliar esse trabalho, diante da ausência de alguns dos avaliadores titulares da banca examinadora.

À professora **Karina Freitas** por todas as sugestões e orientações no desenvolvimento da pesquisa científica. Sua inteligência e competência é admirável. Obrigado pela atenção e disponibilidade que sempre obtive em momentos de dificuldade. Muito obrigado!

Ao professor **Daniel Freitas** por disponibilizar condições para a realização da pesquisa científica, sempre atencioso e disposto a ajudar quando necessário.

À querida secretária **Vera Purgato** que me orientou com a documentação no processo seletivo do Doutorado e me proporcionou um momento marcante em minha vida quando anunciou minha aprovação. Sempre me ajudou com as questões burocráticas do curso de forma atenciosa e competente.

Ao estimado técnico do laboratório e amigo **Luiz Sérgio Vieira** por compartilhar suas histórias e experiências vividas no departamento e pelos ensinamentos durantes as práticas laboratoriais, sempre tentando explicar e orientar da melhor forma a confecção, indicação e efeitos dos aparelhos ortodônticos.

Ao grande amigo **Wagner Baptista** pelos momentos divertidos no departamento, pelas experiências compartilhadas e pela ajuda e orientação na confecção dos aparelhos ortodônticos para o ensino dos alunos de Especialização em Ortodontia.

À querida **Cléo Vieira,** que sempre me recebeu alegremente na Clínica de Ortodontia da Faculdade, por ter me ajudado no início do curso sobre as normas e marcações das clínicas e orientação aos alunos de graduação no atendimento dos pacientes.

Ao amigo **Bonné** por sempre me atender e ajudar a resolver problemas com os computadores da pesquisa, pelos momentos alegres dentro do Departamento de Ortodontia e pela excelência do serviço prestado na formatação e impressão da minha tese de Doutorado.

Aos meu **colegas e amigos do curso de Doutorado** da Faculdade de Odontologia de Bauru, Arthur Medeiros, Ana Liesel, Bruna Furquim, Camilla Fonçatti, Karine Laskos, Louise Resti, Mayara Rizzo, Melissa Lancia, Murilo Matias, Rodrigo Higa, Sérgio Cury, Vinicius Laranjeiras e Waleska Caldas pelo companheirismo, amizade, por me ajudarem nos momentos iniciais do curso, pelas conversas, desabafos, orientações, conselhos, pelos momentos difíceis e pelos momentos de alívio, cada um de vocês terá um lugarzinho em meu coração e espero que nossa amizade permaneça para sempre.

À minha querida **segunda turma**, que no início foi do curso de Mestrado e agora colegas de Doutorado da Faculdade de Odontologia de Bauru, Aron Aliaga, Camila Massaro, Débora Brindeiro, Fabíola Alvarez, Felícia Miranda, Lorena Vilanova, Patrícia Negreiros, Raquel Poletto, Ricardo Rengifo, Rodolfo Francisco, Sorilée Ramón e aos novos integrantes Carolina Gambardela, Diego Tonello, Paula Cotrin e Wilana Moura por me adotarem como novo integrante da turma e me proporcionar momentos de felicidade, alegria, união, sempre dispostos a me ajudar

quando preciso. Tenho um carinho enorme por todos vocês e sempre podem contar comigo para o que der e vier, porque com vocês o lema ***“um por todos e todos por um”*** faz todo o sentido em minha vida.

À **CAPES** pelo apoio financeiro e pelo incentivo ao desenvolvimento de pesquisa e ciência no Brasil.

Ao representante do **Dolphing Imaging** no Brasil, **Rogério** pela disponibilidade, atenção e orientações no uso do software para a realização da metodologia da pesquisa.

À **CDT software** e aos amigos **Roney Rocha** e **Ramão de Souza** pela ajuda e atenção no desenvolvimento metodológico da pesquisa e disponibilização e treinamento do software E-Vol.

À **Paula Castro** pela grande ajuda na localização dos exames dos pacientes da amostra da pesquisa e disponibilidade dispendida durante esses três anos.

A todos que colaboraram de forma direta ou indireta na realização e finalização desse trabalho e que, por ventura, não foram mencionados.

Meu muito obrigado!

“Para se ter sucesso, é necessário amar de verdade o que se faz. Caso contrário, levando em conta apenas o lado racional, você simplesmente desiste. É o que acontece com a maioria das pessoas”

Steve Jobs

ABSTRACT

Cone-beam computed tomography evaluation of upper airway, dental arches dimensions and buccolingual inclination through of cases treated with Damon System

Introduction: The aim of this study was to assess changes in upper airway, dental arches dimensions and buccolingual inclinations of teeth in patients treated orthodontically with the Damon system. **Material and Methods:** Twenty-one patients of both sexes, mean initial age of 14.99 ± 1.97 years, with complete permanent dentition up to second molars, treated with non-extractions and minimum initial crowding of 4mm (maxillary: -6.71 ± 2,99 mm, mandibular: -5,12 ± 2,03 mm were taken to CBCT scan before (T1) and after (T2) orthodontic treatment with the Damon System. The volume, sagittal area and minimum axial area of the upper airway were measured in sagittal and axial sections by means of the upper airways analysis tool of Dolphin Imaging® software. Buccolingual inclinations were performed using CBCT-panoramic cross-sectionals based on the image that presented the most appropriate view of buccal face of the clinical crown. Arches dimensions were measured by means of 2D axial and coronal sections in 3D reconstructions. The reference points used were buccal and mesiobuccal cusp tips for the premolars and molars respectively. Distribution of the variables was verified by Shapiro-Wilk test. Changes in all variables from T1 to T2 were compared using paired t-test. The correlation between the upper airway changes with buccolingual inclinations of teeth and arches dimensions was verified by the Pearson correlation coefficient. **Results:** There was a significant increase in maxillary interfirst premolar, intersecond premolar, interfirst molar and intersecond molar width and the length with significant incisors and premolars labial inclinations. In the mandibular arch there was a significant increase of intercanine, interfirst premolar, intersecond premolar, inferfirst molar and intersecond molar width with significant buccal inclination at posttreatment, exception of the canine and the first molar of the left side. There was no significant increase in the length of the mandibular arch. There was no statistically significant difference in upper airway sagittal area, minimum axial area and volume changes after treatment. **Conclusion:** It can be concluded that Damon System produced a significant transversal increase in the posterior region of the arches with differences in teeth buccolingual inclinations at posttreatment. There were no significant differences in the upper airways; however, there was a significant negative correlation between the changes of length of mandibular arch and the sagittal area and volume airway.

Key-words: Orthodontic Brackets. Cone-Beam Computed Tomography. Oropharynx.

RESUMO

Avaliação das vias aéreas superiores, dimensões dos arcos dentários e inclinações vestibulolinguais através de Tomografia Computadorizada Cone Beam em casos tratados com o Sistema Damon.

Objetivo: Avaliar as alterações do volume e da área das vias aéreas superiores, as dimensões transversais e o comprimento dos arcos dentários e as inclinações dentoalveolares em pacientes tratados ortodonticamente com o sistema Damon. **Material e métodos:** A amostra foi constituída de tomografias computadorizadas cone beam (TCCB) iniciais (T1) e finais (T2) de 21 pacientes com idade inicial média de 14,99 anos (DP 1,97), má oclusão de Classe I de Angle, apinhamento mínimo de 4mm (superior: -6,71mm (DP 2,99), inferior: -5,12mm (DP 2,03), dentadura completa até segundos molares, tratados ortodonticamente sem extrações com braquetes autoligáveis do sistema Damon. As tomografias computadorizadas foram importadas no formato DICOM para o programa Dolphin Imaging® para análise das varáveis. O volume, área e área axial mínima das vias aéreas superiores foram mesuradas nos cortes sagital e axial por meio da ferramenta *upper airways analysis* do software Dolphin Imaging®. Para mensuração das inclinações dentárias, foram utilizados cortes parassagitais gerados a partir da imagem panorâmica da TCFC. As medidas foram realizadas a partir do ângulo formado pela linha vestibular da coroa clínica (LVCC) e o bordo superior ou inferior da imagem selecionada. As dimensões transversais dos arcos foram mensuradas por meio de cortes axiais das reconstruções 3D. Para os premolares, foram utilizadas como referência as pontas de cúspide vestibular e para os molares as pontas de cúspide mesiovestibular. As variáveis foram submetidas ao teste de Shapiro-Wilk para testar sua distribuição. As alterações de todas as variáveis de T1 para T2 foram comparadas por meio dos testes t-pareado. A correlação entre as alterações das vias aéreas superiores com os possíveis fatores associados foi verificada pelo coeficiente de correlação de Pearson. **Resultados:** Houve um aumento significativo das distâncias transversais 4-4 / 5-5 / 6-6 / 7-7 e do comprimento do arco superior com inclinações vestibulares significativas dos incisivos e pré-molares. No arco inferior houve um aumento significativo das distâncias transversais 3-3 / 4-4 / 5-5 / 6-6 / 7-7 sem inclinação vestibular significativa apenas do canino e do primeiro molar do lado esquerdo. Não houve aumento significativo do comprimento do arco inferior. Não houve diferença estatisticamente significante da área, área axial mínima e volume das vias aéreas pós-tratamento. **Conclusão:** Pode-se concluir que o Sistema Damon produziu um aumento transversal significativo na região posterior dos arcos com diferenças nas inclinações dentárias. Não houve diferenças significativas nas vias aéreas superiores, entretanto, houve significante correlação negativa entre as alterações comprimento do arco inferior com a área e o volume das vias aéreas.

Palavras chave: Ortodontia. Aparelhos Ortodônticos. Tomografia Computadorizada de Feixe Cônico.

LIST OF ILLUSTRATIONS

ARTICLE 1

ARTICLE 2

LIST OF TABLES

ARTICLE 1

ARTCLE 2

LIST ABREVIATIONS AND ACRONYMS

T1: Timing 1.

T2: Timing 2.

T2-T1: Changes that occurred during treatment period.

RME: Rapid maxillary expansion.

CBCT: Cone-bean computed tomography.

SLB: Self-ligating brackets.

Ni-Ti: Nickel-titanium.

LIST OF SYMBOLS

3-3	Interfirst permanent canine distance at level buccal cusp tip.
4-4	Interfirst permanent premolar distance at level buccal cusp tip.
5-5	Intersecond permanent premolar distance at level buccal cusp tip.
6-6	Interfirst permanent molar distance at level mesiobuccal cusp tips.
7-7	Intersecond permanent molar distance at level mesiobuccal cusp tips.
Mx AL	Linear distance between a perpendicular line constructed from the mesial contact point of the maxillary central incisors to the point on a perpendicular line ligating the mesial points of the maxillary first molars.
Md AL	Linear distance between a perpendicular line constructed from the mesial contact point of the maxillary central incisors to the point on a perpendicular line ligating the mesial points of the maxillary first molars.
MxII	maxillary irregularity index.
MdII	mandibular irregularity index
i11	Buccolingual inclination of crown in the maxillary right permanent central incisor.
i12	Buccolingual inclination of crown in the maxillary right permanent lateral incisor.
i13	Buccolingual inclination of crown in the maxillary right permanent canine.
i14	Buccolingual inclination of crown in the maxillary right permanent first premolar.
i15	Buccolingual inclination of crown in the maxillary right permanent second premolar.
i16	Buccolingual inclination of crown in the maxillary right permanent first molar.
i17	Buccolingual inclination of crown in the maxillary right permanent second molar.
i21	Buccolingual inclination of crown in the maxillary left permanent central incisor.
i22	Buccolingual inclination of crown in the maxillary left permanent lateral incisor.
i23	Buccolingual inclination of crown in the maxillary left permanent canine.

i24 Buccolingual inclination of crown in the maxillary left permanent first premolar.

i25 Buccolingual inclination of crown in the maxillary left permanent second premolar.

i26 Buccolingual inclination of crown in the maxillary left permanent first molar.

i27 Buccolingual inclination of crown in the maxillary left permanent second molar.

i31 Buccolingual inclination of crown in the mandibular left permanent central incisor.

i32 Buccolingual inclination of crown in the mandibular left permanent lateral incisor.

i33 Buccolingual inclination of crown in the mandibular left permanent canine.

i34 Buccolingual inclination of crown in the mandibular left permanent first premolar.

i35 Buccolingual inclination of crown in the mandibular left permanent second premolar.

i36 Buccolingual inclination of crown in the mandibular left permanent first molar.

i37 Buccolingual inclination of crown in the mandibular left permanent second molar.

i41 Buccolingual inclination of crown in the mandibular right permanent central incisor.

i42 Buccolingual inclination of crown in the mandibular right permanent lateral incisor.

i43 Buccolingual inclination of crown in the mandibular right permanent canine.

i44 Buccolingual inclination of crown in the mandibular right permanent first premolar.

i45 Buccolingual inclination of crown in the mandibular right permanent second premolar.

i46 Buccolingual inclination of crown in the mandibular right permanent first molar.

i47 Buccolingual inclination of crown in the mandibular right permanent second molar.

TABLE OF CONTENTS

1 Introduction

1 INTRODUCTION

First self-ligating brackets emerged in the 1930s with the aim of reducing the time of insertion and removal of orthodontic wires responsible for tooth movement. Since an early stage in the development of self-ligating brackets, authors have proposed some advantages. They allow to perform teeth alignment and leveling more effectively, with a relatively reduced chair time and less need for dental extractions, in cases of significant crowding compared with conventional edgewise brackets(BIRNIE, 2008).

When there is a discrepancy between the teeth size and the arches perimeter, the presence of dental crowding is a clinical sign characteristic of this alteration. In these cases the treatment is based on the obtaining of spaces that can be generated by interproximal wear, increase of the arches width and extractions of dental groups. The treatment without dental extractions in cases of crowding result in arches expansion an increase of the interdental distances of the posterior and intercanine teeth, besides the increase of the arch length with the buccal inclination of the anterior teeth (WEINBERG; SADOWSKY, 1996; ISIK et al., 2005).

The Damon system gained popularity due to the creators statement that their low-friction ligating system, associated with orthodontic wires, which have a greater transverse dimension and high resilience, creates a system of light forces that allows the teeth to accommodate into the bone structures, promoting posterior expansion of the dental arch without incisors buccal inclination with no periodontal damage, claiming that alveolar bone would follow the tooth movement (DAMON, 1998a). The evidence for incisor proclination from a recent meta-analysis indicated that self-ligating brackets resulted in slightly less mandibular incisor proclination (1.5°) and a few studies have suggested greater increases in intermolar widths with self-ligating brackets (FLEMING et al., 2009; CHEN et al., 2010; PANDIS; POLYCHRONOPOULOU; ELIADES, 2010). However, others studies showed that Damon brackets produced significant labial inclination of the mandibular incisors similar to conventional brackets and other types of self-ligating brackets (PANDIS; POLYCHRONOPOULOU; ELIADES, 2007; PANDIS et al., 2010; VAJARIA et al., 2011).

Rapid Maxillary Expansion (RME) is a widely used treatment approach to increase the transverse dimension of the maxillary arch in adolescents and its effectiveness to treat obstructive apnea syndrome in children has been reported (VILLA et al., 2007; VILLA et al., 2011). One study demonstrated that RME in children with maxillary constriction and posterior crossbite changed the low tongue posture after intermolar distance expansion (OZBEK et al., 2009). Other study evaluated the tongue posture and pharyngeal enlargement as secondary effects of rapid maxillary expansion by cone-beam computed tomography. In patients that had low tongue's posture, the authors suggested there was improve in tongue position after RME. It were found reducing of intraoral airway volume after maxillary expansion, and this reduction probably occurred due the tongue's contact in the palate without a gap (IWASAKI et al., 2013). As the anterior oropharynx wall consists of very movable structures such as the tongue and the hyoid bone (TARKAR et al., 2016), there was a hypothesis that airway volume increases after maxillary expansion due to changes on tongue posture.

Maxillary expansion produced by the Damon system compared with the RME in the correction of the dental crowding was reported recently. The study concluded that the two treatment protocols produced a transversal increase of the maxillary arch with buccal dental inclination, with a higher premolars inclinations in patients treated with the Damon system (YU et al., 2008). The literature has reported that these effects are related to the shape of the orthodontic wires used by the Damon system for the alignment and leveling of the arches and not by the type of bracket used (ATIK et al., 2016).

Other studies have demonstrated the dental arch changes produced by the Damon system, but the heterogeneity of the methodologies make it difficult to visualize these changes. The reliability of superpositions in 2D cephalograms to determine the changes occurring by the treatment is uncertain. (BAUMRIND; MILLER; MOLTHEN, 1976) Cone-beam computed tomography (CTBC) presents a higher image quality and allows to evaluate the dimensional and morphological changes produced by the treatment in the three dimensions of the space, in addition to presenting a minimum dose of radiation when compared to medical computed tomography and magnetic resonance imaging (LUDLOW; IVANOVIC, 2008; CATTANEO et al., 2011).

Due to the similarity of the dentoalveolar alterations produced in the maxillary arch by RME and the Damon System, the aim of this study was to evaluate the transversal changes of dental arches, the dental movement pattern and its influence on the dimension of the arches and upper airway volume, sagittal area and minimum axial area using a CBCT in patients treated with Damon System.

2 ARTICLES

2 ARTICLES

The articles presented in this Thesis were written according to the American Journal of Orthodontics and Dentofacial Orthopedics instructions and guidelines for article submission (Annex C).

- **Article 1 -** Evaluation of upper airway and dental arches dimensions in cases treated with Damon System: A CBCT study.

- **Article 2 -** Evaluation of dimensional arch and buccolingual inclination changes with the Damon System through Cone-beam computed tomography.

ARTICLE 1

Evaluation of upper airway and dental arches dimensions in cases treated with Damon System: A CBCT study.

ABSTRACT

Introduction: The aim of this study was to evaluate and compare the volume, sagittal area and minimum axial area of the upper airway with transverse dimensions and dental problems in patients treated orthodontically with the Damon System. **Material and Methods:** The sample consisted of initial (T1) and final (T2) Cone-beam computed tomography (CBCT) images from 21 patients with a mean initial age of 14.99 ± 1.97 years, Class I Angle malocclusion, minimum crowding of 4mm (maxillary -6.71 ± 2.99 mm; mandibular -5.12 ± 2.03 mm), complete permanent dentition up to second molars, treated with no extractions with the Damon System. Volume, sagittal area and minimum axial area of the upper airway were measured through the software Dolphin Imaging®. Arches dimensions were measured by means of 2D and axial coronal sections in the 3D reconstructions. The reference points used were buccal and mesiobuccal cusp tips for the premolars and molars respectively. Variables were submitted to the Shapiro-Wilk test to analyze their distribution. Paired t-test was used to compare the changes of dental inclinations and dimensions of both arches. Correlation between airways dimensions were evaluated by Pearson correlation coefficient. **Results**: There was a significant increase in maxillary length and interfirst premolar, intersecond premolar, interfirst molar and intersecond molar widths. In the mandibular arch, occurred a significant increase of intercanine, interfirst premolar, intersecond premolar, interfirst molar and intersecond molar widths without significant increase in length. There was no statistically significant difference at posttreatment in sagittal area, minimum axial area and volume of upper airway. **Conclusion:** It can be concluded that the Damon system produces a significant transverse increase in the posterior region of both arches and no significant differences in dimensions and volume of the upper airway at posttreatment were found. There were a significant negative correlation between the mandibular arch length with the sagittal area and volume of the airway.

Key-words: Orthodontic Brackets. Cone-Beam Computed Tomography. Oropharynx

INTRODUCTION

Transverse maxillary deficiency is a malocclusion which most common manifestation is the posterior crossbite and is associated to functional problems.[1] This transverse maxillary modification can lead to respiratory impairment due to a retroposition of the tongue, resulting in a reduced oropharyngeal.

In the past, from an orthodontic perspective, dental arches shape affected the size, position and function of the tongue. Consequently, the tongue dysfunction is an essential etiological factor for the development of malocclusion.[2,3] However, the tongue only adapts to changes in the oral cavity for speech and swallowing.[4-6] Literature reports that patients with severe maxillary atresia, also have inadequate space to accommodate the tongue on the palate, causing an inadequate positioning of the tongue.[3,7]

Rapid maxillary expansion (RME) was considered the therapeutic modality for respiratory disorders.[8] Several studies have verified that RME promotes a significant increase of the upper airways although non-uniform in the width[9-12] and can be compared with orthognathic surgery effects.[13,14]

As the anterior wall of the oropharynx consists of very movable structures such as the tongue and the hyoid bone,[15] there was a hypothesis that airway volume increases after maxillary expansion secondary to the tongue´s repositioning to a more anteriorly place in the oral cavity,[16,17] One study demonstrated that RME in young patients with maxillary atresia associated with posterior crossbite and without signs of respiratory disorder resulted in a more elevated tongue position; the authors concluded that the position of the tongue can be altered when the transverse dimension in the posterior region of the arch is increased.[18]

Studies evaluated RME effects on the upper airways in lateral cephalogram,[19-22] rhinometry[23,24] and computed tomography.[25-27] Most of them focused on the airways anatomy, craniofacial growth and development, present limitations, because the use of lateral or frontal two-dimensional X-rays does not permit identification of the (three-dimensional) soft tissue contour, which prevent the volumetric assessment of the area under study.[18,28] The advances in cone-beam computed tomography (CBCT) and three-dimensional technology have allowed the execution of more reliable and precise linear and volumetric airways measurements.[29,30]

The Damon System gain popularity in the world of orthodontics to claim it is possible to achieve large gains in arch perimeter and transverse dimension within the use of an appliance that promotes rapid maxillary expansion. It is suggested that a passive self-ligating appliance associated with new generation nickel-titanium wires promote slight forces capable of promoting dentoalveolar expansion, reducing the need for rapid maxillary expansion.[31,32] The arch length gain is achieved by bodily movement of the teeth or at least with ‘‘minimal’’ tipping combined with alveolar bone and surrounding tissues reshaping with a Fränkel-like effect.[32]

The self-ligating brackets (SLB), those that don’t need the use of ligatures to join them to the orthodontic archwire, are being more and more used in orthodontic offices. It has been said that this kind of appliance has several advantages when comparing to the conventional ones, such as: complete socket of archwire in the slot of the bracket, improving the rotation control;[33] low friction between the bracket and archwire,[31,33-38] means a shorter treatment time;[33,38] shorter chair time;[31,35,39,40] less frequent appointments;[31,33] more comfort for the patient[33] and lesser plaque accumulation.[38,41]

Since then, some studies have evaluated the Damon system effects on the transverse dimensions of the arches. Vajaria et al.[42] evaluated the transverse dimension changes in dental arches in patients treated with the Damon system and a conventional ligated edgewise bracket system by using scanned dental casts and concluded that the change in the maxillary intermolar width in the Damon group (2.8 mm) was significantly greater than in the conventionally ligated group (0.6 mm). Atik et al.[43] compared transverse dimensional changes in patients with dentally constricted maxillary arch treated with Damon system and a quad-helix appliance followed with conventional appliances and concluded that both treatment protocol produced similar transverse dimension changes in maxillary arch.

The purpose of this study was to analyze and compare volume, sagittal area and minimum axial area of the upper airway and dental arches changes after orthodontic treatment with the Damon system using CBCT scans due to lack of scientific evidences in the literature.

MATERIALS AND METHODS

This study was approved by the Ethics in Research Committee of **Bauru Dental School, University of São Paulo, Brazil**. (1.567.403). Consent to undergo the CBCT radiographic examinations and to use the material for the present investigation was obtained from all patients. CBCT-scans were taken following the protocol approved by the **Radiological Department, Bauru Dental School, University of São Paulo.**

Material

It was used an alpha error of 5% and beta error of 20%, considering a standard deviation of 147.73 mm^2 to detect a minimum difference of 95mm^2 for the sagittal area and a real difference of 3800 mm^3 in volume with standard deviation of 5971 mm^3. Results indicated that a minimum of 21 patients were necessary.[44] According to this results, 21 patients were selected.

A restrospective study analysis of 21 patients with a mean age of 14.99 ±1.27 years, who underwent orthodontic treatment in conformity with the guidelines for Damon 3 MX brackets system (Ormco Corporation, Orange, CA, USA) at **the Department of Orthodontics in the Bauru Dental School, University of São Paulo, Brazil** was performed due to functional and esthetic complaints.

The main selection criterion was patients with Class I malocclusion with a minimum of 4mm crowding treated non-extraction. Additional criteria were (1) no previous orthodontic treatment, (2) presence of all permanent teeth until second molars with non-anomalies of number and shape, (3) absence of facial deformities due to oropharyngeal pathologies, genetic syndromes or congenital deformities and (4) sequence of CBCT scans acquired at two stages: pretreatment (T1) and posttreatment (T2).

The treatment was performed using a passive self-ligating brackets Damon 3MX appliance system with 0.022-in slot and standard prescription (Ormco/A Company, San Diego, Calif) with a predetermined Damon archwire sequence. The typical wire sequence followed included an initial 0.014-in Damon Copper Ni-Ti® (left in place an average of 12 weeks) followed by a 0.014 × 0.025-in Damon Copper Ni-Ti® (12–18 weeks) until observe an alignment that would allow the complete insertion of the following archwire in the slot of the bracket and the closing of its lid. The finishing archwire was a 0.019 × 0.025-in stainless steel, which were coordinated based on Damon arch form obtained after the insertion of the 0.014 × 0.025-in

Copper Ni-Ti® Damon archwire. No other appliances, such as headgear, Herbst, lip bumper, or distalizing appliances, were used. The appliances were removed, and posttreatment records were taken when a Class I canine-molar relationship with a satisfactory overjet and overbite, were achieved.

Methods

CBCT scans were taken at beginning (T1) and after (T2) treatment onset when all patients had complete the orthodontic treatment. CBCT images were taken with the i-CAT Classic tomography (Imaging Sciences International, Hatfield, Pa) and the subjects were positioned with the Frankfort horizontal plane parallel to the floor and instructed to maintain maximum intercuspidation with the tongue touching the palate and to avoid swallowing during the scanning period. The imaging protocol used were 120 kV, 5 mA, 13 x 16 cm field of view, 0.25- mm voxel size, and a scanning time of 40 seconds. Some CBCT final images were taken with a 3D Accuitomo-XYZ Slice View Tomography® (J. Morita, Kyoto, Japan) with a 0.33 mm voxel size, voltage of 90 kV, 7 mA, and a 30 seconds scanning time, with the patient following the same positioning protocol.

Images were saved in DICOM files, and these files were imported into Dolphin Imaging Software (version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, Calif) to obtain the primary reconstructed images (sagittal, coronal, and axial) and 3D reconstructions.

Before image selection for measurement, the head should be standardized in all the three planes. Head position standardization was performed in 3D images: in frontal view the infraorbital plane (plane formed by the points located in the infraorbital foramen) parallel to the floor, in axial view the midsagittal line (center point in magnum foramen to a point located on the galli crest) was perpendicular to the floor and in sagittal view the Frankfurt plane (porion to orbital) was parallel to the floor. Head orientation was the same for each CBCT image performed by the same operator (Fig. 1).

All measurements were performed using the tools provided by Dolphin Imaging Software. Only one calibrator visually evaluated all sectional images in a dark room, using a 24.1-in LCD monitor with resolution of 1920 x 1200 pixels.

Upper airways measurements

The area of interest for the upper airway evaluation was the oropharyngeal region. The limits of the upper airway space were 2 lines: the upper line was established by a point at the posterior edge of the nasal spine (PNS) and midpoint of the curvature between upper and lower surfaces of the basilar portion of the occipital bone (Ba). The lower line was established by a point from the lower portion of the upper margin of the third cervical vertebra (VC3i) to a point on the anterior wall of the oropharynx, parallel to the floor (Or) (Fig. 2)

Once the portion of the airway of interest was defined, the Dolphin 3D airway analysis tool were used to define and measure the three parameters of the upper airways. This program allowed the selection of the airway by defining a threshold range of computed tomography units that characterized the air spaces sectioned. In this study, was arbitrarily standardized the threshold range to 30 units (0-200 units were available) after observing consecutively that this number provide the most comprehensive airway selection without adding or leaving out upper airway space.

Due to four patients had taken CBCT final images with a 3D Accuitomo-XYZ Slice View Tomography®, the threshold range was increase to 70 units. Because the air space has a lower computed tomography value than the more dense surrounding soft tissue, it was possible to delimit the same region to carry out the measures. After this, using the sinus/airway analysis option, points were demarcated in the selected region and updated the volume option and the software shows airway volume, airway area and minimum axial area (Fig. 3).

Dental arches dimensions measurements

Transversal and anteroposterior arch dimensions were measured in the maxillary and mandibular dental arches in pretreatment and posttreatment in CBCT scans. Intercanine (3-3), interfirst premolar (4-4), intersecond premolar (5-5), interfirst molar (6-6) and intersecond molar (7-7) widths were measured in the coronal view from 2D images. The coronal image selected from the maxillary and mandibular arches were obtained from the complete visualization of teeth. In order to measure the transverse distances, buccal cusp tips were selected for canines and first and second premolars, while mesiobuccal cusp tips were selected for first and second molars of both arches. The arch length (AL) were measured by a perpendicular line constructed from the mesial contact point of the central incisors (calculated as the midpoint between the mesial points of the central incisors) to the point on a perpendicular line ligating the mesial points of the first molars in both sides (Fig. 4). Crowding was measured by the Little's Irregularity Index[45] (Table II) only in the initial digital models, aiming to assess a means of crowding in maxillary and mandibular arch.

Error study

Fifteen CBCT scans were randomly selected and remeasured by the same examiner (BSV) at two times after a 30-day interval. The random error was calculated according to Dahlberg's formula, $S^2 = \Sigma d^2/2n$, where S^2 is the error variance and "d" is the difference between two determinations of the same variable. The systematic error was estimated by paired t-tests, for $P<.05$.[46,47]

Statistical Analyses

Shapiro-Wilk test was performed to test the hypothesis of variables normal distribution.

A descriptive analysis was performed for all variables on the pretreatment (T1) and posttreatment (T2) and the changes that occurred during this period (T2-T1).

Pre and posttreatment data comparisons of arches dimensions, upper airway dimensions and volume were performed by paired t-test.

The correlation between the changes of upper airway sagittal area, minimum axial area and volume with arches dimension changes were evaluated by Pearson correlation coefficient.

All statistical analyses were performed with Statistica software (Statistica for Windows – Release 7.0 - Copyright Statsoft, Inc. Tulsa, OKla). Results were considered statistically significant at $P<0.05$.

RESULTS

Normal distribution of the variables was evaluated with Shapiro-Wilk tests, because all variables showed normal distribution, parametric tests were used.

The random and systematic error of upper airway volume were statistically significant, however the difference of 77.38 mm^3 was within acceptable limits[48] (Table I).

Table II shows patient`s demographic distribution. It was evaluated at the following aspects: initial and final age, time treatment and Little irregularity index.

There was a significant transverse increase in maxillary and mandibular arch at the end of treatment with the Damon System (Table III), except by the maxillary canines. Maxillary arch length showed a statistically significant increase whereas the mandibular arch length did not show a significant increase.

Table IV showed no statistically significant difference in sagittal area, minimum axial area and volume of the upper airway after treatment with the Damon system.

The amount of change occurred in the sagittal area, minimum axial area and volume with the changes of dental arches, it is presented in Tables V, VI and VII.

A significant negative correlation were found in the mandibular arch length changes with the volume and sagittal area changes of the airways (Table V). The table VI show there was no statistically significant correlation between the arches dimension changes with the minimum axial area changes.

There was a statistically significant negative correlation between the mandibular arch length changes with the airway volume changes (Table VII).

DISCUSSION

Only one previously calibrated examiner made the measurements of this study. The error study used to assess intra examiner reliability proved to be small. The significant differences were found in upper airway volume measurements. An upper airway with mean of volume only 10.000 mm^3 with a standard deviation of 5.000 mm^3, the mean difference of 77.38 mm^3 between the first and second measurement is staticsally significant but acceptable. Similar errors were found in other study and the method error were considerable negligible.[48]

CBCT benefits in the diagnosis and treatment plan in different dental specialties has been widely reported in the literature.[49,50] Upper airway assessment was highlighted due to the great advantages of 3D images. The CBCT analysis scans are considered reliable in defining the border between soft tissues and air spaces thus providing important information about the cross-sectional area and volume of the pharyngeal airway.[51,52] Besides, the CBCT system was developed for the analysis of the craniofacial complex with the advantage of reducing the radiation dose and generating images with high quality when compared to multislices tomography scans.[53-55] However, when compared with resonance magnetic images, CBCT scans has its limitation as difficulty in distinguishing between different types of soft tissues, bordering the upper airway, muscles, fat, and connective tissue.[51]

Another limitation in evaluating the upper airways is the difficulty in performing a patient standardization and a protocol for the acquisition of the tomographic examination. Patient head orientation varies from lying down, to sitting, to standing depending on the CBCT scanner used and the different positions of head producing changes of upper airway dimension and volume.[56] These changes were attributed to gravity acting on the relaxed soft palate, tongue and hyoid bone positions.[57] Natural head position at cone-beam computed tomography acquisition is the suggested standardized posture.[58] However, for repeatable measures of upper airway volumes it may be clinically difficult to obtain.[59] In this study, all patients underwent CBCT scans at the same place and followed the same protocol and standardization of CBCT imaging in T1 and T2, minimizing the possibility of alterations due to patient positioning.

For the airways measurement, it was used the Dolphin Imaging® which is a program that has already been described in the literature as a software that allows this evaluation in a simple, practical way and with a minimum of errors,[30,60] ensuring the reliability of the results obtained in this work. The threshold used in our study was 30, before and after orthodontic treatment with Damon System to compare changes of the upper airways, except of four patients that had their exams in other CBCT machine. However, according to Feng et al.[27] variations of threshold do not produce significant difference among the measurements.

Patient age is another factor that can influence the upper airway measurements. The craniofacial development obtained by growth can cause a dimension increase of the oropharyngeal airspace. The literature shows the oropharyngeal airspace can suffer changes from growth until the age of 13 years.[61] A quiescence period for pharyngeal structures has been reported in adolescents with 14 from 18 years age.[62] Consequently, results found in this study do not carry the risk of presenting bias, since the mean age of the patients was of 14.99 ±1.27 years.

Studies showed that there is great variability in determining the boundaries of the air spaces evaluated in the different papers. International consensus on the region limits does not currently exist, particularly of the landmarks or planes used to demarcate the junction of the nasal cavity, nasopharynx and between regions of the pharynx. The present study evaluated only the alterations in the oropharyngeal region, due to the difficulty of evaluating the nasopharyngeal. One study compared the reliability and accuracy of airway measurement in three dimensions of three different software programs. The authors observed a precision discrepancy in the volume quantification between the different evaluated software. According to the authors, the greatest divergences occurred during the nasopharyngeal evaluation, due to the presence of several anatomical structures such as turbinates and nasal septum.[63]

The malocclusion type do not influence pharyngeal airway width.[64-66] However, literature shows that patients who presents in maxillary constriction tend to have a higher nasal airway resistance[67] and reported that in this cases a RME can be the treatment for respiratory disturbs.[9-12,21] Several authors[12,53] have reported a significant enlargement of the nasal cavity and nasopharynx, but no significant increase in the other investigated airway compartments, such as the oropharynx and hypopharynx, suggesting that effects on the upper airway were local as a result of soft tissue adaptation farther from the midpalatal suture.[44] However, studies have reported that the increase in nasal air space promoted by RME resulted in changes in the respiratory pattern from mouth to a nasal due to improved airflow.[68] In addition, previous studies have shown that the transverse increase of the maxillary arch in patients treated with RME produced a change in tongue posture, especially when the intermolar width was increased.[18] In the present study patients presented severe initial crowding in the maxillary arch (11.39 ± 5.11 mm) and in the mandibular arch (8.36 ± 3.56mm) and were treated orthodontically with the Damon system with non-extraction. The results showed that there was a significant increase in 4-4 / 5-5 / 6-6 / 7-7 width. However, there were no significant changes in the volume and dimensions of the oropharynx with increased transverse distances of the maxillary arch. Since the tongue and soft tissues position of the pharynx are important factors that may affect the shape and volume of the airways, it was speculated that the transverse enlargement of the arch could alter the dimensions and volume of the oropharynx. Iwasaki et al.[48] performed a study that assessed the secondary effects of RME by CBCT scans and concluded that there was an improvement in tongue posture after treatment in patients with nasal obstruction who had low tongue posture. However, there was no significant association with increased pharyngeal airway volume. A similar finding was found in the study by Chang et al.[44] who evaluated the transverse changes produced in the maxillary arch in patients treated with RME using computed tomography and found a mean increase of 4.8 mm in interpremolars and intermolars width although not found significant differences in the total airway volume. Other study investigated the upper airway changes after rapid maxillary expansion utilizing CBCT in 16 children (10 male, 6 female) with a mean age of 12.73 ± 1.73 years. There was no significant changes in the nasopharyngeal airway while the oropharyngeal airway decreased a little.[69] One of the reasons the authors attributed these results was the average expansion amount about 4.4 ±1.3 mm, which may be not large enough to expand the pharyngeal airway. Similar result was found in this study, which obtained a mean expansion amount of 4.40 ± 1.55 mm in the maxillary first premolars width. Despite the results found in this study, there was a significant negative correlation between the changes of the upper airway area (r = -0.691 p = 0.002) and volume (r = -0.707 p = 0.001) with the mandibular arch length. According to Gurani et al.[59] there is a lack of data in the literature demonstrating the effects of tongue posture on upper airway morphology and dimensions.

The increase in the arch transverse dimensions produced by the Damon system and its comparisons with the conventional brackets system and expansion devices have already been reported in the literature.[42,43,70-72]. A strong factor for the determination of the dental arch shape was the archwire used. It is explained by the fact that archwires conformed with larger diagrams causes major arch expansion, regardless the type of bracket used.[25,73,74] An interesting finding in this study were the results found in the maxillary arch. There was a significant increase in all dimensions of the arch except for the intercanine width. There was no significant difference in the transverse dimension in this region. This result is controversial with findings in the literature that show an increase in intercanine width with crowding correction. It has been demonstrated that the arch space gain in the anterior region in crowding cases is generally associated with the incisors buccal inclination and the increase of the intercanine width.[42,71,75,76] Possibly the reason could be the maxillary canine position in cases with significant absence of space in the arch. The mean crowding presented by the patients in the maxillary arch was 11.29 ± 5.11 mm and most of the patients presented maxillary ectopic canines with buccal inclination. Thus, when performing alignment and leveling with the expanded arches of the Damon system there were no significant changes in the intercanine width at posttreatment.

In the mandibular arch, there was a significant transverse dimensions increase without significant length increase. The expansion of the entire dental arch provided space for the alignment of crowded teeth without causing marked incisors buccal inclination, promoting a non-significant increase in arch length. This result in the mandibular arch corroborates Damon's[31] assertions that the use of a low friction bracket system allows a greater distal sliding of the wire avoiding excessive teeth inclination and obtaining space through the transverse increase of the arches. There was a greater expansion in the mandibular molars region when compared to the maxillary arch. As the mandibular molars erupt with a lingual crown inclination that remains after growth, forming the Wilson curve[77], thus greater buccal crown movement is expected after treatment with the Damon System.

Limitations

Ideally, all initial and final CBCT scans should have been performed following the same protocol using the same device. However, it was not possible due to the temporary unavailability of one device (i-Cat) during final CBCT scans period. Thus, in order to avoid a reduction in the number of patients and make it unworkable, they were kept in research, since during the initial tests was observed a homogeneity in the image quality of both i-Cat, voxel size 0.25mm and Accuitomo, voxel size 0.33mm devices.

The data from this study should be interpreted with caution, since the research evidence for one CBCT machine may not apply to other equipment.

CONCLUSION

The null hypothesis was accepted. There was no significant difference in the dimensions and volume of the upper airway in patients treated with the Damon System.

The Damon System produced a significant increase in the transverse dimensions in posterior region of the arches.

REFERENCES

1. Gohl E, Nguyen M, Enciso R. Three-dimensional computed tomography comparison of the maxillary palatal vault between patients with rapid palatal expansion and orthodontically treated controls. Am J Orthod Dentofacial Orthop 2010;138:477-485.

2. Melsen B, Attina L, Santuari M, Attina A. Relationships between swallowing pattern, mode of respiration, and development of malocclusion. Angle Orthod 1987;57:113-120.

3. Ohkiba T, Hanada K. Adaptive functional changes in the swallowing pattern of the tongue following expansion of the maxillary dental arch in subjects with and without cleft palate. Cleft Palate J 1989;26:21-30.

4. Cleall JF. Deglutition: A Study of Form and Function. Am J Orthod 1965;51:566-594.

5. Hanson ML, Cohen MS. Effects of form and function on swallowing and the developing dentition. Am J Orthod 1973;64:63-82.

6. Cheng CF, Peng CL, Chiou HY, Tsai CY. Dentofacial morphology and tongue function during swallowing. Am J Orthod Dentofacial Orthop 2002;122:491-499.

7. Ichida T, Takiguchi R, Yamada K. Relationship between the lingual-palatal contact duration associated with swallowing and maxillofacial morphology with the use of electropalatography. Am J Orthod Dentofacial Orthop 1999;116:146-151.

8. Angell E. Treatment of irregularity of the permanent or adult teeth. Dental Cosmos 1860;1:540-544.

9. Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2010;137:S71-78.

10. Ribeiro AN, de Paiva JB, Rino-Neto J, Illipronti-Filho E, Trivino T, Fantini SM. Upper airway expansion after rapid maxillary expansion evaluated with cone beam computed tomography. Angle Orthod 2012;82:458-463.

11. Pangrazio-Kulbersh V, Wine P, Haughey M, Pajtas B, Kaczynski R. Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders. Angle Orthod 2012;82:448-457.

12. Smith T, Ghoneima A, Stewart K, Liu S, Eckert G, Halum S et al. Three-dimensional computed tomography analysis of airway volume changes after rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2012;141:618-626.

13. Babacan H, Sokucu O, Doruk C, Ay S. Rapid maxillary expansion and surgically assisted rapid maxillary expansion effects on nasal volume. Angle Orthod 2006;76:66-71.

14. Kurt G, Altug-Atac AT, Atac MS, Karasu HA. Changes in nasopharyngeal airway following orthopedic and surgically assisted rapid maxillary expansion. J Craniofac Surg 2010;21:312-317.

15. Tarkar JS, Parashar S, Gupta G, Bhardwaj P, Maurya RK, Singh A et al. An Evaluation of Upper and Lower Pharyngeal Airway Width, Tongue Posture and Hyoid Bone Position in Subjects with Different Growth Patterns. J Clin Diagn Res 2016;10:Zc79-83.

16. Schmidt-Nowara W, Lowe A, Wiegand L, Cartwright R, Perez-Guerra F, Menn S. Oral appliances for the treatment of snoring and obstructive sleep apnea: a review. Sleep 1995;18:501-510.

17. Timms DJ. A study of basal movement with rapid maxillary expansion. Am J Orthod 1980;77:500-507.

18. Ozbek MM, Memikoglu UT, Altug-Atac AT, Lowe AA. Stability of maxillary expansion and tongue posture. Angle Orthod 2009;79:214-220.

19. Basciftci FA, Mutlu N, Karaman AI, Malkoc S, Kucukkolbasi H. Does the timing and method of rapid maxillary expansion have an effect on the changes in nasal dimensions? Angle Orthod 2002;72:118-123.

20. Chung CH, Font B. Skeletal and dental changes in the sagittal, vertical, and transverse dimensions after rapid palatal expansion. Am J Orthod Dentofacial Orthop 2004;126:569-575.

21. Buccheri A, Dilella G, Stella R. Rapid palatal expansion and pharyngeal space. Cephalometric evaluation. Progress in orthodontics 2003;5:160-171.

22. Kurt G, Altug-Ataç AT, Atac MS, Karasu HA. Changes in nasopharyngeal airway following orthopedic and surgically assisted rapid maxillary expansion. Journal of Craniofacial Surgery 2010;21:312-317.

23. Babacan H, Sokucu O, Doruk C, Ay S. Rapid maxillary expansion and surgically assisted rapid maxillary expansion effects on nasal volume. Angle Orthod 2006;76:66-71.

24. Gordon JM, Rosenblatt M, Witmans M, Carey JP, Heo G, Major PW et al. Rapid palatal expansion effects on nasal airway dimensions as measured by acoustic rhinometry. A systematic review. Angle Orthod 2009;79:1000-1007.

25. Cattaneo PM, Treccani M, Carlsson K, Thorgeirsson T, Myrda A, Cevidanes LH et al. Transversal maxillary dento-alveolar changes in patients treated with active and passive self-ligating brackets: a randomized clinical trial using CBCT-scans and digital models. Orthod Craniofac Res 2011;14:222-233.

26. Baka ZM, Akin M, Ucar FI, Ileri Z. Cone-beam computed tomography evaluation of dentoskeletal changes after asymmetric rapid maxillary expansion. Am J Orthod Dentofacial Orthop 2015;147:61-71.

27. Feng X, Li G, Qu Z, Liu L, Nasstrom K, Shi XQ. Comparative analysis of upper airway volume with lateral cephalograms and cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2015;147:197-204.

28. Cakirer B, Kucukkeles N, Nevzatoglu S, Koldas T. Sagittal airway changes: rapid palatal expansion versus Le Fort I osteotomy during maxillary protraction. Eur J Orthod 2012;34:381-389.

29. Ghoneima A, Kula K. Accuracy and reliability of cone-beam computed tomography for airway volume analysis. Eur J Orthod 2013;35:256-261.

30. Mattos CT, Cruz CV, da Matta TC, Pereira Lde A, Solon-de-Mello Pde A, Ruellas AC et al. Reliability of upper airway linear, area, and volumetric measurements in cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2014;145:188-197.

31. Damon DH. The Damon low-friction bracket: a biologically compatible straight-wire system. J Clin Orthod 1998;32:670-680.

32. Damon DH. Treatment of the face with biocompatible orthodontics. In: Graber TM, Vanarsdall RI, Vig KWI, editors. Orthodontics Current Principles and Techniques. Mosby: Elsevier; 2005. p. 753-831.

33. Harradine N. Self-ligating brackets: where are we now? J Orthod 2003;30:262-273.

34. Kim TK, Kim KD, Baek SH. Comparison of frictional forces during the initial leveling stage in various combinations of self-ligating brackets and archwires with a custom-designed typodont system. Am J Orthod Dentofacial Orthop 2008;133:187 e115-124.

35. Shivapuja PK, Berger J. A comparative study of conventional ligation and self-ligation bracket systems. Am J Orthod Dentofacial Orthop 1994;106:472-480.

36. Sims A, Waters N, Birnie D, Pethybridge R. A comparison of the forces required to produce tooth movement in vitro using two self-ligating brackets and a pre-adjusted bracket employing two types of ligation. Eur J Orthod 1993;15:377-385.

37. Thorstenson GA, Kusy RP. Resistance to sliding of self-ligating brackets versus conventional stainless steel twin brackets with second-order angulation in the dry and wet (saliva) states. Am J Orthod Dentofacial Orthop 2001;120:361-370.

38. Voudouris JC. Seven clinical principles of interactive twin mechanisms. J Clin Orthod 1997;31:55.

39. Harradine NW. Self-ligating brackets and treatment efficiency. Clin Orthod Res 2001;4:220-227.

40. Berger JL. The SPEED appliance: a 14-year update on this unique self-ligating orthodontic mechanism. Am J Orthod Dentofacial Orthop 1994;105:217-223.

41. Pellegrini P, Sauerwein R, Finlayson T, McLeod J, Covell DA, Jr., Maier T et al. Plaque retention by self-ligating vs elastomeric orthodontic brackets: quantitative comparison of oral bacteria and detection with adenosine triphosphate-driven bioluminescence. Am J Orthod Dentofacial Orthop 2009;135:426 e421-429; discussion 426-427.

42. Vajaria R, BeGole E, Kusnoto B, Galang MT, Obrez A. Evaluation of incisor position and dental transverse dimensional changes using the Damon system. Angle Orthod 2011;81:647-652.

43. Atik E, Ciger S. An assessment of conventional and self-ligating brackets in Class I maxillary constriction patients. Angle Orthod 2014;84:615-622.

44. Chang Y, Koenig LJ, Pruszynski JE, Bradley TG, Bosio JA, Liu D. Dimensional changes of upper airway after rapid maxillary expansion: a prospective cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2013;143:462-470.

45. Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975;68:554-563.

46. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-390.

47. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience; 1940.

48. Iwasaki T, Saitoh I, Takemoto Y, Inada E, Kakuno E, Kanomi R et al. Tongue posture improvement and pharyngeal airway enlargement as secondary effects of rapid maxillary expansion: a cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2013;143:235-245.

49. De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg 2009;38:609-625.

50. Lagravere MO, Gordon JM, Guedes IH, Flores-Mir C, Carey JP, Heo G et al. Reliability of traditional cephalometric landmarks as seen in three-dimensional analysis in maxillary expansion treatments. Angle Orthod 2009;79:1047-1056.

51. Lenza MG, Lenza MM, Dalstra M, Melsen B, Cattaneo PM. An analysis of different approaches to the assessment of upper airway morphology: a CBCT study. Orthod Craniofac Res 2010;13:96-105.

52. Aboudara C, Nielsen I, Huang JC, Maki K, Miller AJ, Hatcher D. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2009;135:468-479.

53. El H, Palomo JM. Three-dimensional evaluation of upper airway following rapid maxillary expansion: a CBCT study. Angle Orthod 2014;84:265-273.

54. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol 1998;8:1558-1564.

55. Honey OB, Scarfe WC, Hilgers MJ, Klueber K, Silveira AM, Haskell BS et al. Accuracy of cone-beam computed tomography imaging of the temporomandibular joint: comparisons with panoramic radiology and linear tomography. Am J Orthod Dentofacial Orthop 2007;132:429-438.

56. Alsufyani NA, Dietrich NH, Lagravere MO, Carey JP, Major PW. Cone beam computed tomography registration for 3-D airway analysis based on anatomic landmarks. Oral Surg Oral Med Oral Pathol Oral Radiol 2014;118:371-383.

57. Hilgers ML, Scarfe WC, Scheetz JP, Farman AG. Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. Am J Orthod Dentofacial Orthop 2005;128:803-811.

58. Cevidanes LH, Styner MA, Proffit WR. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. Am J Orthod Dentofacial Orthop 2006;129:611-618.

59. Gurani SF, Di Carlo G, Cattaneo PM, Thorn JJ, Pinholt EM. Effect of Head and Tongue Posture on the Pharyngeal Airway Dimensions and Morphology in Three-Dimensional Imaging: a Systematic Review. J Oral Maxillofac Res 2016;7:e1.

60. Alves M, Jr., Baratieri C, Mattos CT, Brunetto D, Fontes Rda C, Santos JR et al. Is the airway volume being correctly analyzed? Am J Orthod Dentofacial Orthop 2012;141:657-661.

61. Jeans WD, Fernando DC, Maw AR, Leighton BC. A longitudinal study of the growth of the nasopharynx and its contents in normal children. Br J Radiol 1981;54:117-121.

62. Taylor M, Hans MG, Strohl KP, Nelson S, Broadbent BH. Soft tissue growth of the oropharynx. Angle Orthod 1996;66:393-400.

63. Abi-Ramia LBP, Carvalho FAR, Coscarelli CT, Almeida MAdO. Aparelho de avanço mandibular aumenta o volume da via aérea superior de pacientes com apneia do sono. Dental Press J Orthod 2010;15:166-171.

64. Watson RM, Jr., Warren DW, Fischer ND. Nasal resistance, skeletal classification, and mouth breathing in orthodontic patients. Am J Orthod 1968;54:367-379.

65. de Freitas MR, Alcazar NM, Janson G, de Freitas KM, Henriques JF. Upper and lower pharyngeal airways in subjects with Class I and Class II malocclusions and different growth patterns. Am J Orthod Dentofacial Orthop 2006;130:742-745.

66. Alves PV, Zhao L, O'Gara M, Patel PK, Bolognese AM. Three-dimensional cephalometric study of upper airway space in skeletal class II and III healthy patients. J Craniofac Surg 2008;19:1497-1507.

67. Cistulli PA, Sullivan CE. Influence of maxillary morphology on nasal airway resistance in Marfan's syndrome. Acta Otolaryngol 2000;120:410-413.

68. Gray LP. Results of 310 cases of rapid maxillary expansion selected for medical reasons. J Laryngol Otol 1975;89:601-614.

69. Zeng J, Gao X. A prospective CBCT study of upper airway changes after rapid maxillary expansion. Int J Pediatr Otorhinolaryngol 2013;77:1805-1810.

70. Pandis N, Polychronopoulou A, Eliades T. Self-ligating vs conventional brackets in the treatment of mandibular crowding: a prospective clinical trial of treatment duration and dental effects. Am J Orthod Dentofacial Orthop 2007;132:208-215.

71. Pandis N, Polychronopoulou A, Katsaros C, Eliades T. Comparative assessment of conventional and self-ligating appliances on the effect of mandibular intermolar distance in adolescent nonextraction patients: a single-center randomized controlled trial. Am J Orthod Dentofacial Orthop 2011;140:99-105.

72. Yu YL, Tang GH, Gong FF, Chen LL, Qian YF. [A comparison of rapid palatal expansion and Damon appliance on non-extraction correction of dental crowding]. Shanghai Kou Qiang Yi Xue 2008;17:237-242.

73. Fleming P, Dibiase A, Sarri G, Lee R. Pain experience during initial alignment with a self-ligating and a conventional fixed orthodontic appliance system: a randomized controlled clinical trial. Angle Orthod 2009;79:46-50.

74. Atik E, Akarsu-Guven B, Kocadereli I, Ciger S. Evaluation of maxillary arch dimensional and inclination changes with self-ligating and conventional brackets using broad archwires. Am J Orthod Dentofacial Orthop 2016;149:830-837.

75. Pandis N, Polychronopoulou A, Makou M, Eliades T. Mandibular dental arch changes associated with treatment of crowding using self-ligating and conventional brackets. Eur J Orthod 2010;32:248-253.

76. Tecco S, Tete S, Perillo L, Chimenti C, Festa F. Maxillary arch width changes during orthodontic treatment with fixed self-ligating and traditional straight-wire appliances. World J Orthod 2009;10:290-294.

77. Marshall S, Dawson D, Southard KA, Lee AN, Casko JS, Southard TE. Transverse molar movements during growth. Am J Orthod Dentofacial Orthop 2003;124:615-624.

FIGURE LEGENDS

Fig.1. Three-dimensional image of the head in front (**A**), sagittal (**B**) and top (facing down) (**C**) of view after standardization by mid-sagittal, axial and coronal reference planes. Dolphin Imaging® 11.9, orientation tool.

Fig.2. Airway area, minimum axial area and volume measurements. Landmarks for the upper airway space delimitation (**A**): Ba, Basion - Midpoint of the curvature between upper and lower surfaces of the basilar portion of the occipital bone; PNS, posterior nasal spine; VC3i, point on the lower portion of the upper margin of the third cervical vertebrae; Or, point on the anterior wall of the oropharynx parallel to the floor. Volume of upper airway in axial view (**B**).

Fig.3. Upper airway sagittal area and minimum axial area measurement (**A**). Smallest cross-sectional area marked on volumetric reproduction (**B**).

Fig.4. Arch length measurement in axial plane of 3D reconstruction (**A**) and transverse measurement in coronal plane of 2D image (**B**).

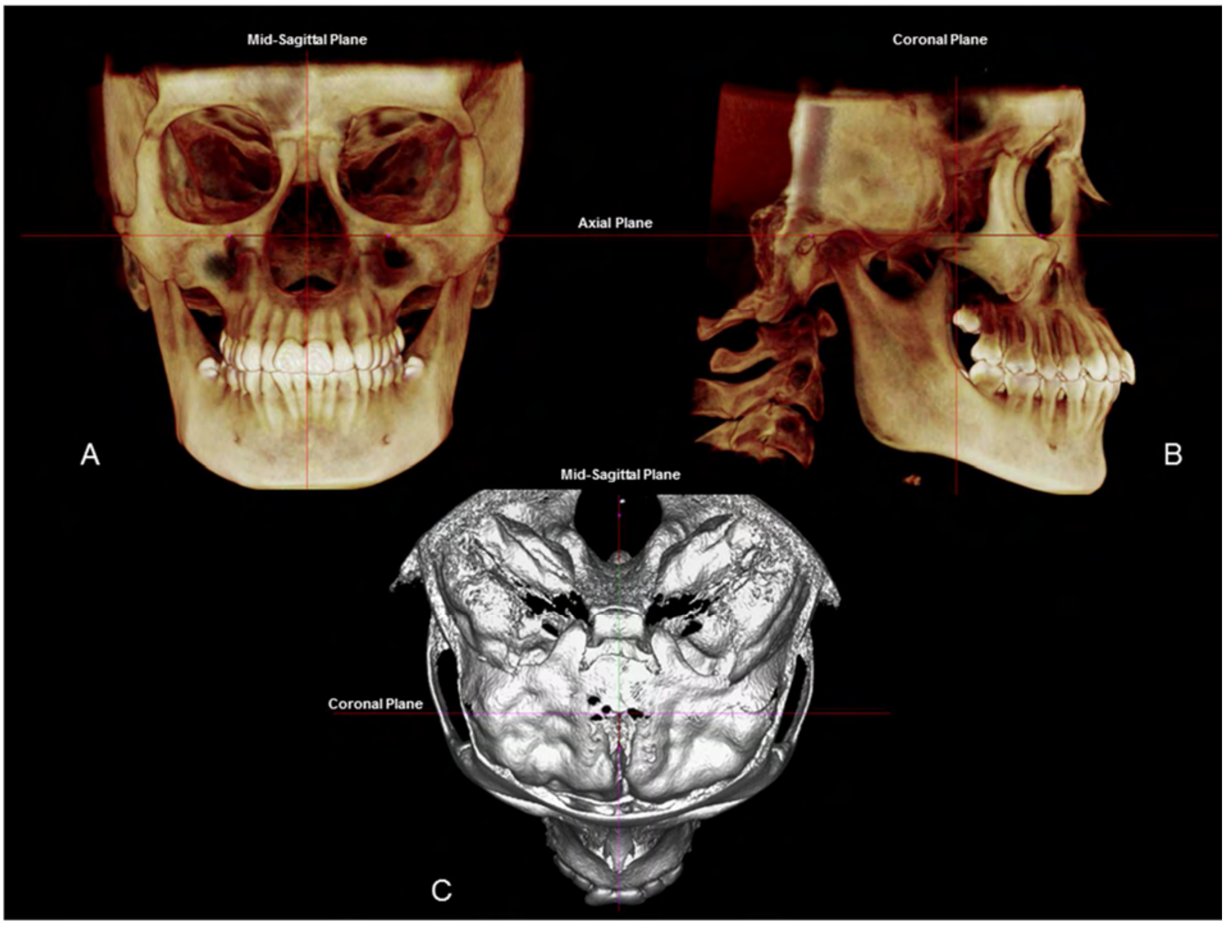

Mid-Sagittal Plane
Coronal Plane
Axial Plane
A
B
Mid-Sagittal Plane
Coronal Plane
C

Fig.1

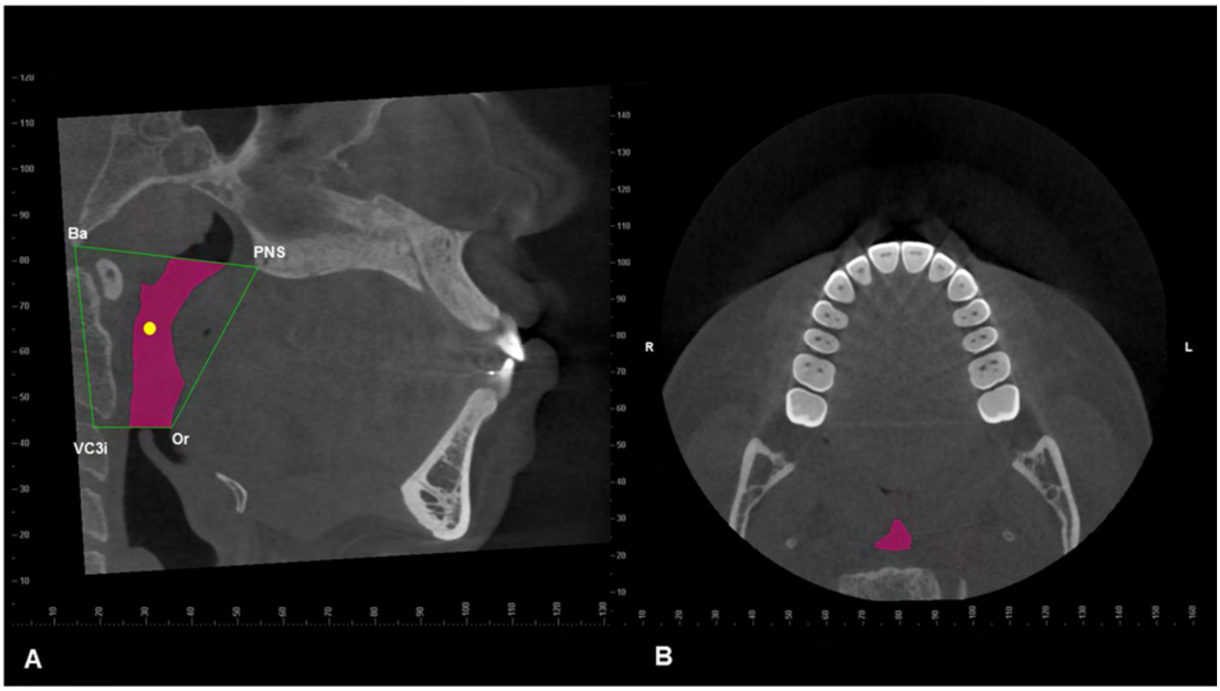


Fig. 2

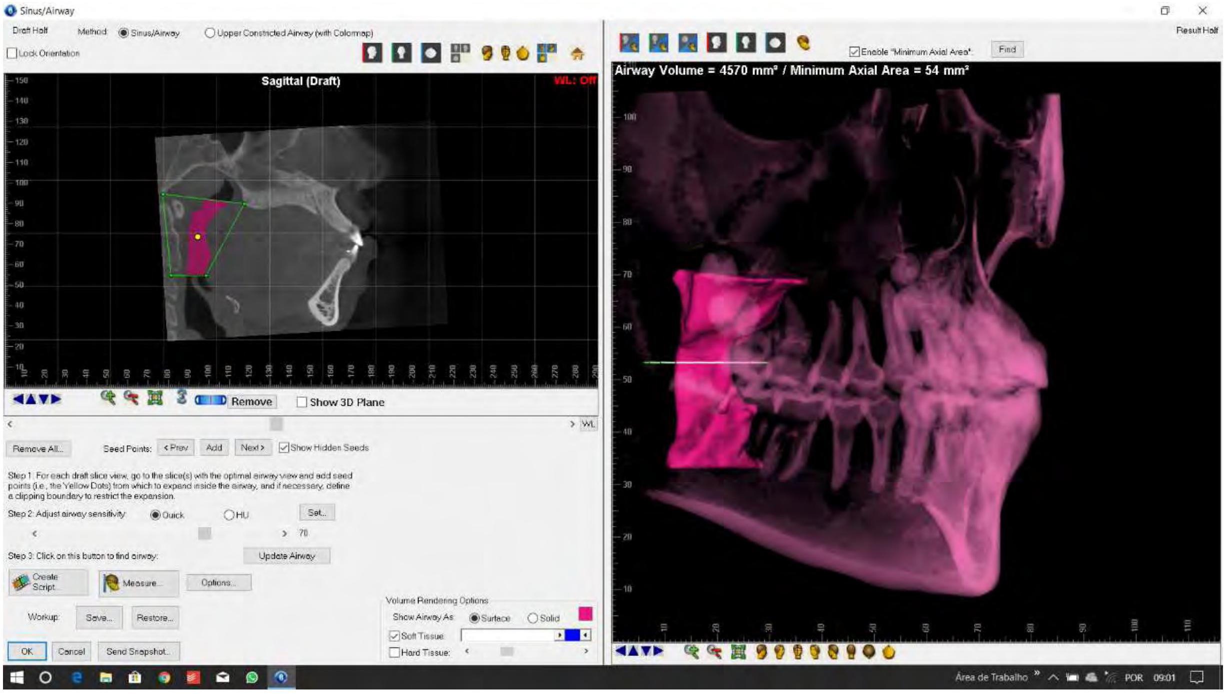

Sinus/Airway
Sagittal (Draft)
Airway Volume = 4570 mm³ / Minimum Axial Area = 54 mm²
Remove
Show 3D Plane
Update Airway
Create Script
Measure...
Options...
OK
Cancel
Send Snapshot...

Fig. 3

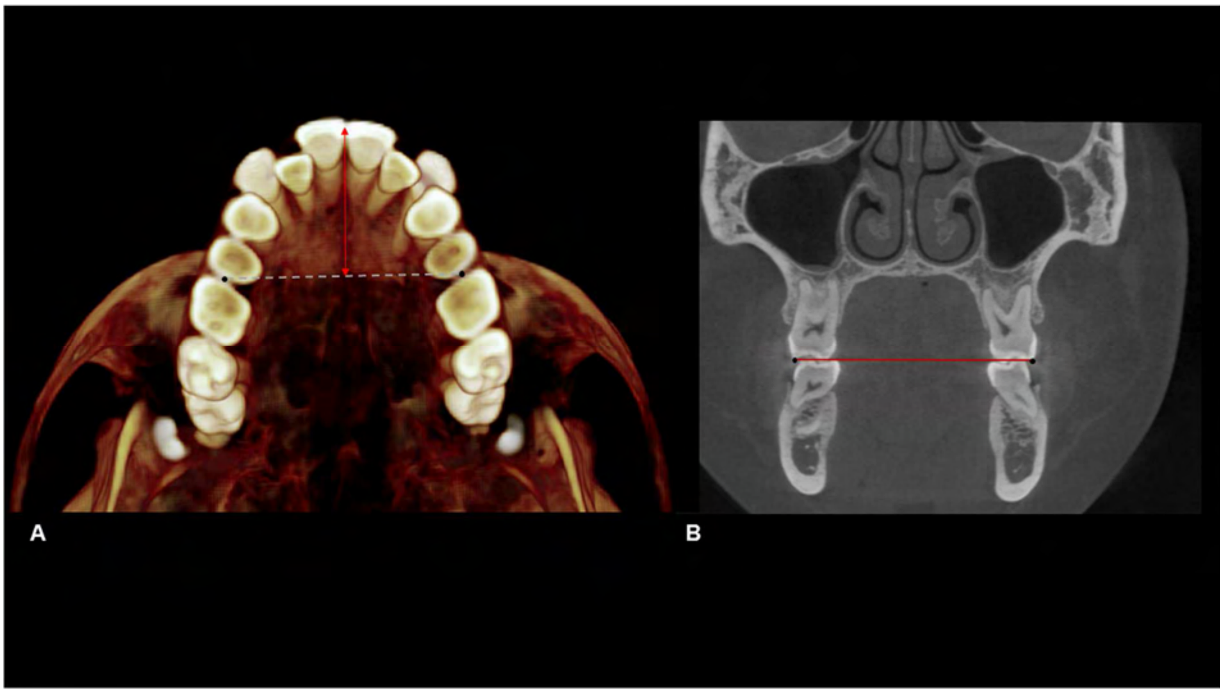


Fig. 4

Table I. Random and systematic error tomography analyses (Dahlberg´s formula and paired *t* test).

Variable	Measurement 1		Measurement 2		t	P	Dahlberg
	Mean	S.D.	Mean	S.D.			
Arches Dimensions (mm)	46.01	9.81	45.96	9.80	0.612	0.066	0.16
Upper airway area (mm^2)	491.00	111.41	488.50	111.98	1.81	0.112	3.12
Upper airway volume (mm^3)	10187.75	5047.22	10110.37	5040.27	3.11	0.017*	71.78
Minimun axial area (mm^2)	114.12	64.34	114.25	64.31	1.0	0.351	0.25

Statistically significant for p<0.05.

Table II. Results of descriptive statistics of the initial and final ages and treatment time. (N=21)

Variable	Mean	S.D.	Minimum	Maximum
Initial age (T1) (years)	14.99	1.27	12.93	17.27
Final age (T2) (years)	17.57	1.15	15.30	20.21
Treatment time (T2-T1) (years)	2.58	0.98	1.07	3.87
Little irregularity index – maxillary arch (mm)	11.39	5.11	5.35	24.01
Little irregularity index – mandibular arch (mm)	8.36	3.56	3.50	17.72

Table III. Comparison of transverse changes (x-x) at T1, T2 and T2-T1 (t test) (N=21).

Variables (mm)	T1		T2		T2-T1		P
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	
			Maxillary				
7-7	57.92	3.17	59.82	2.97	1.90	1.42	0.000*
6-6	52.98	3.44	54.88	2.65	1.90	1.54	0.001*
5-5	46.48	4.35	50.69	2.63	4.21	2.51	0.000*
4-4	41.42	2.05	45.82	2.04	4.40	1.55	0.000*
3-3	37.29	6.62	38.74	1.54	1.44	6.23	0.352
Max LA	28.51	1.85	30.07	1.24	1.55	1.21	0.000*
			Mandibular				
7-7	51.95	4.24	54.34	3.89	2.39	2.82	0.002*
6-6	46.57	3.56	48.71	3.41	2.13	2.19	0.000*
5-5	40.22	4.20	42.98	2.33	2.75	3.72	0.007*
4-4	34.12	3.09	38.09	2.42	3.96	2.10	0.000*
3-3	27.77	3.81	29.94	1.31	2.17	3.74	0.029*
Md LA	21.90	4.68	24.78	4.80	2.88	7.87	0.150

* Statistically significant for p<0.05.*

Table IV. Comparison of airway changes at T1, T2 and T2-T1(t test) (N=21).

Variables (mm^2/mm^3)	**T1**		**T2**		**T2-T1**		**P**
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	
Sagittal Area	578.05	166.68	601.58	174.60	23.52	145.31	0.513
Minimum Axial Area	169.70	97.50	181.76	130.87	12.05	112.46	0.664
Volume	14440.00	8952.52	16621.76	10300.18	2181.76	6284.75	0.171

* Statiscally significant for p<0.05.*

Table V. Results of Pearson correlations between the difference in the dimensions of the both arches with the difference in the sagittal area of the upper airways (N=21)

	Sagittal Area T2-T1	
Correlations	**r**	**P**
Mx 7-7 (T2-T1)	-0.034	0.895
Mx 6-6 (T2-T1)	0.189	0.467
Mx 5-5 (T2-T1)	-0.205	0.428
Mx 4-4 (T2-T1)	-0.007	0.977
Mx 3-3 (T2-T1)	-0.054	0.835
Mx LA (T2-T1)	0.094	0.717
Md 7-7 (T2-T1)	0.010	0.969
Md 6-6 (T2-T1)	0.231	0.371
Md 5-5 (T2-T1)	0.049	0.851
Md 4-4 (T2-T1)	0.186	0.474
Md 3-3(T2-T1)	-0.208	0.422
Md LA (T2-T1)	-0.691	0.002*

* Statiscally significant for p<0.05.*

Table VI. Results of Pearson correlations between the difference in the dimensions of the both arches with the difference in minimum axial area of the upper airways (N=21).

	Minimum axial area T2-T1	
Correlations	**r**	**P**
Mx 7-7 (T2-T1)	0.169	0.516
Mx 6-6 (T2-T1)	0.290	0.259
Mx 5-5 (T2-T1)	-0.073	0.779
Mx 4-4 (T2-T1)	0.103	0.693
Mx 3-3 (T2-T1)	-0.199	0.442
Mx LA (T2-T1)	-0.072	0.781
Md 7-7 (T2-T1)	0.197	0.447
Md 6-6 (T2-T1)	0.426	0.088
Md 5-5 (T2-T1)	-0.126	0.629
Md 4-4 (T2-T1)	0.232	0.370
Md 3-3(T2-T1)	-0.217	0.402
Md LA (T2-T1)	-0.449	0.070

* Statistically significant for p<0.05.*

Table VII. Results of Pearson correlations between the difference in the dimensions of the both arches with the difference in volume of the upper airways (N=21).

	Volume T2-T1	
Correlations	**r**	**P**
Mx 7-7 (T2-T1)	0.032	0.900
Mx 6-6 (T2-T1)	0.298	0.245
Mx 5-5 (T2-T1)	-0.178	0.493
Mx 4-4 (T2-T1)	-0.106	0.687
Mx 3-3 (T2-T1)	-0.077	0.769
Mx LA (T2-T1)	-0.021	0.935
Md 7-7 (T2-T1)	-0.110	0.672
Md 6-6 (T2-T1)	0.208	0.421
Md 5-5 (T2-T1)	0.234	0.929
Md 4-4 (T2-T1)	0.154	0.554
Md 3-3(T2-T1)	-0.243	0.347
Md LA (T2-T1)	-0.707	0.001*

* Statistically significant for p<0.05.*

ARTICLE 2

Evaluation of dimensional arch and buccolingual inclination changes with the Damon System through Cone-beam computed tomography.

ABSTRACT

Introduction: The aim of this study was to evaluate the dimensional arch and buccolingual inclination changes in patients treated with the Damon self-ligating brackets system. **Material and Methods:** Twenty-one patients of both sexes, mean initial age of 14.99 ± 1.97 years, with complete permanent dentition up to second molars, treated with no extractions and minimum initial crowding of 4 mm (maxillary: -6.71 ± 2,99 mm; mandibular: -5,12 ± 2,03 mm) were taken to CBCT scan before (T1) and after (T2) orthodontic treatment with the Damon System. Buccolingual inclinations were performed using CBCT-panoramic cross-sectionals based on the image that presented the most appropriate view of buccal face of the clinical crown. Transversal width measurements were performed in intersecond molar, interfirst molar, intersecond premolar, interfirst premolar and intercanine distances by coronal view at CBCT scans and arch length was assessed by 3D multiplanar reconstruction in maxillary and mandibular arches. Intragroup comparisons were performed using the paired t-test and correlations between arches dimensions and dental inclinations were performed using Pearson's correlation coefficient. **Results:** In the maxillary arch it was detected a significant increase of the arch length and interfirst premolar, intersecond premolar, interfirst molar and intersecond molar width. There was a significant buccal inclination of the incisors and premolars crowns. In the mandibular arch, all teeth showed a statistically significant increase of buccal inclination, except for the left canine and first molar. Regarding arches dimensions, there was a significant increase of intersecond molar, interfirst molar intersecond premolar, interfirst premolar and intercanine width with no significant length changes at the end of treatment. **Conclusion**: Damon self-ligating brackets system promotes a dental arches expansion mainly by buccal inclination of the dental crowns in maxillary and mandibular arches.

Key-words: Orthodontic Brackets. Cone-Beam Computed Tomography. Tooth Movement Techniques.

INTRODUCTION

The technological developments in orthodontic materials have grown exponentially and provided the professional more efficient tools for better orthodontic treatment and comfort for the patient, thus improving its quality of life. Self-ligating orthodontic appliances are currently popular among orthodontists. They allow to perform teeth alignment and leveling more effectively, with a relatively reduced chair time and less need for dental extractions, in cases of significant crowding compared with conventional edgewise brackets.[1]

Self-ligating brackets (SLB) are classified into two categories, passive and active, according to the closing system of the orthodontic appliance. Passive self-ligating brackets usually have a closing system that does not create friction between the archwire and the bracket slot. The main example of this system is the Damon self-ligating brackets (Ormco, Glendora, Calif.). Active self-ligating brackets have a closing system that creates a pressure between the orthodontic wire and the bracket slot to achieve greater control of rotation and torque. In-Ovation (GAC International, Central Islip, NY) is the most common active self-ligating brackets.[2]

The Damon self-ligating system creators stated that their low-friction ligating system, associated with orthodontic wires, which have a greater transverse dimension and high resilience, produces a system of light forces that allows the teeth to accommodate into the bone structures, promoting posterior expansion of the dental arch without incisors labial inclination.[3] However, studies have verified that Damon self-ligating system produces dentoalveolar arch expansion, providing a significant increase in maxillary arch length and width[4,5] also raising the mandibular arch length due to incisors protrusion.[6,7]

A recent study evaluated the buccal corridor width and area of patients treated with Damon self-ligating brackets system and compare with conventional pre-adjusted brackets using pre and posttreatment frontal photographs. The study demonstrated no significant differences for buccal corridor width and area between appliances, at the end of treatment. Both appliances increased dental arch width and decreased buccal corridor.[8]

Changes produced in the dental arches were mainly promotes by the archwires used in Damon System. When compared different types of brackets (passive and active self-ligating and conventional brackets) using the Damon system sequence of arches, it was not observed any difference for maxillary arch dimensions and molars and incisors angles between differents types of brackets.[9]

Although several studies have demonstrated the dental arch changes produced by the Damon system, the heterogeneity of the methodologies make it difficult to visualize these changes. The reliability of superposition reliability in 2D cephalograms to determine the changes occurring by the treatment is uncertain.[10] Cone-beam computed tomography (CBCT) presents a higher image quality and allows to evaluate the dimensional and morphological changes produced by the treatment in the three dimensions of the space, in addition to presenting a minimum dose of radiation when compared to multslice computed tomographies and magnetic resonance imaging.[11-13] Linear and angular measurements from CBCT images have been considered accurate for the evaluation of dental and maxillofacial structures.[14-16]

The objective of this study was to evaluate, through CBCT scans, the changes in the arches dimensions and buccolingual inclinations in the maxillary and mandibular teeth after orthodontic treatment with the Damon System.

MATERIAL AND METHODS

This study was approved by the Ethics in Research Committee of **Bauru Dental School, University of São Paulo, Brazil.** (1.567.403). Informed consent to undergo the CBCT radiographic examinations and to use the material for the present investigation was obtained from all patients. CBCT scans were taken following the protocol approved by the **Radiological Department, Bauru Dental School, University of São Paulo.**

Material

Using an alpha error of 5% and a beta error of 20%, considering a standard deviation of 1.0°, to detect a minimum difference of 0.64° for the buccal inclination variable, indicated that a minimum of 21 patients were necessary.[12] According this results, were selected 21 patients.

A retrospective study of the patients treated by **Department of Orthodontics, Bauru Dental School, University of São Paulo, Brazil**, from 2010 to 2016, was performed.

The following inclusion criteria were considered: Patients between 12 and 17 years age, with no previous history of orthodontic treatment, with a minimal crowding of 4mm, absence of crossbite, complete permanent dentition up to second molar, without agenesis, or dental losses, impacted or supernumerary teeth and patients of both sexes with Class I malocclusion.

The exclusion criteria included patients with missing teeth and agenesis, posterior crossbite, CBCT images suggesting periodontal disease such as horizontal or vertical proximal bone loss, furcal involvement and calculus. Were also excluded from the evaluation the teeth with extensive restorations involving the cementoenamel junction.

All patients were treated with a 0.022-in Damon 3MX standard prescription appliance system (Ormco/A Company, San Diego, Calif) with a predetermined Damon archwire sequence. The wire sequence followed included an initial 0.014-in Damon Copper Ni-Ti® (left in place an average of 12 weeks) followed by a 0.014 × 0.025-in Damon Copper Ni-Ti® (12–18 weeks) until observe an alignment that would allow the complete insertion of the following archwire in the slot of the bracket and the closing of its lid. The finishing archwire was a 0.019 × 0.025-in stainless steel which were coordinated based on Damon arch form obtained after the insertion of the 0.014 × 0.025-in Copper Ni-Ti Damon® archwire. No other appliances, such as headgear, Herbst, lip bumper, or distalizing appliances, were used. The appliances were removed, and posttreatment records were taken when a Class I canine-molar relationship with a satisfactory overjet and overbite was obtained.

Methods

CBCT scans were taken at the beginning (T1) and after (T2) complete orthodontic treatment. CBCT images were taken with the i-CAT Classic tomograph (Imaging Sciences International, Hatfield, Pa) and the subjects were positioned with the Frankfort horizontal plane parallel to the floor, instructed to maintain maximum intercuspidation with the tongue touching the palate and avoiding swallowing during the scanning period. The imaging protocol used were 120 kV, 5 mA, 13 x 16 cm field of view, 0.25- mm voxel size, and a scanning time of 40 seconds. Some CBCT final images were taken with a 3D Accuitomo-XYZ Slice View Tomography® (J. Morita, Kyoto, Japan) with a voxel size of 0.33 mm, voltage of 90 kV, 7 mA, and a scanning time of 30 seconds, with the patient following the same positioning protocol.

Images were saved in DICOM files, and these files were imported into Dolphin Imaging Software (version 11.9; Dolphin Imaging and Management Solutions, Chatsworth, Calif) to obtain the primary reconstructed images (sagittal, coronal, and axial) and 3D reconstructions.

Before image selection for measurement, the head should be standardized in all the three planes. The standardization of head position was performed in 3D images: in frontal view the infraorbital plane (plane formed by the points located in the infraorbital foramen) parallel to the floor, in axial view the midsagittal line (center point in magnum foramen to a point located on the galli crest) was perpendicular to the floor and in sagittal view the Frankfurt plane (porion to orbital) was parallel to the floor. Head orientation was the same for each CBCT image performed by the same operator (Fig. 1).

All measurements were performed using the tools provided by Dolphin Imaging Software. Only one calibrator visually evaluated all sectional images in a dark room, using a 24.1-in LCD monitor with resolution of 1920 x 1200 pixels.

Dental arches dimensions measurements

Two images were used for measuring intercanine (3-3), interfirst premolars (4-4), intersecond premolar (5-5), interfirst molar (6-6) and intersecond molar (7-7) widths, in coronal view. The coronal image selected from the maxillary and mandibular arches were obtained from the complete visualization of teeth. In order to measure the transverse distances, buccal cusp tips were selected for maxillary and mandibular first and second premolars, while mesiobuccal cusp tips were selected for first and second molars. The arch length was measured by a line constructed from the mesial contact point of the central incisors (calculated as the midpoint between the mesial points of the central incisors) to the point on a perpendicular line ligating the mesial points of the first molars in both sides (Fig. 2). Crowding was measured by the Little's Irregularity Index[17] only in the initial digital models, aiming to assess a mean of crowding in maxillary and mandibular arch.

Buccolingual inclination measurements

The software created a 2D CBCT-panoramic cross-sectional images with 0.5 mm of thickness. The region selection was evaluated based on the image that presented better vestibular face visualization of the clinical crown. Buccolingual inclination was measured from the angle formed by the line of the clinical crown (VLCC) and the maxillary or mandibular edge of the selected image. The VLCC is formed by a point located in the cementoenamel junction (CEJ) to incisal and/or buccal cusp tip of incisors, canines, premolars and molars (Fig. 3).

Error study

Fifteen CBCT were randomly selected and remeasured by the same examiner (BSV) at two times after a 30-day interval. The random error was calculated according to Dahlberg's formula, $S^2 = \Sigma d^2/2n$, where S^2 is the error variance and "d" is the difference between two determinations of the same variable. The systematic error was estimated with paired t-test, for $P<.05$.[18,19]

Statistical Analyses

Shapiro-Wilk test was used to test the hypothesis of variables normal distribution.

Pre and posttreatment data comparisons of dimensions arches and dental inclinations were performed with paired t-test.

Pearson´s Correlation coefficients was used to determine the relationship between the arch dimensions and dental inclinations.

All statistical analyses were performed with Statistica software (Statistica for Windows – Release 7.0 - Copyright Statsoft, Inc. Tulsa, OKla). Results were considered statistically significant at $P<0.05$.

RESULTS

Systematic (paired t-test) and random error (Dahlberg's formula) showed no intraexaminer difference. Random for dental arches dimensions and dental inclinations measurements were 0.16 and 0.88, respectively, showing acceptable reliability (Table I).

Table II shows patient`s demographic distribution, evaluated by the following aspects: initial and final age, time treatment and Little irregularity index.

There was a significant transverse increase in maxillary and mandibular arch at posttreatment with the Damon System (Table III), except for the maxillary canines. Maxillary arch length (Mx AL) showed a statistically significant increase whereas the mandibular arch length (Md AL) did not show a significant increase.

In maxillary arch, there was a significant increase in buccolingual inclinations (i) of premolars and incisors. There was a significant increase of inclinations in all teeth in the mandibular arch, except in the first left mandibular molar and the left mandibular canine. These elements presented an increase of the dental slope after the treatment, but it was not significant (Table IV).

The correlation coefficient between the maxillary arch transverse measurements and the inclinations in the maxillary teeth (Table V) showed that there was a mean positive correlation between the inclinations of the maxillary second premolars and the intersecond premolar width. There was a moderate positive correlation between the 3-3 transverse measure and the right maxillary inclination, and the same did not occur with the left side canine, which did not present a statistically significant correlation. The maxillary arch length showed a positive, moderate correlation with the right lateral incisor inclination, and the same did not occur in relation to the other anterior teeth. In mandibular arch, there was a moderate positive correlation in the inclinations of right mandibular first premolar, right mandibular first and second molar and left mandibular second premolar teeth with their respective transverse measurements (Table VI).

DISCUSSION

In this sample, patients were treated by different dentists, but in order to obtain more reliable results, measurements were made only by one previously calibrated examiner. In the error study, no significant differences were found between measurements at two different time points. This may have occurred due to high-resolution images offering excellent view without overlapping structures.

Dental casts were used in previous studies to assess dental inclinations and measurements of arch dimensions and because of the easy of analysis and low cost.[20,21] However the analyzes are restricted to crowns, making it impossible to evaluate changes in alveolar morphology and supporting tissues (fenestrations and dehiscences) after orthodontic treatment. After the development of the CBCT, an evaluation of the dental crowns and roots in different planes was carried out with a dose of reduced radiation and an affordable cost to the professional in comparison to the multislice computerized tomographies, besides having its proven accuracy in linear and angular teeth measurements.[13-15]

The main advantage attributed to self-ligating brackets is the treatment time reduction.[22,23] However, there is a lack of evidence due to conflicting findings. Some authors reported a efficiency of self-ligating brackets in the alignment and leveling of the arches[24-26] and overall time[27] while others disagree, performing prospective clinical studies.[28,29] The treatment time mean in the present study was 2.58 ± 0.98 years, higher when compared to other studies that used self-ligating brackets,[30,31] probably due patients treated by different dentists.

The transverse increase of the dental arches is a common feature in orthodontic treatments performed with brackets of the Damon system.[32] Similar findings were found in our study. In general, there was a statistically significant increase in the transverse width in maxillary and mandibular arches. Studies have shown a greater transverse increase in patients treated with the Damon system when compared to the conventional bracket system.[7,26,33]

The most significant change occurred in the first maxillary premolars region. There was an average increase of 4.40 ± 1.55 mm. Similar results were found in a randomized clinical trial where a mean expansion of 4.51 ± 2.6 mm was found.[34] Franchi et al[35] in a prospective follow-up of 20 patients treated with a fixed appliance of low friction ligatures, reported a mean expansion of 3.65 ± 2.67 mm, however, in this study the evaluations were made in the final phase of alignment and leveling with a mean time of 6 months and not using the wire sequence recommended by the Damon System.

Arches width changes occurred mainly due to the expanded wires shape used in the Damon system, which shows a greater expansion in the region of the premolars. The expanded shape of the copper Ni-Ti and stainless steel wire from the Damon system can generate as much expansion as a conventional straight wire system combined with a quad-helix appliance.[36] A recent study[9] evaluated three different types of brackets using the same orthodontic wire sequence advocated by the Damon system, founding a similar increase in the interpremolar width in the evaluated groups. Similar to this, Pandis et al.[33] found no difference in the arch width with the same sequence of expanded wires advocated by the Damon system in conventional and passive self-ligating brackets.

An interesting finding was the differences found in the maxillary and mandibular arch length after orthodontic treatment. The maxillary arch suffer a significant increase in length differently from the mandibular arch. The patients of the present study were treated with non-extraction and presented mean crowding of 11.39 ± 5.11 mm in the maxillary arch and 8.36 ± 3.56 mm in the mandibular arch. It is known that in cases with dental crowding and absence of space, at alignment, the use of nickel-titanium wires generates a buccal movement of the teeth crowns. In conventional mechanics, this effect occurs mainly in the mandibular incisors due to its crown and root volume, promoting an increase in arch length.[37] Germane et al.[38] created a mathematical formula that demonstrated that the arch length increase is related to the location where the arch expansion occurs. They concluded that a greater length of the arch is obtained with the combination of labial tip of the incisors and the expansion in the canines region. Therefore, the increase of the maxillary arch length can be explained by the labial tip of the maxillary incisor for crowding correction since the intercanine width has not undergone significant changes. In the mandibular arch, there was a significant increase of the transverse measurements throughout the arch, which allowed the reduction of labial tip of the mandibular incisors. Consequently, there was no significant increase in arch length.

This result in the mandibular arch corroborates Damon's affirmation[3] that the use of a low friction bracket system allows a greater distal sliding of the wire during alignment avoiding excessive inclination of the anterior teeth obtaining space through the transverse increase of the arches. Another situation that may occur is the reduction of arch length when the treatment is performed with the Damon System associated with dental extractions. In this case the distal movement of the canines promotes an increase in the intercanine width and the mesial movement of the molars added with less labial inclination of the incisors generates a decrease in the arch length.[24]

An advantage attributed to the Damon system is the ability to create balanced forces that allows the modification of the arch length and transverse distances with body dental movement and minimal buccal inclination.[39] Contrary this idea, several studies found buccal teeth inclination after treatment.[6,36,40] Cattaneo et al.[12] observed that the transverse increase in the premolars region occurred when the buccal movement of the dental crowns. Similar result was found in this research. In general, there is a predominance of buccal inclination associated with a transverse increase of the arches. However, the results showed differences of tooth movement between the maxillary and mandibular arches. In the maxillary arch, there was no significant changes for the intercanine distance. This is a controversial result with literature, that show an increase in the intercanine distance for crowding corrections.[6,7,32,33] This can be justified because of the maxillary canine position in cases of significant absence of space. Normally, the canines are located in a more buccal position relative to the adjacents teeth at the treatment beginning. Therefore, when realizing the alignment and leveling with expanded Damon archwires, there was no significant changes in its position at posttreatment. In the molar region, there was a significant increase of interfirst and intersecond molars width, but with a lingual inclination of the crowns at posttreatment. It has been proposed that maxillary molars that erupt in the oral cavity with buccal crown torque[41] and a more buccal position at the beginning of treatment could cause a lingual inclination at the end of treatment. Unlike this study, Atik and

Ciger[36] showed a buccal inclination of the maxillary molars in a group treated with the Damon system. Yu et al.[5] compared the effects of Rapid Maxillary Expansion with the Damon system for correction of dental crowding and showed that occurred molars buccal inclination in both groups. Probably the results found in these studies is related to the amount of expansion promoted by the treatment. The mean increase of the intermolar distances showed by these studies was greater than 3 mm, meanwhile in this study was demonstrated an intermolar mean distance increase of 1.9 mm. Another study where CBCT was used to measure the inclination angle of the molars following rapid maxillary expansion, the inclination angle was reported to have increased in the maxillary posterior teeth.[42,43] This provides justification for excluding patients with posterior crossbite as these teeth show more dental tipping than the treatment effects on teeth in this study.

The mandibular arch presented significantly buccal inclination with an increase of the transverse dimensions for most of the teeth confirming findings of the literature.[5,9,36] Only the canine and first mandibular right molar did not present a significant buccal inclination. It has been reported that maintaining the mandibular intercanine width during treatment may reduce the possibility of orthodontic relapse[44,45]. Due to this a negative torque in the mandibular canine bracket is usually found, a canine should lean lingually; however, the present findings show that almost all mandibular canines moved buccally. The mandibular molars erupt with a lingual crown inclination, which remains stable after growing developing Wilson's curve[46] and therefore, greater vestibular movement of crowns is expected after treatment. In general, there was a moderate positive correlation between the increase of the transverse distances and the buccal inclination of the teeth crowns, although has been significant only in some mandibular and maxillary teeth (Table V and VI). Therefore, increase of the transverse dimensions in the mandibular arch is due to the predominance of the crown buccal inclination.

Limitations

Ideally, all initial and final CBCT scans should have been performed following the same protocol using the same device. However, it was not possible due to the temporary unavailability of one device (i-Cat) during final CBCT scans period. Thus, in order to avoid a reduction in the number of patients and make it unworkable, they were kept in research, since during the initial tests was observed a homogeneity in the image quality of both i-Cat, voxel size 0.25mm and Accuitomo, voxel size 0.33mm devices.

The data from this study should be interpreted with caution, since the research evidence for one CBCT machine may not apply to other equipment.

CONCLUSION

According to results of this study, orthodontic treatment with Damon System produced an expansion in maxillary arch with significant increase of buccal inclination in premolars and incisors teeth and an expansion in mandibular arch with all teeth showed a significant increase of buccal inclination.

REFERENCES

1. Birnie D. The Damon passive self-ligating appliance system Seminars in Orthodontics: Elsevier; 2008: p. 19-35.

2. Chen SS, Greenlee GM, Kim JE, Smith CL, Huang GJ. Systematic review of self-ligating brackets. Am J Orthod Dentofacial Orthop 2010;137:726 e721-726 e718; discussion 726-727.

3. Damon DH. The Damon low-friction bracket: a biologically compatible straight-wire system. J Clin Orthod 1998;32:670-680.

4. Tao L, Yao R, Tang GH, Xu XC, Yu YL. Arch perimeter changes on non-extraction correction of dental crowding with Damon appliance. Shanghai Kou Qiang Yi Xue 2008;17:243-249.

5. Yu YL, Tang GH, Gong FF, Chen LL, Qian YF. A comparison of rapid palatal expansion and Damon appliance on non-extraction correction of dental crowding. Shanghai Kou Qiang Yi Xue 2008;17:237-242.

6. Pandis N, Polychronopoulou A, Makou M, Eliades T. Mandibular dental arch changes associated with treatment of crowding using self-ligating and conventional brackets. Eur J Orthod 2010;32:248-253.

7. Vajaria R, BeGole E, Kusnoto B, Galang MT, Obrez A. Evaluation of incisor position and dental transverse dimensional changes using the Damon system. Angle Orthod 2011;81:647-652.

8. Shook C, Kim SM, Burnheimer J. Maxillary arch width and buccal corridor changes with Damon and conventional brackets: A retrospective analysis. Angle Orthod 2016;86:655-660.

9. Atik E, Akarsu-Guven B, Kocadereli I, Ciger S. Evaluation of maxillary arch dimensional and inclination changes with self-ligating and conventional brackets using broad archwires. Am J Orthod Dentofacial Orthop 2016;149:830-837.

10. Baumrind S, Miller D, Molthen R. The reliability of head film measurements. 3. Tracing superimposition. Am J Orthod 1976;70:617-644.

11. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:106-114.

12. Cattaneo PM, Treccani M, Carlsson K, Thorgeirsson T, Myrda A, Cevidanes LH. Transversal maxillary dento-alveolar changes in patients treated with active and passive self-ligating brackets: a randomized clinical trial using CBCT-scans and digital models. Orthod Craniofac Res 2011;14:222-233.

13. Garib DG, Henriques JF, Janson G, Freitas MR, Coelho RA. Rapid maxillary expansion--tooth tissue-borne versus tooth-borne expanders: a computed tomography evaluation of dentoskeletal effects. Angle Orthod 2005;75:548-557.

14. Periago DR, Scarfe WC, Moshiri M, Scheetz JP, Silveira AM, Farman AG. Linear accuracy and reliability of cone beam CT derived 3-dimensional images constructed using an orthodontic volumetric rendering program. Angle Orthod 2008;78:387-395.

15. Tong H, Enciso R, Van Elslande D, Major PW, Sameshima GT. A new method to measure mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2012;142:133-143.

16. Patcas R, Muller L, Ullrich O, Peltomaki T. Accuracy of cone-beam computed tomography at different resolutions assessed on the bony covering of the mandibular anterior teeth. Am J Orthod Dentofacial Orthop 2012;141:41-50.

17. Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975;68:554-563.

18. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience; 1940.

19. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-390.

20. Ross VA, Isaacson RJ, Germane N, Rubenstein LK. Influence of vertical growth pattern on faciolingual inclinations and treatment mechanics. Am J Orthod Dentofacial Orthop 1990;98:422-429.

21. Janson G, Bombonatti R, Cruz KS, Hassunuma CY, Del Santo M, Jr. Buccolingual inclinations of posterior teeth in subjects with different facial patterns. Am J Orthod Dentofacial Orthop 2004;125:316-322.

22. Harradine NW. Self-ligating brackets and treatment efficiency. Clin Orthod Res 2001;4:220-227.

23. Eberting JJ, Straja SR, Tuncay OC. Treatment time, outcome, and patient satisfaction comparisons of Damon and conventional brackets. Clin Orthod Res 2001;4:228-234.

24. Scott P, DiBiase AT, Sherriff M, Cobourne MT. Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: a randomized clinical trial. Am J Orthod Dentofacial Orthop 2008;134:470 e471-478.

25. Fleming PS, DiBiase AT, Sarri G, Lee RT. Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances. Am J Orthod Dentofacial Orthop 2009;136:340-347.

26. Pandis N, Polychronopoulou A, Eliades T. Self-ligating vs conventional brackets in the treatment of mandibular crowding: a prospective clinical trial of treatment duration and dental effects. Am J Orthod Dentofacial Orthop 2007;132:208-215.

27. Miles PG. Self-ligating brackets in orthodontics: Do they deliver what they claim? Aust Dent J 2009;54:9-11.

28. Fleming PS, Johal A. Self-ligating brackets in orthodontics. A systematic review. Angle Orthod 2010;80:575-584.

29. DiBiase AT, Nasr IH, Scott P, Cobourne MT. Duration of treatment and occlusal outcome using Damon3 self-ligated and conventional orthodontic bracket systems in extraction patients: a prospective randomized clinical trial. Am J Orthod Dentofacial Orthop 2011;139:e111-e116.

30. Johansson K, Lundstrom F. Orthodontic treatment efficiency with self-ligating and conventional edgewise twin brackets: a prospective randomized clinical trial. Angle Orthod 2012;82:929-934.

31. Machibya FM, Bao X, Zhao L, Hu M. Treatment time, outcome, and anchorage loss comparisons of self-ligating and conventional brackets. Angle Orthod 2013;83:280-285.

32. Tecco S, Tete S, Perillo L, Chimenti C, Festa F. Maxillary arch width changes during orthodontic treatment with fixed self-ligating and traditional straight-wire appliances. World J Orthod 2009;10:290-294.

33. Pandis N, Polychronopoulou A, Katsaros C, Eliades T. Comparative assessment of conventional and self-ligating appliances on the effect of mandibular intermolar distance in adolescent nonextraction patients: a single-center randomized controlled trial. Am J Orthod Dentofacial Orthop 2011;140:e99-e105.

34. Fleming PS, Lee RT, Marinho V, Johal A. Comparison of maxillary arch dimensional changes with passive and active self-ligation and conventional brackets in the permanent dentition: a multicenter, randomized controlled trial. Am J Orthod Dentofacial Orthop 2013;144:185-193.

35. Franchi L, Baccetti T, Camporesi M, Lupoli M. Maxillary arch changes during leveling and aligning with fixed appliances and low-friction ligatures. Am J Orthod Dentofacial Orthop 2006;130:88-91.

36. Atik E, Ciger S. An assessment of conventional and self-ligating brackets in Class I maxillary constriction patients. Angle Orthod 2014;84:615-622.

37. Maltagliati LA, Myiahira YI, Fattori L, Filho LC, Cardoso M. Transversal changes in dental arches from non-extraction treatment with self ligating brackets. Dental Press J Orthod 2013;18:39-45.

38. Germane N, Lindauer SJ, Rubenstein LK, Revere JH, Jr., Isaacson RJ. Increase in arch perimeter due to orthodontic expansion. Am J Orthod Dentofacial Orthop 1991;100:421-427.

39. Damon DH. Treatment of the face with biocompatible orthodontics. In: Graber TM, Vanarsdall RI, Vig KWI, editors. Orthodontics Current Principles and Techniques. Mosby: Elsevier; 2005. p. 753-831.

40. Pandis N, Polychronopoulou A, Makou M, Eliades T. Mandibular dental arch changes associated with treatment of crowding using self-ligating and conventional brackets. The European Journal of Orthodontics 2009;32:248-253.

41. Sayania B, Merchant M, Josephs P, Chung CH. Changes in the buccolingual inclination of first molars with growth in untreated subjects: A longitudinal study. Angle Orthod 2017;87:681-687.

42. Ghoneima A, Abdel-Fattah E, Eraso F, Fardo D, Kula K, Hartsfield J. Skeletal and dental changes after rapid maxillary expansion: a computed tomography study. Aust Orthod J 2010;26:141-148.

43. Garrett BJ, Caruso JM, Rungcharassaeng K, Farrage JR, Kim JS, Taylor GD. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2008;134:8-9.

44. Burke SP, Silveira AM, Goldsmith LJ, Yancey JM, Van Stewart A, Scarfe WC. A meta-analysis of mandibular intercanine width in treatment and postretention. Angle Orthod 1998;68:53-60.

45. Blake M, Bibby K. Retention and stability: a review of the literature. Am J Orthod Dentofacial Orthop 1998;114:299-306.

46. Marshall S, Dawson D, Southard KA, Lee AN, Casko JS, Southard TE. Transverse molar movements during growth. Am J Orthod Dentofacial Orthop 2003;124:615-624.

FIGURE LEGENDS

Fig.1. Three-dimensional image of the head in front (A), sagittal (B) and top (facing down) (C) view after standardization by mid-sagittal, axial and coronal reference planes. Dolphin Imaging® 11.9, orientation tool.

Fig.2. Arch length measurement in axial plane of 3D reconstruction (A) and transverse measurement in coronal plane of 2D image (B).

Fig.3. Panoramic image (A) reconstructed by TCCB and buccolingual inclination measurements of clinical crown (B) - VLCC: vestibular line of clinical crown.

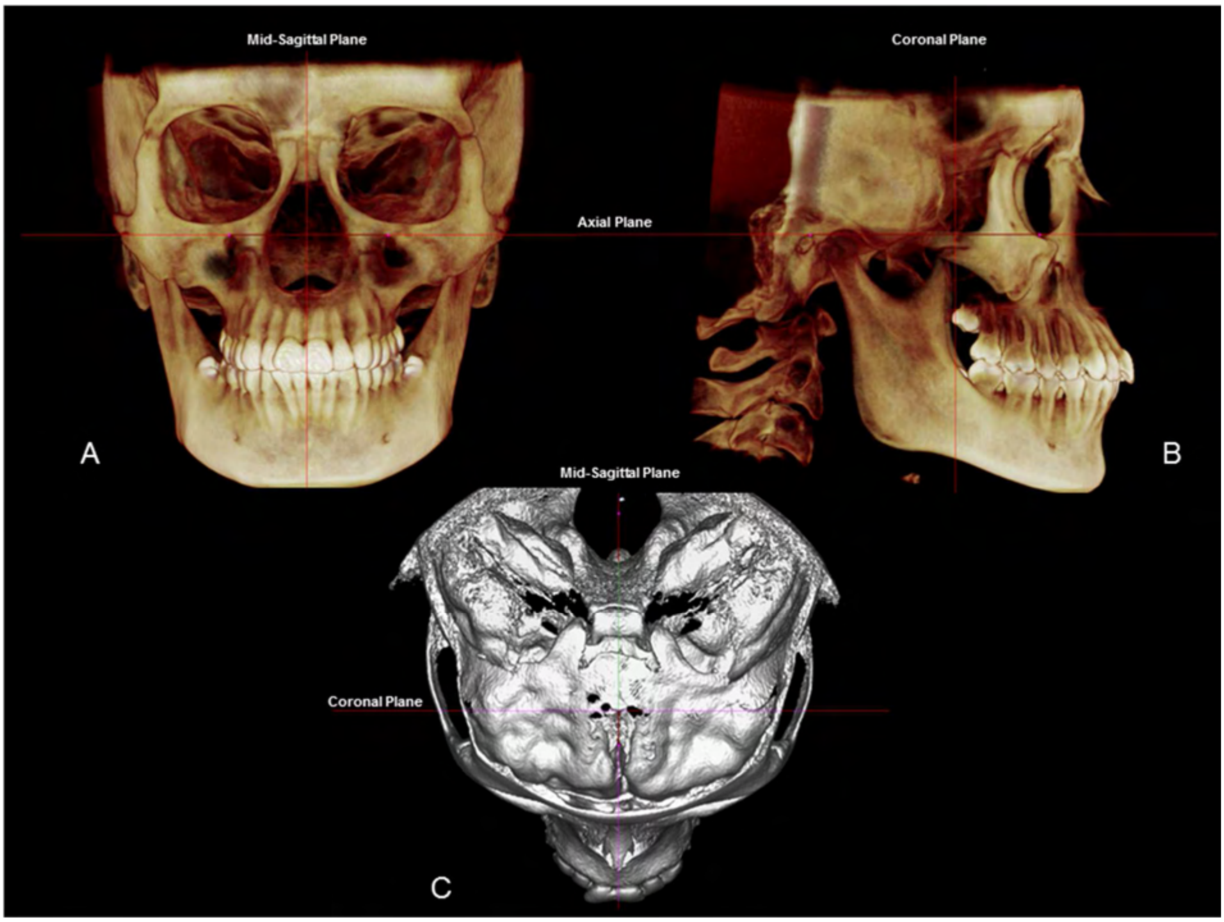

Mid-Sagittal Plane
Coronal Plane
Axial Plane
A
B
Mid-Sagittal Plane
Coronal Plane
C

Fig.1

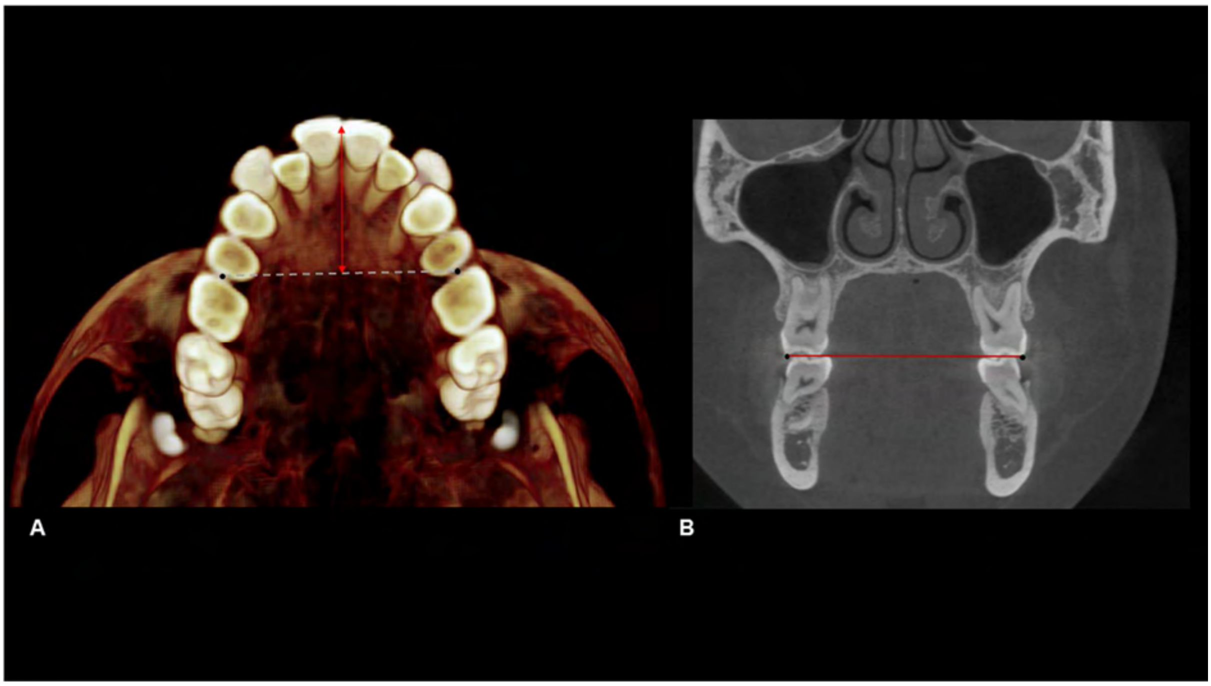


Fig. 2

Fig.3

Table I. Tomography random and systematic error analyses (Dahlberg´s formula and paired *t* test).

Variable	Measurement 1		Measurement 2		t	P	Dahlberg
	Mean	S.D.	Mean	S.D.			
Arches Dimensions (mm)	46.01	9.81	45.96	9.80	0.612	0.066	0.16
Buccolingual inclination (º)	83.82	15.16	83.85	15.25	0.391	0.696	0.88

Statistically significant for p<0.05.

Table II. Results of descriptive statistics of the initial and final ages and treatment time. (N=21)

Variable	Mean	S.D.	Minimum	Maximum
Initial age (T1)	14.99	1.27	12.93	17.27
Final age (T2)	17.57	1.15	15.30	20.21
Treatment time (T2-T1)	2.58	0.98	1.07	3.87
MxII	11.39	5.11	5.35	24.01
MdII	8.36	3.56	3.50	17.72

MxII. – Maxillary irregularity index
MdII. – Mandibular irregularity index

Table III. Comparison of transverse (x-x) changes at T1, T2 and T2-T1 (t tests) (N=21).

Variables (mm)	T1		T2		T2-T1		p
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
			Maxillary				
7-7	57.92	3.17	59.82	2.97	1.90	1.42	0.000*
6-6	52.98	3.44	54.88	2.65	1.90	1.54	0.001*
5-5	46.48	4.35	50.69	2.63	4.21	2.51	0.000*
4-4	41.42	2.05	45.82	2.04	4.40	1.55	0.000*
3-3	37.29	6.62	38.74	1.54	1.44	6.23	0.352
Mx LA	28.51	1.85	30.07	1.24	1.55	1.21	0.000*
			Mandibular				
7-7	51.95	4.24	54.34	3.89	2.39	2.82	0.002*
6-6	46.57	3.56	48.71	3.41	2.13	2.19	0.000*
5-5	40.22	4.20	42.98	2.33	2.75	3.72	0.007*
4-4	34.12	3.09	38.09	2.42	3.96	2.10	0.000*
3-3	27.77	3.81	29.94	1.31	2.17	3.74	0.029*
Md LA	21.90	4.68	24.78	4.80	2.88	7.87	0.150

Statistically significant for p<0.05.

.

Table IV. Comparison between pre and posttreatment time regarding buccolingual inclination (i) in the maxillary and mandibular arch (t-dependent test) (N=21).

Variables (º)	T1		T2		T2-T1		p
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Maxillary							
i17	82.69	5.47	79.96	6.73	-2.72	5.43	0.055
i16	79.01	5.75	77.14	5.09	-1.87	5.19	0.157
i15	80.41	7.58	84.77	6.26	4.35	6.52	0.014*
i14	80.85	8.05	87.81	3.98	6.95	6.80	0.000*
i13	97.20	8.79	94.40	5.45	-2.80	8.37	0.186
i12	100.25	8.84	106.60	4.61	6.35	7.81	0.004*
i11	107.03	5.52	110.04	3.74	3.00	4.00	0.006*
i21	106.78	6.14	111.51	3.74	4.73	5.37	0.002*
i22	100.16	10.54	109.02	3.80	8.86	11.91	0.007*
i23	96.70	10.56	96.96	3.92	0.26	9.82	0.912
i24	81.55	7.12	89.65	5.97	8.10	7.64	0.000*
i25	83.51	9.47	88.87	5.22	5.35	6.52	0.003*
i26	82.46	7.57	79.95	7.47	-2.51	6.99	0.158
i27	86.25	8.94	84.02	8.27	-2.22	5.52	0.115
Mandibular							
i37	59.52	7.82	63.77	8.42	4.24	6.64	0.018*
i36	62.70	5.74	64.21	4.91	1.51	6.22	0.331
i35	68.10	5.93	71.00	5.35	2.90	3.55	0.003*
i34	69.74	8.81	78.14	4.36	8.34	7.71	0.000*
i33	85.53	9.58	85.68	4.56	0.15	7.20	0.931
i32	89.17	8.29	97.62	5.13	8.44	6.52	0.000*
i31	94.73	8.28	100.01	5.12	5.28	6.14	0.002*
i41	93.49	7.30	100.32	4.45	6.83	5.59	0.000*
i42	89.31	7.77	98.14	3.87	8.83	7.64	0.000*
i43	85.22	7.27	89.56	4.61	4.33	6.98	0.020*
i44	71.60	7.43	78.88	3.35	7.27	6.75	0.000*
i45	67.10	6.98	72.57	4.09	5.47	5.51	0.000*
i46	60.61	6.04	63.49	5.29	2.87	3.74	0.005*
i47	56.19	5.88	61.92	7.16	5.73	7.62	0.006*

Statistically significant for $p<0.05$.

Table V. Results of Pearson correlation between dental inclinations (i) and transverse measurements (x-x) in the maxillary arch at posttreatment period (N=21).

Correlations	r	P
i17 x Mx 7-7	-0.043	0.868
i27 x Mx 7-7	0.352	0.165
i16 x Mx 6-6	0.444	0.074
i26 x Mx 6-6	0.376	0.136
i15 x Mx 5-5	0.533	0.027*
i25 x Mx 5-5	0.744	0.001*
i14 x Mx 4-4	0.369	0.145
i24 x Mx 4-4	0.397	0.114
i13 x Mx 3-3	0.506	0.038*
i23 x Mx 3-3	0.374	0.139
i12 x Mx LA	0.596	0.012*
i22 x Mx LA	-0.330	0.195
i11 x Mx LA	0.080	0.759
i21 x Mx LA	0.362	0.153

Statistically significant for p<0.05.

Table VI. Results of Pearson correlation between dental inclinations (i) and transverse measurements (x-x) in the mandibular arch at posttreatment period (N=21).

Correlations	**r**	**P**
i37 x Md 7-7	0.697	0.002*
i47 x Md 7-7	0.336	0.187
i36 x Md 6-6	0.665	0.004*
i46 x Md 6-6	0.429	0.085
i35 x Md 5-5	0.227	0.380
i45 x Md 5-5	0.611	0.009*
i34 x Md 4-4	0.458	0.064
i44 x Md 4-4	0.608	0.010*
i33 x Md 3-3	0.394	0.118
i43 x Md 3-3	0.437	0.079
i32 x Md LA	0.125	0.631
i42 x Md LA	-0.222	0.390
i31 x Md LA	-0.121	0.642
i41 x Md LA	0.128	0.623

Statistically significant for $p<0.05$.

3 DISCUSSION

3 DISCUSSION

Methodology

In this sample, patients were treated by different dentists, but in order to obtain more reliable results, measurements were made by only one previously calibrated examiner. The error study used to assess intra examiner reliability proved to be small (IWASAKI et al., 2013). No significant differences were found between measurements at two different time points. This may have occurred due to high-resolution images offering excellent view without overlapping structures.

CBCT benefits in the diagnosis and treatment plan in different dental specialties has been widely reported in the literature (DE VOS; CASSELMAN; SWENNEN, 2009; LAGRAVERE et al., 2009). Upper airway assessment was highlighted due to the great advantages of 3D images. The CBCT analysis scans are considered reliable in defining the border between soft tissues and air spaces thus providing important information about the cross-sectional area and volume of the pharyngeal airway (ABOUDARA et al., 2009; LENZA et al., 2010). Besides, the CBCT system was developed for the analysis of the craniofacial complex with the advantage of reducing the radiation dose and generating images with high quality when compared to medical tomography scans (MOZZO et al., 1998; HONEY et al., 2007; EL; PALOMO, 2014). However, when compared with resonance magnetic images, CBCT scans has its limitation as difficulty in distinguishing between different types of soft tissues, bordering the upper airway, muscles, fat, and connective tissue (LENZA et al., 2010).

For the airways measurement, it was used the Dolphin Imaging® which is a program that has already been described in the literature as a software that allows this evaluation in a simple, practical way and with a minimum of errors (ALVES et al., 2012; MATTOS et al., 2014), ensuring the reliability of the results obtained in this study. Threshold of 30 was used, before and after orthodontic treatment with Damon System to compare changes of the upper airways, except of four patients that had their exams in other CBCT machine. However, according to Feng et al. (FENG et al.,

2015) variations of threshold do not produce significant difference among the measurements.

Patient age is another factor that can influence the upper airway measurements. The craniofacial development obtained by growth can cause a dimensions increase of the oropharyngeal airspace. The literature shows the oropharyngeal airspace can suffer changes from growth until 13 years old (JEANS et al., 1981). A quiescence period for pharyngeal structures has been reported in adolescents with 14 from 18 years age (TAYLOR et al., 1996). Consequently, results found in this study do not carry the risk of presenting bias, since the mean age of the patients was of 14.99 ±1.27 years.

Studies showed that there is great variability in determining the boundaries of the air spaces evaluated in the different papers. International consensus on the region limits does not currently exist, particularly of the landmarks or planes used to demarcate the junction of the nasal cavity, nasopharynx and between regions of the pharynx. The present study evaluated only the alterations in the oropharyngeal region, due to the difficulty of evaluating the nasopharyngeal. One study compared the reliability and accuracy of airway measurement in three dimensions of three different software programs. The authors observed a precision discrepancy in the volume quantification between the different evaluated software. According to the authors, the greatest divergences occurred during the nasopharyngeal evaluation, due to the presence of several anatomical structures such as turbinates and nasal septum (ABI-RAMIA et al., 2010).

Buccolingual inclination and arches dimension changes

The main advantage attributed to self-ligating brackets is the treatment time reduction (EBERTING; STRAJA; TUNCAY, 2001; HARRADINE, 2001). However, there is a lack of evidence due to conflicting findings. Some authors reported a efficiency of self-ligating brackets in the alignment and leveling of the arches (PANDIS; POLYCHRONOPOULOU; ELIADES, 2007; SCOTT et al., 2008; FLEMING et al., 2009) and overall time (MILES, 2009) while others disagree, performing prospective clinical studies (FLEMING; JOHAL, 2010; DIBIASE et al., 2011). The treatment time mean in the present study was 2.58 ± 0.98 years, higher when compared to other studies that used self-ligating brackets (JOHANSSON; LUNDSTRÖM, 2012; MACHIBYA et al., 2013), probably due patients treated by different dentists.

The crowding correction in non-extractions cases treated promotes the incisors buccal inclination and arches transverse increase, regardless of the bracket type (CATTANEO et al., 2011; LOMBARDO et al., 2012; BASCIFTCI et al., 2014). In this study, the Damon system produced arches dimensions changes and in the pattern of tooth movement differently in the maxillary and mandibular arches. In the maxillary arch, there was an increase in the interpremolar width (4.40 ± 1.55 mm) with significant buccal inclination and a significant intermolar distances increase without significant dental crowns alteration. This result corroborate with the literature. According to the Damon system authors the low friction added to light forces allow a physiological adaptation to which the lips would be able to avoid the incisors buccal inclination and an expansion would be produced in the posterior teeth with body movement and minimal buccal inclination (DAMON, 1998a, 1998b). Unlike this study, Atik and Ciger (ATIK; CIGER, 2014) showed a buccal inclination of the maxillary molars in a group treated with the Damon system. Yu et al. (GARRETT et al., 2008; YU et al., 2008) compared the effects of Rapid Maxillary Expansion with the Damon System for correction of dental crowding and showed that occurred molars buccal inclination in both groups. Probably this results found in these works is related to the amount of expansion promoted by the treatment. Another study where CBCT was used to measure the inclination angle of the molars following rapid maxillary expansion, the inclination angle was reported to have increased in the maxillary posterior teeth (Ghoneima et al, 2010). This provides justification for excluding patients with posterior crossbite, as these teeth, show more dental tipping than the treatment effects on teeth in this study.

Studies regarding buccolingual molar inclination support the generally accepted idea that palatal inclination of permanent molars in the coronal plane is part of the normal occlusal scheme (ANDREWS, 1972; SMITH, 1986). In these studies, the results showed that palatal tipping of the maxillary molars increased with age, and this occurs as the arches increase in width in the molar region from 9 to 14 years of age. The molar uprighting that was found in this sample during normal growth justifies achieving a more upright posterior tooth position by the orthodontic treatment end. All maxillary molars palatal inclination showed, although not statistically significant, an interesting increase in this sample. Our findings confirmed previously reported results for subjects with Class I occlusion (FERRARIO et al., 2001; MARSHALL et al., 2003) which studied buccolingual molar inclination in untreated subjects with Class I occlusion. They reported that maxillary first and second molars uprighted palatally by means of 3.3º and 5.9º, respectively. They concluded that the 3-dimensional inclination of the facial axis of the clinical crown changes from adolescence to young adulthood, with an age-related palatal inclination. There is no evidence that these findings are temporally related to the permanent second molar eruption. Bjork (BJORK; SKIELLER, 1972) stated that tooth position changes constantly to compensate for changes in jaw position during growth.

There was no significant increase in maxillary intercanine width. This is a controversial result with literature, which show an increase in the intercanine width for crowding corrections (TECCO et al., 2009; PANDIS et al., 2010; PANDIS et al., 2011; VAJARIA et al., 2011). This can be justified because the maxillary canine position in cases of significant absence of space. Normally, the canines are located in a more buccal position relative to the adjacent teeth at the treatment beginning. Therefore, when realizing the alignment and leveling with enlarged Damon arches there will be no significant changes in its position at the treatment end, in the canine region. There was a significant increase in maxillary length and can be justified by the significant incisors labial inclination. Others studies found similar results in cases with crowding treated with Damon System with non-extraction (LOMBARDO et al., 2012; MALTAGLIATI et al., 2013; PANDIS et al., 2014).

In mandibular arch, the Damon System produced a significant increase in intermolars, interpremolars and intercanines width confirming literature findings (YU et al., 2008; ATIK; CIGER, 2014; ATIK et al., 2016). In cases with non-extraction the literature shows that the passive self-ligating brackets produce an increase in the intermolar width statistically higher than conventional appliances, even with different degrees of initial crowding (PANDIS et al., 2010; PANDIS et al., 2011). However, studies showed that arch expansion in the posterior region did not promote gain of space in anterior region. The arch alignment is promoted with buccal inclination of the incisors crown and an increase in the intercanine width (BURKE et al., 1998; PANDIS; POLYCHRONOPOULOU; ELIADES, 2007; FLEMING et al., 2009).

Although the intercanine width increased, the results of this study did not show a significant increase in the mandibular length even with the buccal inclination of the mandibular incisor crowns. This can be explained by the significant increase in intercanine, interpremolar and intermolar widths. There was a significant increase of the transverse measurements throughout the arch, which allowed the reduction of labial tip of the mandibular incisors. Consequently, there was no significant increase in arch length. This result in the mandibular arch corroborates Damon's affirmation (DAMON, 1998a) that the use a low friction bracket system allows a greater distal sliding of the wire during alignment avoiding excessive inclination of the anterior teeth obtaining space through the transverse increase of the arches.

Upper airway changes with Damon System

The malocclusion type do not influence pharyngeal airway width (WATSON; WARREN; FISCHER, 1968; DE FREITAS et al., 2006; ALVES et al., 2008). However, literature shows that patients who presents maxillary constriction tend to have a higher nasal airway resistance (CISTULLI; SULLIVAN, 2000) and reported that in this cases a RME can be the treatment for respiratory disturbs (BUCCHERI; DILELLA; STELLA, 2003; ZHAO et al., 2010; PANGRAZIO-KULBERSH et al., 2012; RIBEIRO et al., 2012; SMITH et al., 2012). Some authors (SMITH et al., 2012; EL; PALOMO, 2014) have reported a significant enlargement of the nasal cavity and nasopharynx, but no significant increase in the other investigated airway compartments, such as the oropharynx and hypopharynx, suggesting that effects on the upper airway were local as a result of soft tissue adaptation farther from the midpalatal suture (CHANG et al., 2013). However, studies have reported that the increase in nasal air space promoted by RME resulted in the respiratory pattern from mouth to a nasal due to improved airflow (GRAY, 1975). In addition, previous studies have shown that the maxillary arch transverse increase in patients treated with RME produced a change in tongue posture, especially when the intermolar distance was increased (OZBEK et al., 2009).

In the present study patients presented severe initial crowding in the maxillary arch (11.39 ± 5.11 mm) and in the mandibular arch (8.36 ± 3.56mm), were treated orthodontically with the Damon system with non-extraction. The results showed that there was a significant increase in 4-4 / 5-5 / 6-6 / 7-7 width. However, there were no significant changes in the oropharynx volume and dimensions with increased transverse distances of the maxillary arch.

Since the tongue and soft tissues position of the pharynx are important factors that may affect the shape and volume of the airways, it was speculated that the transverse enlargement of the arch could alter the dimensions and volume of the oropharynx. Iwasaki et al. (IWASAKI et al., 2013) performed a study that assessed the secondary effects of RME by CBCT scans and concluded that there was an improvement in tongue posture after treatment in patients with nasal obstruction who had low tongue posture. However, there was no significant association with increased pharyngeal airway volume. A similar result was found by Chang et al. study (CHANG et al., 2013) who evaluated the transverse changes produced in the maxillary arch in patients treated with RME using computed tomography and found a mean increase of 4.8 mm in interpremolars and intermolars width although not found significant differences in the total airway volume.

Other study investigated the upper airway changes after rapid maxillary expansion utilizing CBCT in 16 children (10 male, 6 female) with a mean age of 12.73 ± 1.73 years. There is no significant changes in the nasopharyngeal airway while the oropharyngeal airway decreased a little (ZENG; GAO, 2013). One of the reasons were attributed for these results was the average expansion amount about 4.4 ± 1.3 mm, which may be not large enough to expand the pharyngeal airway. Similar result was found in this study, which obtained a mean expansion amount of 4.40 ± 1.55 mm in the maxillary first premolars width. Despite the results found in this study, there was a significant negative correlation between the changes of the upper airway area ($r = -0.691$ $p = 0.002$) and volume ($r = -0.707$ $p = 0.001$) with the mandibular arch length. According to Gurani et al. (GURANI et al., 2016) there is a lack of data in the literature demonstrating the effects of tongue posture on upper airway morphology and dimensions.

Limitations

Ideally, all initial and final CBCT scans should have been performed following the same protocol using the same device. However, it was not possible due to the temporary unavailability of one device (i-Cat) during final CBCT scans period. Thus, in order to avoid a reduction the patients number and make it unworkable, they were kept in research, since during the initial tests was observed a homogeneity in the image quality of both i-Cat, voxel size 0.25mm and Accuitomo, voxel size 0.33mm devices.

The data from this study should be interpreted with caution, since the research evidence for one CBCT machine may not apply to other equipment.

4 FINAL CONSIDERATIONS

4 FINAL CONSIDERATIONS

The Damon System promoted significant expansion on the posterior region of the dental arches, with higher expansion in premolars. In the maxillary, there was an arch expansion with a significant buccal inclination of incisors and premolars while molars showed no significant lingual inclination of crown. In the mandibular arch, there was a significant expansion, (with exception left canine and left first molar) Furthermore, there were significant increase of maxillary arch length, in contrast no significant mandibular arch length changes were found at posttreatment with Damon System. Regarding upper airway, there were no statiscally differences in dimensions and volume after treatment with Damon System. These findings suggesting that the dentoalveolar expansion crated by Damon System not produced a tongue position changes capable of producing significant changes in the upper airways.

REFERENCES

REFERENCES

Abi-Ramia LBP, Carvalho FAR, Coscarelli CT, Almeida MAdO. Aparelho de avanço mandibular aumenta o volume da via aérea superior de pacientes com apneia do sono. Dental Press J Orthod. 2010;15(5):166-71.

Aboudara C, Nielsen I, Huang JC, Maki K, Miller AJ, Hatcher D. Comparison of airway space with conventional lateral headfilms and 3-dimensional reconstruction from cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2009;135(4):468-79.

Alves M, Jr., Baratieri C, Mattos CT, Brunetto D, Fontes Rda C, Santos JR, et al. Is the airway volume being correctly analyzed? Am J Orthod Dentofacial Orthop. 2012;141(5):657-61.

Alves PV, Zhao L, O'Gara M, Patel PK, Bolognese AM. Three-dimensional cephalometric study of upper airway space in skeletal class II and III healthy patients. J Craniofac Surg. 2008;19(6):1497-507.

Andrews LF. The six keys to normal occlusion. Am J Orthod. 1972;62(3):296-309.

Atik E, Akarsu-Guven B, Kocadereli I, Ciger S. Evaluation of maxillary arch dimensional and inclination changes with self-ligating and conventional brackets using broad archwires. Am J Orthod Dentofacial Orthop. 2016;149(6):830-7.

Atik E, Ciger S. An assessment of conventional and self-ligating brackets in Class I maxillary constriction patients. Angle Orthod. 2014;84(4):615-22.

Basciftci FA, Akin M, Ileri Z, Bayram S. Long-term stability of dentoalveolar, skeletal, and soft tissue changes after non-extraction treatment with a self-ligating system. Korean J Orthod. 2014;44(3):119-27.

Baumrind S, Miller D, Molthen R. The reliability of head film measurements. 3. Tracing superimposition. Am J Orthod. 1976;70(6):617-44.

Birnie D, editor The Damon passive self-ligating appliance system. Seminars in Orthodontics; 2008: Elsevier.

Bjork A, Skieller V. Facial development and tooth eruption. An implant study at the age of puberty. Am J Orthod. 1972;62(4):339-83.

Buccheri A, Dilella G, Stella R. Rapid palatal expansion and pharyngeal space. Cephalometric evaluation. Progress in orthodontics. 2003;5(2):160-71.

Burke SP, Silveira AM, Goldsmith LJ, Yancey JM, Van Stewart A, Scarfe WC. A meta-analysis of mandibular intercanine width in treatment and postretention. Angle Orthod. 1998;68(1):53-60.

Cattaneo PM, Treccani M, Carlsson K, Thorgeirsson T, Myrda A, Cevidanes LH, et al. Transversal maxillary dento-alveolar changes in patients treated with active and passive self-ligating brackets: a randomized clinical trial using CBCT-scans and digital models. Orthod Craniofac Res. 2011;14(4):222-33.

Chang Y, Koenig LJ, Pruszynski JE, Bradley TG, Bosio JA, Liu D. Dimensional changes of upper airway after rapid maxillary expansion: a prospective cone-beam computed tomography study. Am J Orthod Dentofacial Orthop. 2013;143(4):462-70.

Chen SS-H, Greenlee GM, Kim J-E, Smith CL, Huang GJ. Systematic review of self-ligating brackets. Am J Orthod Dentofacial Orthop. 2010;137(6):726. e1-. e18.

Cistulli PA, Sullivan CE. Influence of maxillary morphology on nasal airway resistance in Marfan's syndrome. Acta Otolaryngol. 2000;120(3):410-3.

Damon DH. The Damon low-friction bracket: a biologically compatible straight-wire system. J Clin Orthod. 1998a;32(11):670-80.

Damon DH. The rationale, evolution and clinical application of the self-ligating bracket. Clin Orthod Res. 1998b;1(1):52-61.

de Freitas MR, Alcazar NM, Janson G, de Freitas KM, Henriques JF. Upper and lower pharyngeal airways in subjects with Class I and Class II malocclusions and different growth patterns. Am J Orthod Dentofacial Orthop. 2006;130(6):742-5.

De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg. 2009;38(6):609-25.

DiBiase AT, Nasr IH, Scott P, Cobourne MT. Duration of treatment and occlusal outcome using Damon3 self-ligated and conventional orthodontic bracket systems in extraction patients: a prospective randomized clinical trial. Am J Orthod Dentofacial Orthop. 2011;139(2):e111-e6.

Eberting JJ, Straja SR, Tuncay OC. Treatment time, outcome, and patient satisfaction comparisons of Damon and conventional brackets. Clin Orthod Res. 2001;4(4):228-34.

El H, Palomo JM. Three-dimensional evaluation of upper airway following rapid maxillary expansion: a CBCT study. Angle Orthod. 2014;84(2):265-73.

Feng X, Li G, Qu Z, Liu L, Nasstrom K, Shi XQ. Comparative analysis of upper airway volume with lateral cephalograms and cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2015;147(2):197-204.

Ferrario VF, Sforza C, Colombo A, Ciusa V, Serrao G. Three-dimensional inclination of the dental axes in healthy permanent dentitions--A cross-sectional study in a normal population. Angle Orthod. 2001;71(4):257-64.

Fleming PS, DiBiase AT, Sarri G, Lee RT. Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances. Am J Orthod Dentofacial Orthop. 2009;136(3):340-7.

Fleming PS, Johal A. Self-ligating brackets in orthodontics. A systematic review. Angle Orthod. 2010;80(3):575-84.

Garrett BJ, Caruso JM, Rungcharassaeng K, Farrage JR, Kim JS, Taylor GD. Skeletal effects to the maxilla after rapid maxillary expansion assessed with cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2008;134(1):8-9.

Gray LP. Results of 310 cases of rapid maxillary expansion selected for medical reasons. J Laryngol Otol. 1975;89(6):601-14.

Gurani SF, Di Carlo G, Cattaneo PM, Thorn JJ, Pinholt EM. Effect of Head and Tongue Posture on the Pharyngeal Airway Dimensions and Morphology in Three-Dimensional Imaging: a Systematic Review. J Oral Maxillofac Res. 2016;7(1):e1.

Harradine NW. Self-ligating brackets and treatment efficiency. Clin Orthod Res. 2001;4(4):220-7.

Honey OB, Scarfe WC, Hilgers MJ, Klueber K, Silveira AM, Haskell BS, et al. Accuracy of cone-beam computed tomography imaging of the temporomandibular joint: comparisons with panoramic radiology and linear tomography. Am J Orthod Dentofacial Orthop. 2007;132(4):429-38.

Isik F, Sayinsu K, Nalbantgil D, Arun T. A comparative study of dental arch widths: extraction and non-extraction treatment. Eur J Orthod. 2005;27(6):585-9.

Iwasaki T, Saitoh I, Takemoto Y, Inada E, Kakuno E, Kanomi R, et al. Tongue posture improvement and pharyngeal airway enlargement as secondary effects of rapid maxillary expansion: a cone-beam computed tomography study. Am J Orthod Dentofacial Orthop. 2013;143(2):235-45.

Jeans WD, Fernando DC, Maw AR, Leighton BC. A longitudinal study of the growth of the nasopharynx and its contents in normal children. Br J Radiol. 1981;54(638):117-21.

Johansson K, Lundström F. Orthodontic treatment efficiency with self-ligating and conventional edgewise twin brackets: a prospective randomized clinical trial. Angle Orthod. 2012;82(5):929-34.

Lagravere MO, Gordon JM, Guedes IH, Flores-Mir C, Carey JP, Heo G, et al. Reliability of traditional cephalometric landmarks as seen in three-dimensional analysis in maxillary expansion treatments. Angle Orthod. 2009;79(6):1047-56.

Lenza MG, Lenza MM, Dalstra M, Melsen B, Cattaneo PM. An analysis of different approaches to the assessment of upper airway morphology: a CBCT study. Orthod Craniofac Res. 2010;13(2):96-105.

Lombardo L, Ficara P, Maltoni I, Moser L, Guarneri MP, Siciliani G. Comparison of the anterior limit of the dentition in patients treated with self-ligating straight-wire, conventional straight-wire and standard edgewise appliances. ISRN Dent. 2012;2012(748758.

Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;106(1):106-14.

Machibya FM, Bao X, Zhao L, Hu M. Treatment time, outcome, and anchorage loss comparisons of self-ligating and conventional brackets. Angle Orthod. 2013;83(2):280-5.

Maltagliati LA, Myiahira YI, Fattori L, Filho LC, Cardoso M. Transversal changes in dental arches from non-extraction treatment with self ligating brackets. Dental Press J Orthod. 2013;18(3):39-45.

Marshall S, Dawson D, Southard KA, Lee AN, Casko JS, Southard TE. Transverse molar movements during growth. Am J Orthod Dentofacial Orthop. 2003;124(6):615-24.

Mattos CT, Cruz CV, da Matta TC, Pereira Lde A, Solon-de-Mello Pde A, Ruellas AC, et al. Reliability of upper airway linear, area, and volumetric measurements in cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2014;145(2):188-97.

Miles PG. Self-ligating brackets in orthodontics: Do they deliver what they claim? Aust Dent J. 2009;54(1):9-11.

Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998;8(9):1558-64.

Ozbek MM, Memikoglu UT, Altug-Atac AT, Lowe AA. Stability of maxillary expansion and tongue posture. Angle Orthod. 2009;79(2):214-20.

Pandis N, Fleming PS, Spineli LM, Salanti G. Initial orthodontic alignment effectiveness with self-ligating and conventional appliances: a network meta-analysis in practice. Am J Orthod Dentofacial Orthop. 2014;145(4 Suppl):S152-63.

Pandis N, Polychronopoulou A, Eliades T. Self-ligating vs conventional brackets in the treatment of mandibular crowding: a prospective clinical trial of treatment duration and dental effects. Am J Orthod Dentofacial Orthop. 2007;132(2):208-15.

Pandis N, Polychronopoulou A, Eliades T. Active or passive self-ligating brackets? A randomized controlled trial of comparative efficiency in resolving maxillary anterior crowding in adolescents. Am J Orthod Dentofacial Orthop. 2010;137(1):12.e1-6; discussion -3.

Pandis N, Polychronopoulou A, Katsaros C, Eliades T. Comparative assessment of conventional and self-ligating appliances on the effect of mandibular intermolar distance in adolescent nonextraction patients: a single-center randomized controlled trial. Am J Orthod Dentofacial Orthop. 2011;140(3):e99-e105.

Pandis N, Polychronopoulou A, Makou M, Eliades T. Mandibular dental arch changes associated with treatment of crowding using self-ligating and conventional brackets. Eur J Orthod. 2010;32(3):248-53.

Pangrazio-Kulbersh V, Wine P, Haughey M, Pajtas B, Kaczynski R. Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders. Angle Orthod. 2012;82(3):448-57.

Ribeiro AN, de Paiva JB, Rino-Neto J, Illipronti-Filho E, Trivino T, Fantini SM. Upper airway expansion after rapid maxillary expansion evaluated with cone beam computed tomography. Angle Orthod. 2012;82(3):458-63.

Scott P, DiBiase AT, Sherriff M, Cobourne MT. Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: a randomized clinical trial. Am J Orthod Dentofacial Orthop. 2008;134(4):470 e1-8.

Smith BH. Development and evolution of the helicoidal plane of dental occlusion. Am J Phys Anthropol. 1986;69(1):21-35.

Smith T, Ghoneima A, Stewart K, Liu S, Eckert G, Halum S, et al. Three-dimensional computed tomography analysis of airway volume changes after rapid maxillary expansion. Am J Orthod Dentofacial Orthop. 2012;141(5):618-26.

Tarkar JS, Parashar S, Gupta G, Bhardwaj P, Maurya RK, Singh A, et al. An Evaluation of Upper and Lower Pharyngeal Airway Width, Tongue Posture and Hyoid Bone Position in Subjects with Different Growth Patterns. J Clin Diagn Res. 2016;10(1):Zc79-83.

Taylor M, Hans MG, Strohl KP, Nelson S, Broadbent BH. Soft tissue growth of the oropharynx. Angle Orthod. 1996;66(5):393-400.

Tecco S, Tete S, Perillo L, Chimenti C, Festa F. Maxillary arch width changes during orthodontic treatment with fixed self-ligating and traditional straight-wire appliances. World J Orthod. 2009;10(4):290-4.

Vajaria R, BeGole E, Kusnoto B, Galang MT, Obrez A. Evaluation of incisor position and dental transverse dimensional changes using the Damon system. Angle Orthod. 2011;81(4):647-52.

Villa MP, Malagola C, Pagani J, Montesano M, Rizzoli A, Guilleminault C, et al. Rapid maxillary expansion in children with obstructive sleep apnea syndrome: 12-month follow-up. Sleep Med. 2007;8(2):128-34.

Villa MP, Rizzoli A, Miano S, Malagola C. Efficacy of rapid maxillary expansion in children with obstructive sleep apnea syndrome: 36 months of follow-up. Sleep Breath. 2011;15(2):179-84.

Watson RM, Jr., Warren DW, Fischer ND. Nasal resistance, skeletal classification, and mouth breathing in orthodontic patients. Am J Orthod. 1968;54(5):367-79.

Weinberg M, Sadowsky C. Resolution of mandibular arch crowding in growing patients with Class I malocclusions treated nonextraction. Am J Orthod Dentofacial Orthop. 1996;110(4):359-64.

Yu YL, Tang GH, Gong FF, Chen LL, Qian YF. [A comparison of rapid palatal expansion and Damon appliance on non-extraction correction of dental crowding]. Shanghai Kou Qiang Yi Xue. 2008;17(3):237-42.

Zeng J, Gao X. A prospective CBCT study of upper airway changes after rapid maxillary expansion. Int J Pediatr Otorhinolaryngol. 2013;77(11):1805-10.

Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2010;137(4 Suppl):S71-8.

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 "Evaluation of upper airway and dental arches dimensions in cases treated with Damon System: A CBCT study" will be included in Thesis of the student Bruno da Silva Vieira and may not be used in other works of Graduate Programs at the Bauru Dental School, University of São Paulo.

Bauru, December 09th of 2017.

Bruno da Silva Vieira ____________________ Signature

Guilherme Janson ____________________ Signature

Marcos Roberto de Freitas ____________________ Signature

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 “Evaluation of dimensional arche and buccolingual inclination changes with the Damon System through Cone-beam computed tomography will be included in Thesis of the student Bruno da Silva Vieira and may not be used in other works of Graduate Programs at the Bauru Dental School, University of São Paulo.

Bauru, December 09th of 2017.

Bruno da Silva Vieira ______________________
Signature

Guilherme Janson ______________________
Signature

Marcos Roberto de Freitas ______________________
Signature

ANNEXES

ANNEXES

ANNEX A – Research Institutional Board approval, protocol number 1.567.403 (front)

FACULDADE DE ODONTOLOGIA DE BAURU-USP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Avaliações dimensionais dos arcos dentários, das vias aéreas superiores e do volume da língua por meio de Tomografia Computadorizada Cone Beam (TCCB) pós-tratamento ortodôntico com o sistema autoligável Damon.

Pesquisador: Bruno Vieira

Área Temática:

Versão: 2

CAAE: 53777916.7.0000.5417

Instituição Proponente: Universidade de Sao Paulo

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.567.403

Apresentação do Projeto:

Projeto : Avaliações dimensionais dos arcos dentários, das vias aéreas superiores e do volume da língua por meio de Tomografia Computadorizada Cone Beam (TCCB) pós-tratamento ortodôntico com o sistema autoligável Damon

Idem parecer Número 1.456.340

Objetivo da Pesquisa:

Idem parecer Número 1.456.340

Avaliação dos Riscos e Benefícios:

Idem parecer Número 1.456.340

Comentários e Considerações sobre a Pesquisa:

O projeto analisado em reunião constava seguintes pendencias:

Incoerência quanto ao numero das amostras que serão examinadas.

Justificativa para o uso de (TCCB), no tratamento realizado.

Adequação da solicitação de dispensa do TCLE.

Endereço: DOUTOR OCTAVIO PINHEIRO BRISOLLA 75 QUADRA 9
Bairro: VILA NOVA CIDADE UNIVERSITARIA **CEP:** 17.012-901
UF: SP **Município:** BAURU
Telefone: (14)3235-8356 **Fax:** (14)3235-8356 **E-mail:** cep@fob.usp.br

FACULDADE DE ODONTOLOGIA DE BAURU-USP

Plataforma Brasil

Continuação do Parecer: 1.567.403

Considerações sobre os Termos de apresentação obrigatória:

Quanto as pendencias apontadas as justificativas apresentadas foram:

Amostra:

A amostra será constituída pela documentação inicial e final de 22 pacientes.

Dispensa do TCLE:

A seleção da amostra será de caráter retrospectivo, realizada a partir dos prontuários pertencentes ao arquivo da disciplina de Ortodontia, do Departamento de Odontopediatria, Ortodontia e Saúde Coletiva da Faculdade de Odontologia de Bauru - Universidade de São Paulo.

Justificativa para o uso de (TCCB), no tratamento realizado

Os pacientes tratados com o aparelho autoligado passivo Damon fazem parte de uma amostra já tratada na disciplina de Ortodontia do Departamento de Odontopediatria, Ortodontia e Saúde Coletiva da Faculdade de Odontologia de Bauru. Estudos anteriores foram desenvolvidos na referida disciplina, avaliando esta amostra e foram submetidos previamente à análise neste mesmo Comitê, tendo o parecer favorável (CEP: registro CAAE: 23216514.3.0000.5417 em 12/03/2014; Processo n° 120/2011 em 31/08/2011; Processo n0 136/2010 em 23/02/2011)

Recomendações:

não se aplica

Conclusões ou Pendências e Lista de Inadequações:

não se aplica

Considerações Finais a critério do CEP:

Esse projeto foi considerado APROVADO na reunião ordinária do CEP de 18.05.2016, 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.

Endereço: DOUTOR OCTAVIO PINHEIRO BRISOLLA 75 QUADRA 9
Bairro: VILA NOVA CIDADE UNIVERSITARIA **CEP:** 17.012-901
UF: SP **Município:** BAURU
Telefone: (14)3235-8356 **Fax:** (14)3235-8356 **E-mail:** cep@fob.usp.br

FACULDADE DE ODONTOLOGIA DE BAURU-USP

Continuação do Parecer: 1.567.403

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_658354.pdf	11/05/2016 09:11:02		Aceito
Outros	Uso_do_arquivo.pdf	11/05/2016 09:09:42	Bruno Vieira	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_de_Pesquisa_corrigido.docx	10/05/2016 09:42:27	Bruno Vieira	Aceito
Outros	Questionario_Projeto_Pesquisa.pdf	10/05/2016 09:39:13	Bruno Vieira	Aceito
Recurso Anexado pelo Pesquisador	Recurso_Pesquisador.pdf	10/05/2016 09:34:30	Bruno Vieira	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	Dispensa_do_TCLE.pdf	10/05/2016 09:32:05	Bruno Vieira	Aceito
Declaração de Pesquisadores	Termo_de_compromisso_resultados.pdf	24/02/2016 21:12:19	Bruno Vieira	Aceito
Outros	Termo_de_aquiescencia_externo.pdf	24/02/2016 21:07:42	Bruno Vieira	Aceito
Outros	Termo_de_Aquiescencia.pdf	24/02/2016 21:02:03	Bruno Vieira	Aceito
Folha de Rosto	Folha_de_rosto.pdf	24/02/2016 20:55:24	Bruno Vieira	Aceito

Situação do Parecer:
Aprovado

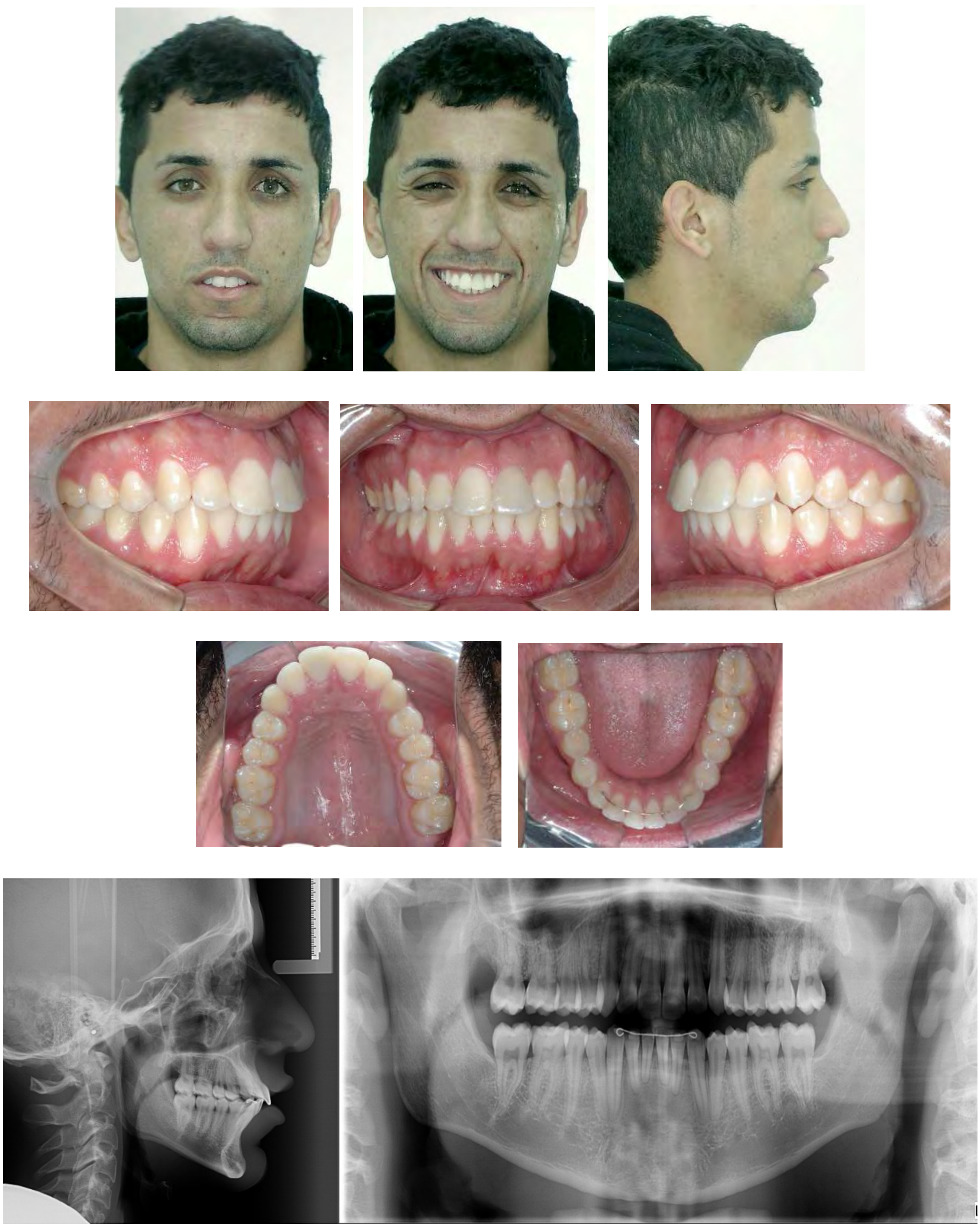
Necessita Apreciação da CONEP:
Não

BAURU, 30 de Maio de 2016

Assinado por:
Izabel Regina Fischer Rubira Bullen
(Coordenador)

Endereço: DOUTOR OCTAVIO PINHEIRO BRISOLLA 75 QUADRA 9
Bairro: VILA NOVA CIDADE UNIVERSITARIA **CEP:** 17.012-901
UF: SP **Município:** BAURU
Telefone: (14)3235-8356 **Fax:** (14)3235-8356 **E-mail:** cep@fob.usp.br

ANNEX B - One of the patients that illustrates the main facial and occlusal features presented by the sample patients treated with the Damon System.



ANNEX C - Guidelines for AJO-DO submissions: Original Article

AMERICAN JOURNAL OF ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS

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

TABLE OF CONTENTS

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.

According to the 2014 Journal Citation Reports®, published by Thomson Reuters, *AJO-DO* is the highest ranked orthodontic title by number of citations. *AJO-DO* ranks 9th of 87 journals for total citations in the Dentistry, Oral Surgery and Medicine category, and has a five year impact factor of 1.981.

Benefits to authors
We also provide many author benefits, such as free PDFs, a liberal copyright policy, special discounts on Elsevier publications and much more. Please click here for more information on our author services.

Please see our Guide for Authors for information on article submission. If you require any further information or help, please visit our Support Center

IMPACT FACTOR

2016: 1.472 © Thomson Reuters Journal Citation Reports 2017

ABSTRACTING AND INDEXING

CINAHL
MEDLINE®
Scopus

EDITORIAL BOARD

GUIDE FOR AUTHORS

General Information

The *American Journal of Orthodontics and Dentofacial Orthopedics* publishes original research, reviews, case reports, clinical material, and other material related to orthodontics and dentofacial orthopedics.

Submitted manuscripts must be original, written in English, and not published or under consideration elsewhere. Manuscripts will be reviewed by the editor and consultants and are subject to editorial revision. Authors should follow the guidelines below.

Statements and opinions expressed in the articles and communications herein are those of the author(s) and not necessarily those of the editor(s) or publisher, and the editor(s) and publisher disclaim any responsibility or liability for such material. Neither the editor(s) nor the publisher guarantees, warrants, or endorses any product or service advertised in this publication; neither do they guarantee any claim made by the manufacturer of any product or service. Each reader must determine whether to act on the information in this publication, and neither the Journal nor its sponsoring organizations shall be liable for any injury due to the publication of erroneous information.

Electronic manuscript submission and review

The American Journal of Orthodontics and Dentofacial Orthopedics uses the *Elsevier Editorial System (EES)*, an online manuscript submission and review system.

To submit or review an article, please go to the AJO-DO EES website: http://ees.elsevier.com/ajodo.

Rolf G. Behrents, Editor-in-Chief
E-mail: behrents@slu.edu

Send other correspondence to:
Chris Burke, Managing Editor
American Journal of Orthodontics and Dentofacial Orthopedics
University of Washington
Department of Orthodontics, D-569
HSC Box 357446
Seattle, WA 98195-7446
Telephone (206) 221-5413
E-mail:ckburke@aol.com

BEFORE YOU BEGIN

Ethics in publishing

Please see our information pages on Ethics in publishing and Ethical guidelines for journal publication.

Human and animal rights

If the work involves the use of human subjects, the author should ensure that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; Uniform Requirements for manuscripts submitted to Biomedical journals. Authors should include a statement in the manuscript that informed consent was obtained for experimentation with human subjects. The privacy rights of human subjects must always be observed.

All animal experiments should comply with the ARRIVE guidelines and should be carried out in accordance with the U.K. Animals (Scientific Procedures) Act, 1986 and associated guidelines, EU Directive 2010/63/EU for animal experiments, or the National Institutes of Health guide for the care and use of Laboratory animals (NIH Publications No. 8023, revised 1978) and the authors should clearly indicate in the manuscript that such guidelines have been followed.

Conflict of interest

Each author should complete and submit a copy of the International Committee of Medical Journal Editors Form for the Disclosure of Conflicts of Interest, available at http://www.icmje.org/conflicts-of-interest/.

Submission declaration and verification
Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see 'Multiple, redundant or concurrent publication' section of our ethics policy for more information), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. To verify originality, your article may be checked by the originality detection service CrossCheck.

Contributors
Each author is required to declare his or her individual contribution to the article: all authors must have materially participated in the research and/or article preparation, so roles for all authors should be described. The statement that all authors have approved the final article should be true and included in the disclosure.

Changes to authorship
Authors are expected to consider carefully the list and order of authors **before** submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion or rearrangement of author names in the authorship list should be made only **before** the manuscript has been accepted and only if approved by the journal Editor. To request such a change, the Editor must receive the following from the **corresponding author**: (a) the reason for the change in author list and (b) written confirmation (e-mail, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed.
Only in exceptional circumstances will the Editor consider the addition, deletion or rearrangement of authors **after** the manuscript has been accepted. While the Editor considers the request, publication of the manuscript will be suspended. If the manuscript has already been published in an online issue, any requests approved by the Editor will result in a corrigendum.

Copyright
Upon acceptance of an article, authors will be asked to complete a 'Journal Publishing Agreement' (see more information on this). An e-mail will be sent to the corresponding author confirming receipt of the manuscript together with a 'Journal Publishing Agreement' form or a link to the online version of this agreement.

Subscribers may reproduce tables of contents or prepare lists of articles including abstracts for internal circulation within their institutions. Permission of the Publisher is required for resale or distribution outside the institution and for all other derivative works, including compilations and translations. If excerpts from other copyrighted works are included, the author(s) must obtain written permission from the copyright owners and credit the source(s) in the article. Elsevier has preprinted forms for use by authors in these cases.

For open access articles: Upon acceptance of an article, authors will be asked to complete an 'Exclusive License Agreement' (more information). Permitted third party reuse of open access articles is determined by the author's choice of user license.

Author rights
As an author you (or your employer or institution) have certain rights to reuse your work. More information.

Elsevier supports responsible sharing
Find out how you can share your research published in Elsevier journals.

Role of the funding source
You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated.

Funding body agreements and policies
Elsevier has established a number of agreements with funding bodies which allow authors to comply with their funder's open access policies. Some funding bodies will reimburse the author for the Open Access Publication Fee. Details of existing agreements are available online.

Open access

The American Journal of Orthodontics and Dentofacial Orthopedics offers authors a choice in publishing their research:

Traditional Access
Articles are available at no additional cost to subscribers through individual or library subscriptions. Users in some developing countries and patient groups can access articles through our universal access programs. Other users can access articles on a pay-per-view basis. No publication fees are charged for traditional publication.

Open access
Open access articles are available to subscribers and nonsubscribers, and to the wider public with permitted reuse. For open access articles, permitted third party (re)use is defined by the following Creative Commons user licenses. The open access publication fee for this journal is $3000, excluding taxes. Learn more about Elsevier's pricing policy: http://www.elsevier.com/openaccesspricing.
Green open access

Authors can share their research in a variety of different ways and Elsevier has a number of green open access options available. We recommend authors see our green open access page for further information. Authors can also self-archive their manuscripts immediately and enable public access from their institution's repository after an embargo period. This is the version that has been accepted for publication and which typically includes author-incorporated changes suggested during submission, peer review and in editor-author communications.
Regardless of how you choose to publish your article, the journal will apply the same peer review criteria and acceptance standards.

Green open access embargo period

For subscription articles, an appropriate amount of time is needed for journals to deliver value to subscribing customers before an article becomes freely available to the public. This is the embargo period and it begins from the date the article is formally published online in its final and fully citable form. Find out more.

This journal has an embargo period of 12 months.

Language (usage and editing services)
Please write your text in good English (American or British usage is accepted, but not a mixture of these). Authors who feel their English language manuscript may require editing to eliminate possible grammatical or spelling errors and to conform to correct scientific English may wish to use the English Language Editing service available from Elsevier's WebShop.

Informed consent and patient details

Studies on patients or volunteers require ethics committee approval and informed consent, which should be documented in the paper. Appropriate consents, permissions and releases must be obtained where an author wishes to include case details or other personal information or images of patients and any other individuals in an Elsevier publication. Written consents must be retained by the author and copies of the consents or evidence that such consents have been obtained must be provided to Elsevier on request. For more information, please review the Elsevier Policy on the Use of Images or Personal Information of Patients or other Individuals. Unless you have written permission from the patient (or, where applicable, the next of kin), the personal details of any patient included in any part of the article and in any supplementary materials (including all illustrations and videos) must be removed before submission.

Submission
Our online submission system guides you stepwise through the process of entering your article details and uploading your files. The system converts your article files to a single PDF file used in the peer-review process. Editable files (e.g., Word, LaTeX) are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent by e-mail.

Blinding
The *AJO-DO* uses a blind review process; the identity of the author and the location of the research are concealed from the reviewers, and the identities of the reviewers are concealed from the author. The following submission items are sent to reviewers during the review process and should not contain any identifying information.
Manuscript * Figures * Tables * Other Material
The title page, which should contain complete author information, is not sent to reviewers. In the manuscript, please pay special attention to Material and Methods and Acknowledgments sections; wherever author is mentioned, use the "hidden" format in Word to conceal it, or move it to the title page.

Guidelines for Original Articles
guidelines Submit Original Articles via EES: http://ees.elsevier.com/ajodo.

Before you begin, please review the guidelines below. To view a 7-minute video explaining how to prepare your article for submission, go to Video on Manuscript Preparation.

1. *Title Page.* Put all information pertaining to the authors in a separate document. Include the title of the article, full name(s) of the author(s), academic degrees, and institutional affiliations and positions; identify the corresponding author and include an address, telephone and fax numbers, and an e-mail address. This information will not be available to the reviewers.

2. *Abstract.* Structured abstracts of 200 words or less are preferred. A structured abstract contains the following sections: Introduction, describing the problem; Methods, describing how the study was performed; Results, describing the primary results; and Conclusions, reporting what the authors conclude from the findings and any clinical implications.

3. *Manuscript.* The manuscript proper should be organized in the following sections: Introduction and literature review, Material and Methods, Results, Discussion, Conclusions, References, and figure captions. Express measurements in metric units, whenever practical. Refer to teeth by their full name or their FDI tooth number. For style questions, refer to the *AMA Manual of Style, 10th edition*. Cite references selectively, and number them in the order cited. Make sure that all references have been mentioned in the text. Follow the format for references in "Uniform Requirements for Manuscripts Submitted to Biomedical Journals" (Ann Intern Med 1997;126:36-47); http://www.icmje.org. Include the list of references with the manuscript proper. Submit figures and tables separately (see below); do not embed figures in the word processing document.

4. *Figures.* Digital images should be in TIF or EPS format, CMYK or grayscale, at least 5 inches wide and at least 300 pixels per inch (118 pixels per cm). Do not embed images in a word processing program. If published, images could be reduced to 1 column width (about 3 inches), so authors should ensure that figures will remain legible at that scale. For best results, avoid screening, shading, and colored backgrounds; use the simplest patterns available to indicate differences in charts. If a figure has been previously published, the legend (included in the manuscript proper) must give full credit to the original source, and written permission from the original publisher must be included. Be sure you have mentioned each figure, in order, in the text.

5. *Tables.* Tables should be self-explanatory and should supplement, not duplicate, the text. Number them with Roman numerals, in the order they are mentioned in the text. Provide a brief title for each. If a table has been previously published, include a footnote in the table giving full credit to the original source and include written permission for its use from the copyright holder. Submit tables as text-based files (Word is preferred, Excel is accepted) and not as graphic elements. Do not use colors, shading, boldface, or italic in tables. Do not submit tables as parts A and B; divide into 2 separate tables. Do not "protect" tables by making them "read-only." The table title should be put above the table and not as a cell in the table. Similarly, table footnotes should be under the table, not table cells.

6. *Model release and permission forms.* Photographs of identifiable persons must be accompanied by a release signed by the person or both living parents or the guardian of minors. Illustrations or tables that have appeared in copyrighted material must be accompanied by written permission for their use from the copyright owner and original author, and the legend must properly credit the source. Permission also must be obtained to use modified tables or figures.

7. *Copyright release.* In accordance with the Copyright Act of 1976, which became effective February 1, 1978, all manuscripts must be accompanied by the following written statement, signed by all authors: *"The undersigned author(s) transfers all copyright ownership of the manuscript [insert title of article here] to the American Association of Orthodontists in the event the work is published. The undersigned author(s) warrants that the article is original, does not infringe upon any copyright or other proprietary right of any third party, is not under consideration by another journal, has not been previously published, and includes any product that may derive from the published journal, whether print or electronic media. I (we) sign for and accept responsibility for releasing this material."* Scan the printed copyright release and submit it via EES.

8. *Use the International Committee of Medical Journal Editors Form for the Disclosure of Conflict of Interest (ICMJE Conflict of Interest Form).* If the manuscript is accepted, the disclosed information will be published with the article. The usual and customary listing of sources of support and institutional affiliations on the title page is proper and does not imply a conflict of interest. Guest editorials, Letters, and Review articles may be rejected if a conflict of interest exists.

9. *Institutional Review Board approval.* For those articles that report on the results of experiments of treatments where patients or animals have been used as the sample, Institutional Review Board (IRB) approval is mandatory. No experimental studies will be sent out for review without an IRB approval accompanying the manuscript submission.

Guidelines for Systematic Reviews

Systematic Reviews and Meta-Analyses must be prepared according to contemporary PRISMA (Preferred Reporting for Systematic Reviews and Meta-Analyses) standards. The *AJO-DO* will screen submissions for compliance before beginning the review process. To help authors understand and apply the standards, we have prepared a separate Guidelines for AJO-DO Systematic Reviews and Meta-Analyses. This guide includes links to a Model Orthodontic Systematic Review and an accompanying Explanation and Elaboration document.

These guidelines are supplemental to the Guidelines for Original Articles, which describe how to meet general submission requirements, such as figure formats, reference style, required releases, and blinding.

Systematic Review and Meta-Analysis Guide for Authors
You can access a link to an annotated example of a Model Orthodontic Systematic Review. Further explanation of reporting practices is given in the accompanying Explanation and Elaboration document. These documents have been prepared in accordance with PRISMA guidelines and the "PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies that Evaluate Health Care Interventions: Explanations and Elaboration" (http://www.plosmedicine.org/article/info:doi/10.1371/journal.pmed.1000100).

However, we have made these guidelines more relevant to orthodontics and have adapted the reporting template to encourage transparent and pertinent reporting by introducing subheadings corresponding to established PRISMA items.

Further information on reporting of systematic reviews can also be obtained in the Cochrane Handbook for Systematic Reviews of Interventions (http://www.cochrane-handbook.org).

Guidelines for Randomized Clinical Trials

Randomized Clinical Trials must meet current CONSORT (Consolidated Standards of Reporting Trials) requirements. The *AJO-DO* will screen submissions for compliance before beginning the review process. To help authors understand and apply the standards, we have prepared a separate document, Guidelines for AJO-DO Submissions: Randomized Clinical Trials. This document contains links to an Annotated RCT Sample Article and The CONSORT Statement: Application within and adaptations for orthodontic trials.

These guidelines are supplemental to the Guidelines for Original Articles, which describe how to meet general submission requirements, such as figure formats, reference style, required releases, and blinding.

Guidelines for Miscellaneous Submissions

Letters to the Editor and their responses appear in the Readers' Forum section and are encouraged to stimulate healthy discourse between authors and our readers. Letters to the Editor must refer to an article that was published within the previous six (6) months and must be less than 500 words including references. Submit Letters via the EES Web site. Submit a signed copyright release with the letter.

Brief, substantiated commentary on subjects of interest to the orthodontic profession is published occasionally as a Special Article. Submit Guest Editorials and Special Articles via the Web site.

Books and monographs (domestic and foreign) will be reviewed, depending upon their interest and value to subscribers. Send books to Chris Burke, Department of Orthodontics, University of Washington D-569, HSC Box 357446, Seattle,WA98195-7446. They will not be returned.

Checklist for Authors

____Title page, including full name, academic degrees, and institutional affiliation and position of each author; brief description of each author's contribution to the submission; and author to whom correspondence and reprint requests are to be sent, including address, business and home phone numbers, fax numbers, and e-mail address

____Highlights (up to 5 Highlights, written in complete sentences, 85 characters each

____Abstract (structured, 250 words; a graphical abstract is optional)

____Manuscript, including references and figure legends

____Figures, in TIF or EPS format

____Tables

____Copyright release statement, signed by all authors

____Photographic consent statement(s)

____ICMJE Conflict of interest statement for each author

____Permissions to reproduce previously published material

____Permission to reproduce proprietary images (including screenshots that include a company logo)

PREPARATION

Double-blind review

This journal uses double-blind review, which means the identities of the authors are concealed from the reviewers, and vice versa. More information is available on our website. To facilitate this, please include the following separately:
Title page (with author details): This should include the title, authors' names, affiliations, acknowledgements and any Declaration of Interest statement, and a complete address for the corresponding author including an e-mail address.
Blinded manuscript (no author details): The main body of the paper (including the references, figures, tables and any acknowledgements) should not include any identifying information, such as the authors' names or affiliations.

Article structure

Introduction
Provide an adequate background so readers can understand the nature of the problem and its significance. State the objectives of the work. Cite literature selectively, avoiding a detailed literature survey or a summary of the results.

Material and Methods
Provide sufficient detail to allow the work to be reproduced. If methods have already been published, indicate by a reference citation and describe only the relevant modifications. Include manufacturer information (company name and location) for any commercial product mentioned. Report your power analysis and ethics approval, as appropriate.

Results
Results should be clear and concise.

Discussion
Explain your findings and explore their significance. Compare and contrast your results with other relevant studies. Mention the limitations of your study, and discuss the implications of the findings for future research and for clinical practice. Do not repeat information given in other parts of the manuscript.

Conclusions
Write a short Conclusions section that can stand alone. If possible, refer back to the goals or objectives of the research.

Essential title page information

• ***Title.*** Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.
• ***Author names and affiliations.*** Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.
• ***Corresponding author.*** Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. This responsibility includes answering any future queries about Methodology and Materials. **Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.**
• ***Present/permanent address.*** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

Abstract

A structured abstract using the headings Introduction, Methods, Results, and Conclusions is required for Original Article, Systematic Review, Randomized Controlled Trial, and Techno Bytes. An unstructured abstract is acceptable for Case Report and Clinician's Corner.

Graphical abstract
Although a graphical abstract is optional, its use is encouraged as it draws more attention to the online article. The graphical abstract should summarize the contents of the article in a concise, pictorial form designed to capture the attention of a wide readership. Graphical abstracts should be submitted as a separate file in the online submission system. Image size: Please provide an image with a minimum of 531 × 1328 pixels (h × w) or proportionally more. The image should be readable at a size of 5 × 13 cm using a regular screen resolution of 96 dpi. Preferred file types: TIFF, EPS, PDF or MS Office files. You can view Example Graphical Abstracts on our information site.
Authors can make use of Elsevier's Illustration Services to ensure the best presentation of their images and in accordance with all technical requirements.

Highlights
Highlights are a short collection of bullet points that convey the core findings of the article. Highlights are optional and should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point). You can view example Highlights on our information site.

Acknowledgments

Collate acknowledgments in a separate section at the end of the article before the references; do not include them on the title page, as a footnote to the title page, or otherwise. List here those individuals who provided help during the research (eg, providing help with language or writing assistance, or proofreading the article).

Formatting of funding sources
List funding sources in this standard way to facilitate compliance to funder's requirements:

Funding: This work was supported by the National Institutes of Health [grant numbers xxxx, yyyy]; the Bill & Melinda Gates Foundation, Seattle, WA [grant number zzzz]; and the United States Institutes of Peace [grant number aaaa].

It is not necessary to include detailed descriptions on the program or type of grants and awards. When funding is from a block grant or other resources available to a university, college, or other research institution, submit the name of the institute or organization that provided the funding.

If no funding has been provided for the research, please include the following sentence:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Artwork

Image manipulation
Whilst it is accepted that authors sometimes need to manipulate images for clarity, manipulation for purposes of deception or fraud will be seen as scientific ethical abuse and will be dealt with accordingly. For graphical images, this journal is applying the following policy: no specific feature within an image may be enhanced, obscured, moved, removed, or introduced. Adjustments of brightness, contrast, or color balance are acceptable if and as long as they do not obscure or eliminate any information present in the original. Nonlinear adjustments (e.g. changes to gamma settings) must be disclosed in the figure legend.

Electronic artwork
General points
• Make sure you use uniform lettering and sizing of your original artwork.
• Embed the used fonts if the application provides that option.
• Aim to use the following fonts in your illustrations: Arial, Courier, Times New Roman, Symbol, or use fonts that look similar.
• Number the illustrations according to their sequence in the text.
• Use a logical naming convention for your artwork files.
• Provide captions to illustrations separately.
• Size the illustrations close to the desired dimensions of the published version.
• Submit each illustration as a separate file.
A detailed guide on electronic artwork is available.
You are urged to visit this site; some excerpts from the detailed information are given here.
Formats
If your electronic artwork is created in a Microsoft Office application (Word, PowerPoint, Excel) then please supply 'as is' in the native document format.
Regardless of the application used other than Microsoft Office, when your electronic artwork is finalized, please 'Save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):
EPS (or PDF): Vector drawings, embed all used fonts.
TIFF (or JPEG): Color or grayscale photographs (halftones), keep to a minimum of 300 dpi.
TIFF (or JPEG): Bitmapped (pure black & white pixels) line drawings, keep to a minimum of 1000 dpi.
TIFF (or JPEG): Combinations bitmapped line/half-tone (color or grayscale), keep to a minimum of 500 dpi.
Please do not:
• Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); these typically have a low number of pixels and limited set of colors;
• Supply files that are too low in resolution;
• Submit graphics that are disproportionately large for the content.

Color artwork
Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF) or MS Office files) and with the correct resolution. If, together with your accepted article, you submit usable color figures then Elsevier will ensure, at no additional charge, that these figures will appear in color online (e.g., ScienceDirect and other sites) in addition to color reproduction in print. Further information on the preparation of electronic artwork.

Figure captions
Ensure that each illustration has a caption. Supply captions separately, not attached to the figure. A caption should comprise a brief title (**not** on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

Tables
Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules and shading in table cells.

References
Citation in text
Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

Reference links
Increased discoverability of research and high quality peer review are ensured by online links to the sources cited. In order to allow us to create links to abstracting and indexing services, such as Scopus, CrossRef and PubMed, please ensure that data provided in the references are correct. Please note that incorrect surnames, journal/book titles, publication year and pagination may prevent link creation. When copying references, please be careful as they may already contain errors. Use of the DOI is encouraged.

A DOI can be used to cite and link to electronic articles where an article is in-press and full citation details are not yet known, but the article is available online. A DOI is guaranteed never to change, so you can use it as a permanent link to any electronic article. An example of a citation using DOI for an article not yet in an issue is: VanDecar J.C., Russo R.M., James D.E., Ambeh W.B., Franke M. (2003). Aseismic continuation of the Lesser Antilles slab beneath northeastern Venezuela. Journal of Geophysical Research, https://doi.org/10.1029/2001JB000884. Please note the format of such citations should be in the same style as all other references in the paper.

Web references
As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Data references
This journal encourages you to cite underlying or relevant datasets in your manuscript by citing them in your text and including a data reference in your Reference List. Data references should include the following elements: author name(s), dataset title, data repository, version (where available), year, and global persistent identifier. Add [dataset] immediately before the reference so we can properly identify it as a data reference. The [dataset] identifier will not appear in your published article.

References in a special issue
Please ensure that the words 'this issue' are added to any references in the list (and any citations in the text) to other articles in the same Special Issue.

Reference management software
Most Elsevier journals have their reference template available in many of the most popular reference management software products. These include all products that support Citation Style Language styles, such as Mendeley and Zotero, as well as EndNote. Using the word processor plug-ins from these products, authors only need to select the appropriate journal template when preparing their article, after which citations and bibliographies will be automatically formatted in the journal's style. If no template is yet available for this journal, please follow the format of the sample references and citations as shown in this Guide.

Users of Mendeley Desktop can easily install the reference style for this journal by clicking the following link:
http://open.mendeley.com/use-citation-style/american-journal-of-orthodontics-and-dentofacial-orthopedics
When preparing your manuscript, you will then be able to select this style using the Mendeley plug-ins for Microsoft Word or LibreOffice.

Reference style
Text: Indicate references by superscript numbers in the text. The actual authors can be referred to, but the reference number(s) must always be given.
List: Number the references in the list in the order in which they appear in the text.
Examples:
Reference to a journal publication:
1. Van der Geer J, Hanraads JAJ, Lupton RA. The art of writing a scientific article. Sci Commun 2010;16351-9.
Reference to a book:
2. Strunk Jr W, White EB. The elements of style. 4th ed. New York: Longman; 2000.
Reference to a chapter in an edited book:
3. Mettam GR, Adams LB. How to prepare an electronic version of your article. In: Jones BS, Smith RZ, editors. Introduction to the electronic age. New York: E-Publishing Inc; 2009. p. 281-304.
Note shortened form for last page number. e.g., 51-9, and that for more than 6 authors the first 6 should be listed followed by 'et al.' For further details you are referred to 'Uniform Requirements for Manuscripts submitted to Biomedical Journals' (J Am Med Assoc 1997;**277**:927–34) (see also http://www.nlm.nih.gov/bsd/uniform_requirements.html).

Video
Elsevier accepts video material and animation sequences to support and enhance your scientific research. Authors who have video or animation files that they wish to submit with their article are strongly encouraged to include links to these within the body of the article. This can be done in the same way as a figure or table by referring to the video or animation content and noting in the body text where it should be placed. All submitted files should be properly labeled so that they directly relate to the video file's content. . In order to ensure that your video or animation material is directly usable, please provide the file in one of our recommended file formats with a preferred maximum size of 150 MB per file, 1 GB in total. Video and animation files supplied will be published online in the electronic version of your article in Elsevier Web products, including ScienceDirect. Please supply 'stills' with your files: you can choose any frame from the video or animation or make a separate image. These will be used instead of standard icons and will personalize the link to your video data. For more detailed instructions please visit our video instruction pages. Note: since video and animation cannot be embedded in the print version of the journal, please provide text for both the electronic and the print version for the portions of the article that refer to this content.

RESEARCH DATA
This journal encourages and enables you to share data that supports your research publication where appropriate, and enables you to interlink the data with your published articles. Research data refers to the results of observations or experimentation that validate research findings. To facilitate reproducibility and data reuse, this journal also encourages you to share your software, code, models, algorithms, protocols, methods and other useful materials related to the project.

Below are a number of ways in which you can associate data with your article or make a statement about the availability of your data when submitting your manuscript. If you are sharing data in one of these ways, you are encouraged to cite the data in your manuscript and reference list. Please refer to the "References" section for more information about data citation. For more information on depositing, sharing and using research data and other relevant research materials, visit the research data page.

Data linking
If you have made your research data available in a data repository, you can link your article directly to the dataset. Elsevier collaborates with a number of repositories to link articles on ScienceDirect with relevant repositories, giving readers access to underlying data that gives them a better understanding of the research described.

There are different ways to link your datasets to your article. When available, you can directly link your dataset to your article by providing the relevant information in the submission system. For more information, visit the database linking page.

For supported data repositories a repository banner will automatically appear next to your published article on ScienceDirect.

In addition, you can link to relevant data or entities through identifiers within the text of your manuscript, using the following format: Database: xxxx (e.g., TAIR: AT1G01020; CCDC: 734053; PDB: 1XFN).

Mendeley Data
This journal supports Mendeley Data, enabling you to deposit any research data (including raw and processed data, video, code, software, algorithms, protocols, and methods) associated with your manuscript in a free-to-use, open access repository. Before submitting your article, you can deposit the relevant datasets to *Mendeley Data*. Please include the DOI of the deposited dataset(s) in your main manuscript file. The datasets will be listed and directly accessible to readers next to your published article online.

For more information, visit the Mendeley Data for journals page.

Data statement
To foster transparency, we encourage you to state the availability of your data in your submission. This may be a requirement of your funding body or institution. If your data is unavailable to access or unsuitable to post, you will have the opportunity to indicate why during the submission process, for example by stating that the research data is confidential. The statement will appear with your published article on ScienceDirect. For more information, visit the Data Statement page.

ARTICLE ENRICHMENTS

AudioSlides

The journal encourages authors to create an AudioSlides presentation with their published article. AudioSlides are brief, webinar-style presentations that are shown next to the online article on ScienceDirect. This gives authors the opportunity to summarize their research in their own words and to help readers understand what the paper is about. More information and examples are available. Authors of this journal will automatically receive an invitation e-mail to create an AudioSlides presentation after acceptance of their paper.

3D models

You can enrich your online articles by providing 3D models (optional) in PLY, OBJ or U3D format, which will be visualized using the interactive viewer next to the article. Each 3D model will have to be zipped and uploaded to the online submission system via the '3D models' submission category. Please be advised that the recommended model size before zipping is maximum 150 MB. Multiple models can be submitted. Please provide a short informative description for each model by filling in the 'Description' field when uploading a dataset. Note: all datasets will be available for download from the online article on ScienceDirect. If you have concerns about your data being downloadable, please provide a video instead. More information on OBJ and PLY models or U3D models.

Submission Checklist

The following list will be useful during the final checking of an article prior to sending it to the journal for review. Please consult this Guide for Authors for further details of any item.
Ensure that the following items are present:
One author has been designated as the corresponding author with contact details:
• E-mail address
• Full postal address
• Phone numbers
All necessary files have been uploaded, and contain:

- All figure captions
- All tables (including title, description, footnotes)

Further considerations

- Manuscript has been 'spell-checked' and 'grammar-checked'
- References are in the correct format for this journal
- All references mentioned in the Reference list are cited in the text, and vice versa
- Permission has been obtained for use of copyrighted material from other sources (including the Web)

For any further information please visit our customer support site at http://support.elsevier.com.

Permissions

To use information borrowed or adapted from another source, authors must obtain permission from the copyright holder (usually the publisher). This is necessary even if you are the author of the borrowed material. It is essential to begin the process of obtaining permissions early; a delay may require removing the copyrighted material from the article. Give the source of a borrowed table in a footnote to the table; give the source of a borrowed figure in the legend of the figure. The source must also appear in the list of references. Use exact wording required by the copyright holder. For more information about permission issues, contact permissionshelpdesk@elsevier.com or visit http://www.elsevier.com/about/policies/author-agreement/obtaining-permission.

Permission is also required for the following images:

•Photos of a product if the product is identified or can reasonably be identified from the photo
•Logos
•Screenshots that involve copyrighted third-party material, whether a reasonably identifiable user interface or any nonincidental material appearing in the screenshot

AFTER ACCEPTANCE

Proofs

One set of page proofs (as PDF files) will be sent by e-mail to the corresponding author (if we do not have an e-mail address then paper proofs will be sent by post) or, a link will be provided in the e-mail so that authors can download the files themselves. Elsevier now provides authors with PDF proofs which can be annotated; for this you will need to download the free Adobe Reader, version 9 (or higher). Instructions on how to annotate PDF files will accompany the proofs (also given online). The exact system requirements are given at the Adobe site.
If you do not wish to use the PDF annotations function, you may list the corrections (including replies to the Query Form) and return them to Elsevier in an e-mail. Please list your corrections quoting line number. If, for any reason, this is not possible, then mark the corrections and any other comments (including replies to the Query Form) on a printout of your proof and scan the pages and return via e-mail. Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. We will do everything possible to get your article published quickly and accurately. It is important to ensure that all corrections are sent back to us in one communication: please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proofreading is solely your responsibility.

Offprints

The corresponding author will, at no cost, receive a customized Share Link providing 50 days free access to the final published version of the article on ScienceDirect. The Share Link can be used for sharing the article via any communication channel, including email and social media. For an extra charge, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier's Webshop.

AUTHOR INQUIRIES

Visit the Elsevier Support Center to find the answers you need. Here you will find everything from Frequently Asked Questions to ways to get in touch.
You can also check the status of your submitted article or find out when your accepted article will be published.