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Centro de Ciências da Saúde

Faculdade de Odontologia

EXPANSÃO RÁPIDA DA MAXILA APOIADA EM MINI-IMPLANTES (*MARPE*): EFEITOS DA ANCORAGEM BICORTICAL (*IN VITRO*) E ANÁLISE CLINICA DA ESPESSURA ÓSSEA ALVEOLAR VESTIBULAR ATRAVÉS DE REVISÃO SISTEMÁTICA E META-ANÁLISE

Flávio de Mendonça Copello

CD, MO

Tese submetida ao corpo docente da Faculdade de Odontologia da Universidade Federal do Rio de Janeiro – UFRJ, como parte dos requisitos, para a obtenção do Título de Doutor em Odontologia (Ortodontia).

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Orientadores: Prof. Dr. Eduardo Franzotti Sant'Anna

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DEDICO

A Deus,

pelo dom da vida.

Aos meus pais Vicente Gonçalves Copello e Heloisa Helena B. de M. Copello,

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“Dificuldades preparam pessoas comuns

para destinos extraordinários”

C.S. Lewis

RESUMO

COPELLO, Flávio de Mendonça. **Expansão rápida da maxila apoiada em mini-implantes (*MARPE*): efeitos da ancoragem bicortical (*in vitro*) e análise clínica da espessura óssea alveolar vestibular através de revisão sistemática e meta-análise.** Orientadores: Dr. Eduardo Franzotti Sant'Anna e Dr. Dale Rick Sumner. Rio de Janeiro: UFRJ/Faculdade de Odontologia, 2018. Tese (Doutorado em Odontologia – Ortodontia). 51f.

O objetivo desse estudo foi avaliar, *in vitro,* a influência mecânica do tipo de ancoragem (monocortical ou bicortical), utilizada na técnica de expansão rápida da maxila apoiada em mini-implantes (*MARPE*), na microarquitetura óssea trabecular onde o disjuntor é instalado, e, analisar, através de revisão sistemática e meta-análise, os efeitos desta técnica na espessura da tábua óssea vestibular dos dentes de suporte, comparando com a técnica de expansão convencional. Dezesseis mini-implantes do tipo auto-perfurantes foram distribuídos em dois grupos (dois dispositivos *MARPE* com 4 mini-implantes cada grupo) de acordo com o tipo de inserção óssea (monocortical e bicortical), instalados em osso de costela bovina, e, ativados em cinco tempos distintos onde a cada ativação, o corpo de prova era microtomografado. O espaçamento das trabéculas (Tb.Sp [mm]) foi o parâmetro utilizado para avaliar a microarquitetura óssea em cinco regiões de interesse (ROI) peri-implantar (osso ao redor do dispositivo, superior, inferior, anterior e posterior). O teste *ANOVA two-way* com análise post-hoc de

Tukey (α = 0,05) foi usado para avaliar o efeito do tipo de inserção na microarquitetura óssea durante os ciclos de ativação. O efeito do tempo foi avaliado usando o teste *ANOVA-MR* com correção de Bonferroni (α = 0,003). Para responder à pergunta da revisão sistemática, as bases *PubMed (MEDLINE), Scopus, Web of Science, The Cochrane Library, Virtual Health Library* e *OpenGrey* foram utilizadas até março de 2019. Avaliações de risco de viés foram realizadas usando as ferramentas *Cochrane Collaboration* e *ROBINS-I*. No estudo *in vitro*, apenas o ROI superior (cervical) teve diferença significativa (p <0,003) após o quarto ciclo de ativação ao longo do tempo entre as ativações. Para o grupo monocortical, o espaçamento trabecular foi afetado quando todo o ROI foi analisado a partir do quarto ciclo de ativação, enquanto para o ROI superior, essa diferença tornou-se aparente a partir do terceiro ciclo de ativação (p <0,003). Em relação a revisão sistemática, as evidências limitadas indicaram que pacientes tratados com a técnica convencional tiveram uma perda maior da espessura óssea alveolar vestibular em comparação com pacientes usando *MARPE* (p=0,001). As análises de subgrupo mostraram que as diferenças foram significativas em ambas as regiões de pré-molares, direita (p = 0,004) e esquerda (p <0,0001). Baseado nos resultados encontrados pode-se concluir que a ancoragem monocortical é mais suscetível a danos ósseos ao redor dos mini-implantes, sendo a região superior (cervical) mais afetada. Assim como, evidências limitadas sugerem que o *MARPE* pode diminuir a perda do osso alveolar vestibular quando comparado a técnica de expansão convencional.

SUMMARY

COPELLO, Flávio de Mendonça. **Mini-implant assisted rapid palatal expansion (*MARPE*): the effects of bicortical anchorage (in vitro) and buccal alveolar bone thickness clinical analysis through systematic review and meta-analysis.** Orientadores: Dr. Eduardo Franzotti Sant'Anna e Dr. Dale Rick Sumner. Rio de Janeiro: UFRJ/Faculdade de Odontologia, 2018. Tese (Doutorado em Odontologia – Ortodontia). 51f.

This study aimed to evaluate, in vitro, the mechanical influence of the type of anchorage (monocortical or bicortical), that is used in the mini-implant assisted rapid palatal expansion (MARPE) technique, on the trabecular bone microarchitecture where the appliance is installed, and to analyze, through systematic review and meta-analysis, the effects of this technique on the buccal palatal bone thickness of the supporting teeth, compared to the conventional technique. Sixteen self-drilling mini-implants were distributed into two groups (two *MARPE* devices with 4 mini-implants each group) according to the type of bone insertion (monocortical and bicortical), installed in bovine rib bone, and activated five different times where at each activation, the specimen was microtomographed. Trabecular spacing (Tb.Sp [mm]) was the parameter used to assess bone microarchitecture in five peri-implant regions of interest (ROI) (the whole area around the device, superior, inferior, anterior ,and posterior). The two-way ANOVA test with post-hoc Tukey analysis ($\alpha = 0.05$) was used to assess the effect of insertion type on bone microarchitecture during activation cycles.

The effect of time was evaluated using the ANOVA-MR test with Bonferroni correction (α = 0.003). To answer the systematic review question, PubMed (MEDLINE), Scopus, Web of Science, The Cochrane Library, Virtual Health Library and OpenGrey databases were used for research until March 2019. Bias risk assessments were performed using the Cochrane Collaboration and ROBINS-I tools. In the in vitro study, only the superior (cervical) ROI had a significant difference ($p<0.003$) after the fourth activation cycle. For the monocortical group, trabecular spacing was affected when the whole area ROI was analyzed from the fourth activation cycle, on the other hand, when analyzing the superior ROI, this difference was significant from the third activation over time between the actvations ($p<0.003$). Regarding the systematic review, limited evidence indicated that patients treated with the conventional technique had a greater loss of buccal alveolar bone thickness compared to patients treated with the *MARPE* technique ($p=0.001$). Subgroup analyzes showed that differences were significant in both the right ($p = 0.004$) and left ($p < 0.0001$) premolar regions. Based on the results found, it can be concluded that monocortical anchorage is more susceptible to bone damage around the mini-implants, and the superior (cervical) region is more affected. As well, limited evidence suggests that *MARPE* technique may reduce the loss of buccal alveolar bone when compared to the conventional palatal expansion technique.

LISTA DE SIGLAS E ABREVIATURAS

α	Nível de significância
ANOVA	*Analysis of variance* / Análise de Variância
ANVISA	Agencia Nacional de Vigilancia Sanitária
CEUA	Comite de Ética de Pesquisa em Animais
ERM	Expansão rápida de maxila
IC	Intervalo de Confiança
ICC	Coeficiente de Correlação Intraclasse
Kgf	Quilograma-força
MARPE	*Miniscrew-assisted rapid palatal expander ou expansion*
MI	Mini-implante
n	Número
N	Newtons
SMD	*Standardized Mean Diferences* / Diferenças Médias Padronizadas
SD	Standard deviation / desvio padrão
SPM	Sutura palatina mediana
T	Tempo
Tb. N	*Trabecular Number* / Número de Trabéculas

Tb.Sp *Trabecular Spacing* / Espaço entre as Trabéculas

Ti-6Al-4V Liga de titânio, alumínio e vanádio

ROI *Region of Interest* / Região de Interesse

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1 INTRODUÇÃO

Estudos prévios demonstram que cerca de 20% dos pacientes na dentição mista possuem constrição maxilar (Brunelle et al., 1996; Egermark-Eriksson et al., 1990; Heikinheimo et al., 1987, Kutin e Hawes, 1969). Embora a etiologia da desta condição seja multifatorial, o tratamento preconizado nos dias atuais é a expansão rápida de maxila (ERM) o qual promove a abertura da sutura palatina mediana (SPM), reduzindo a deficiência transversa da maxila (Bell, 1982 e Perillo et al., 2014).

Sabe-se que a ERM tradicional proposta por Haas em 1961 possui efeitos esqueléticos e dentários que podem variar de proporção a depender da idade do paciente e do desenho do aparelho. Já está bem descrito na literatura que, quando a técnica ERM é usada em crianças, o resultado da expansão é de 50% de efeito esquelético, com a abertura da sutura palatina mediana e 50% de movimentação dentária por inclinação. Já em adolescentes ocorre apenas 35% de expansão esquelética e 65% dentária, e, assim a redução dos efeitos esqueléticos são diminuídos sucessivamente com o avançar da idade (Krebs, 1964). A redução relatada, relacionada aos efeitos esqueléticos com o desenvolvimento do indivíduo acontece devido a progressiva calcificação e interdigitação das suturas craniofaciais incluindo a SPM, dificultando com isso, a abertura da mesma (Persson e Thilander, 1977; Melsen e Melsen, 1982).

Em pacientes adultos onde não há potencial para abertura da SPM de maneira convencional, o tratamento de escolha é a ERM cirurgicamente

assistida (Kokich, 1976; Harzer et al., 2006; Tausche et al., 2007, Rachmiel et al., 2020). Porém essa técnica é invasiva e possui efeitos colaterais no periodonto. Além disso, relatos de casos mostram que ocorre recidiva de parte da deficiência transversa de maxila no período pós-cirúrgico com certa frequência (Byloff and Mossaz, 2004; Gauthier et al., 2011).

Com a intenção de minimizar os efeitos dentários e aumentar os efeitos esqueléticos no tratamento de pacientes adultos, em 2008 foi proposta pela primeira vez a utilização de mini-implantes (MI) apoiados no osso cortical do palato ósseo como coadjuvante na ERM afim de potencializar os efeitos esqueléticos (Garib et al., 2008, Wilmes and Dieter, 2008), técnica atualmente conhecida como *MARPE (Mini-implant assisted rapid palatal expansion).*

Os expansores apoiados em MI inseridos no palato ósseo como auxiliar na ERM, trazem a força horizontal para mais próximo da sutura, potencializando os efeitos esqueléticos e diminuindo os efeitos dentários (Lee et. al; 2010). Resultado esse de grande valia quando se pensa no tratamento de problemas transversos em pacientes adultos. Baseado nesses estudos iniciais, surgiram outros desenhos e propostas de aparelhos para expansão da maxila apoiados esqueleticamente que, de maneira geral, são compostos por quatro MI inseridos no corpo do parafuso expansor (Moon, 2013; MacGinnis et al., 2014; Suzuki et al., 2016).

Acredita-se que para se obter maior estabilidade do disjuntor faz-se necessário também que esses sejam inseridos bicorticalmente (dispositivos inseridos nas corticais nasal e bucal do palato ósseo), uma vez que a força utilizada é ortopédica e não ortodôntica na ERM apoiada em MI (Lee, Moon and Hong, 2017; Brunetto et al., 2017).

O expansor proposto por Kee-Joon Lee em 2010 preconiza a instalação dos MI tanto na porção posterior quanto na anterior da maxila sendo que a ancoragem bicortical não pode ser alcançada na região anterior devido a espessura óssea deste local (KJ Lee et al., 2010). Já o expansor proposto por Moon em 2013 preconiza a inserção dos quatro dispositivos na região posterior de maneira paralela objetivando a ancoragem bicortical de todos os MI.

A eficácia da ancoragem bicortical nessa abordagem de tratamento somente foi relatada na literatura por meio de estudos com métodos de elementos finitos, e, Lee, Moon e Hong mostraram que ao passar 1mm pela cortical nasal do palato ósseo, a ancoragem se tornaria mais eficaz (Poorsattar-bejeh, 2017; Lee, Moon and Hong, 2017). Há uma escassez de estudos relacionando os efeitos microestruturais ósseos ao redor dos dispositivos associados à ancoragem bicortical, uma vez que estes efeitos e alterações ao redor dos MI podem ser associados à estabilidade primária e secundária, sendo estes fatores relacionados ao sucesso do tratamento.

Pelo fato dos efeitos de inclinação dentária serem reduzidos com a utilização da técnica *MARPE*, espera-se que ocorra uma redução dos efeitos colaterais periodontais quando comparado com a técnica de disjunção convencional, principalmente em relação a perda óssea alveolar vestibular na região de pré-molares e molares superiores (Toklu et. Al., 2015). Com o aumento de estudos sendo publicados para responder essa indagação, e, o crescente interesse clínico pelos ortodontistas em relação a técnica *MARPE*, justifica-se a confecção de uma revisão sistemática para responder essa pergunta clinica seguindo os princípios da Odontologia baseada em evidências científicas.

2 PROPOSIÇÃO

O objetivo deste estudo foi avaliar parâmetros ósseos e estruturais da técnica *MARPE*, através de:

2.1 Análise microestrutural, por meio de avaliação *in vitro* utilizando material ex vivo e microtomografia computadorizada:

2.1.1 Definir a relação da ancoragem bicortical e monocortical com a ativação do disjuntor *MARPE* através de parâmetros ósseos como o espaçamento e número das trabéculas ao redor dos mini-implantes;

2.1.2 Determinar qual tipo de ancoragem causa maior dano ósseo ao redor destes dispositivos de ancoragem esquelética;

2.1.3 Mapear as regiões peri-implantar que sofrem maior ou menor dano quando esses dois tipos de ancoragem são empregados.

2.2 Revisão Sistemática e meta-análise, para, através dos princípios da Odontologia baseada em evidências, responder à pergunta clínica: “O osso alveolar vestibular é menos afetado pela técnica *MARPE* do que pela expansão rápida da maxila convencional?”

3 DELINEAMENTO DA PESQUISA

3.1 COMITÊ DE ÉTICA E CADASTRO DE DOMÍNIO DA REVISÃO SISTEMÁTICA

Para o segmento *in vitro* do presente estudo, o mesmo foi submetido e aprovado no Comitê de Ética e Pesquisa em Animais (CEUA) do Centro de Ciências da Saúde da Universidade Federal do Rio de Janeiro, sob número de parecer 071/18 (Anexo 1, página 50).

O domínio da pergunta referente a Revisão Sistemática proposta neste estudo foi submetido e aprovado na plataforma PROSPERO (Plataforma internacional de Registros de Revisões Sistemáticas), sob o número de parecer CDR42014007510 (Anexo 2, página 51).

3.2 EXPERIMENTO *IN VITRO*

3.2.1 Cálculo amostral

A fórmula descrita por Pandis (Pandis, 2012) foi utilizada para realizar o cálculo amostral do segmento *in vitro* do presente estudo. Para determinar o número de mini-implantes necessários para as análises *in* vitro, parâmetros para análises através de microtomografia foram considerados para fazer o cálculo amostral, considerando um poder de teste de 80%, α de 0,05, baseado em

estudo prévio (Espinar-Escanola, 2016), e, revelou a necessidade de uma amostra composta por, pelo menos, 7 mini-implantes por grupo. Portanto, foram confeccionados dois dispositivos *MARPE* por grupo, totalizando 8 mini-implantes por grupo.

3.2.2 Substrato ósseo

A amostra foi composta por fragmentos de costela bovina (*Bos taurus indicus*) de um único animal da raça Nelore, abatidos para consumo humano e obtidos imediatamente após sua eutanásia com certificação da Agencia Nacional de Vigilancia Sanitária (ANVISA). Em cada costela, foram excisados quatro fragmentos teciduais (3 cm x 5 cm). A remoção dos fragmentos foi realizada com uso de disco diamantado (KG® Sorensen, Medical Burs, São Paulo, Brasil) adaptado ao motor de baixa rotação (Beltec® LB100, Araraquara, Brasil) sob refrigeração com soro fisiológico. Em seguida os fragmentos foram regularizados em lixa d'água nº 1000 (3M®, São Paulo, Brasil) (Figura 1, página 7) de maneira que ao final dessa etapa se obtivessem dois grupos de corpos de prova: 1 mm de osso cortical de ambos os lados com 4 mm de osso esponjoso no centro (n=2) e 1 mm de osso cortical de ambos os lados e 6 mm de osso esponjoso no centro (n=2) (Figura 2, página 7). A diferença na espessura do osso esponjoso é ideal para que se obtenha, após a inserção dos mini-implantes, ancoragem bicortical na amostra com 4 mm de osso esponjoso, e, monocortical na amostra com 6 mm de osso esponjoso (Copello et. al., 2021). Até o momento da inserção dos mini-implantes, as amostras ficaram armazenadas em soro fisiológico (-20°C) para conservação da integridade e propriedades mecânicas (Lim et al., 2008).

Um segmento de borracha EVA (Angare® - Carapicuiba, SP, Brasil) com 1 mm de espessura foi fixado com cola de cianoacrilato (SuperBonder® - São Paulo, SP, Brasil) à superfície do corpo de prova simulando a espessura de tecido mole da cavidade bucal.

Sabendo que não há artigos relatando a força, em *Newtons* (N), necessária para romper a sutura palatina mediana, neste estudo foi adotado o princípio de que a sutura estava fechada ao receber as forças iniciais da abertura do disjuntor. Assim, ocorre melhor padronização da resistência sofrida pelos mini-implantes, isolando apenas o fator profundidade de ancoragem (monocortical e bicortical), como foi utilizado em estudo com métodos de elementos finitos proposto por Lee, Moon e Hong em 2017 (Lee, Moon and Hong, 2017).

Figura 1. Preparo do corpo de prova. A) Verificação da altura do osso esponjoso necessário. B) Desgaste das corticais através de lixa d'água número 1000 em máquina Politriz para obtenção de 1 mm cada lado. C) Aspecto final do corpo de prova com as superfícies superior e inferior regularizadas.

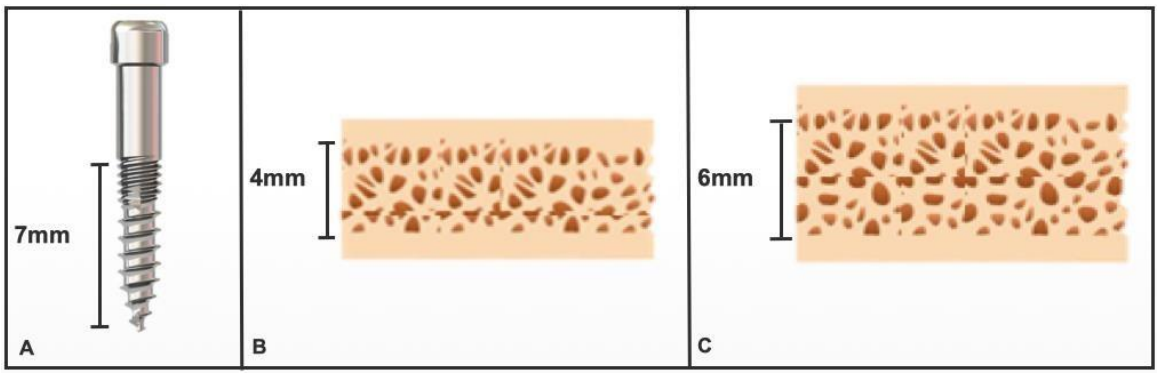

Figura 2. Esquema ilustrativo da relação entre o preparo do corpo de prova e o mini-implante. A) Dimensão do comprimento de parte ativa dos mini-implantes utilizados. B) Corpo de prova com 4 mm de osso esponjoso onde a inserção completa do dispositivo resultará em ancoragem bicortical. B) Corpo de prova com 6mm de osso esponjoso onde a inserção do mini-implante resultará em ancoragem monocortical.

3.2.3 Mini-implantes e dispositivo *MARPE*

Foram utilizados 16 MI usinados a partir da liga Ti-6AI-4V (PECLAB® Sistema de Implantes Dentários – Belo Horizonte, MG, Brasil) da linha HS *MARPE* (Ref. 2926) com 1.8 mm de diâmetro, 7 mm de porção ativa e 4 mm de transmucoso. Estes 16 MI foram divididos em dois grupos: ancoragem bicortical e ancoragem monocortical, cada grupo foi constituído de dois dispositivos *MARPE* (PECLAB® Sistema de Implantes Dentários – Belo Horizonte, MG, Brasil) da linha *MARPE* EX com 11 mm de abertura (Ref. 5512). Cada dispositivo *MARPE* necessita de 4 MI para sua instalação, logo, cada grupo foi composto de 2 dispositivos *MARPE* com 8 MI.

3.2.4 Instalação dos Dispositivos

Cada dispositivo *MARPE* foi instalado seguindo o protocolo estipulado pela empresa PECLAB®, tornando o estudo mais próximo da realidade clínica. O kit de instalação de mini-implantes da PECLAB® foi utilizado durante todo o processo de instalação (Figura 3, página 9).

Figura 3. Kit para instalação de dispositivos para ancoragem esquelética PECLAB®.

Uma vez que os dispositivos não possuem sustentação dentária, as extensões pré-fabricadas foram removidas com o auxilio de disco de carborundum (Carbo® – São Paulo, SP, Brasil) (Figura 4, página 9).

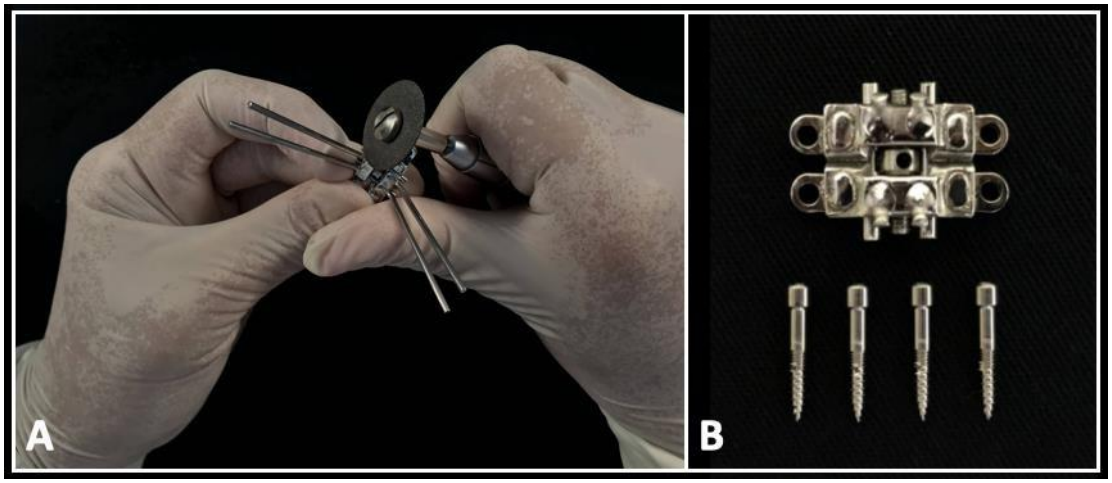

Figura 4. Ajuste do disjuntor para os propósitos da pesquisa. A) Remoção da extensão para apoio dentário pré-fabricada, com auxilio de disco de carborundum. B) Aspecto final do disjuntor, pronto para ser instalado ao corpo de prova com quatro mini-implantes.

O disjuntor foi posicionado sobre o substrato ósseo e a broca para perfuração de cortical do Kit foi utilizada para romper a cortical superior,

utilizando micromotor de bancada (Beltec® LB100, Araraquara, Brasil) e contra ângulo (KAVO® 500, Charlotte, NC, EUA). Após o rompimento da cortical óssea, o adaptador de inserção de mini-implantes para contra ângulo foi acoplado e a instalação dos dispositivos foi efetuada (Figura 5, página 10).

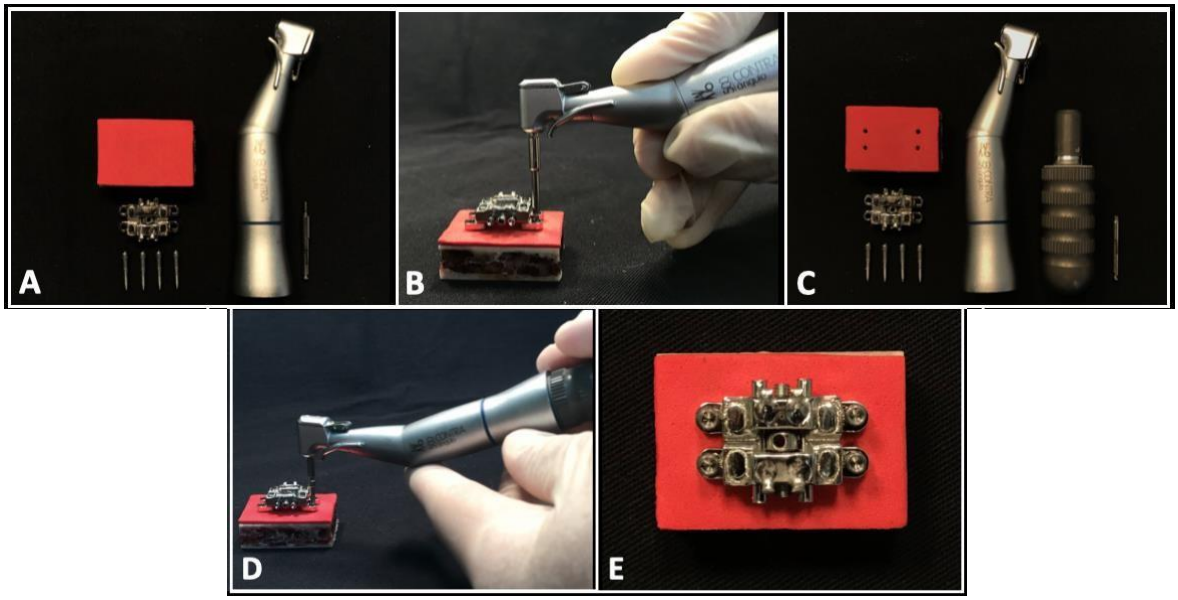

Figura 5. Instalação do dispositivo *MARPE*. A) Materiais necessários para inicio do processo onde foi feita a perfuração da cortical superior do corpo de prova. B) Utilização da broca apropriada para cortico perfuração com auxilio de contra-ângulo. C) Material necessário para instalação dos mini-implantes. Adaptador para contra-ângulo e ponta para inserir os dispositivos. D) Instalação dos dispositivos. E) Aspecto final após a instalação dos quatro mini-implantes.

Cada ativação foi feita com o objetivo de abrir 0.5 mm do parafuso disjuntor, ou seja, dois ¼ de volta por tempo da pesquisa. Ao final dos seis períodos de tempo, o disjuntor apresentou uma abertura de 3 mm. O processo de ativação foi feito com chave especifica para o dispositivo *MARPE* EX da PECLAB® (Figura 6, página 11).

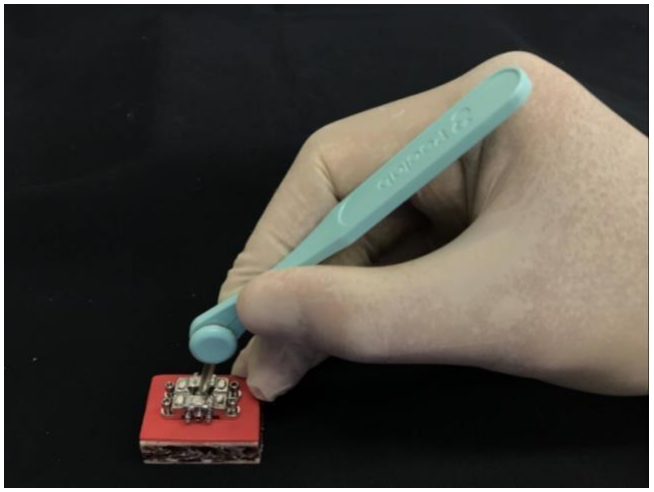

Figura 6. Ativação dos disjuntores *MARPE* com auxilio de chave especifica para este procedimento.

3.2.5 Aquisição das Imagens de Micro-tomografia Computadorizada

A aquisição das imagens de cada corpo de prova foi obtida através do equipamento VTOMEX/m (General Eletric GE® - Boston, Massachusetts, EUA) (Figura 7, página 12), sob os seguintes parâmetros de exposição: tensão de 80 kV, corrente 280 µA e pixels com tamanho de 24,23 µm. Os arquivos foram obtidos no formato DICOM.

Para cada corpo de prova foram obtidas seis imagens: T0 (antes da primeira ativação), T1 (após a primeira ativação), T2 (após a segunda ativação), T3 (após a terceira ativação), T4 (após a quarta ativação), T5 (após a quinta ativação) e T6 (após a sexta ativação).

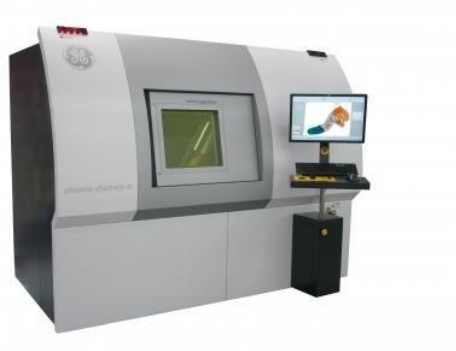

Figura 7.Micro-tomografo VTOMEX/m GE® utilizado para aquisições das imagens.

3.2.6 Análise Microestrutural Óssea

Os arquivos DICOM foram convertidos em arquivos ISQ e analisados no software µCT Evaluation versão 6.5-3 (Scanco Medical®, Brüttisellen, Suíça). A microestrutura óssea trabecular foi avaliada ao redor dos MIs para obter os parâmetros: número trabecular (Tb.N - 1 / mm) e o espaçamento trabecular (Tb.Sp - mm). Cinco áreas de interesse (ROI) foram determinadas para a análise do osso trabecular: 1) Área inteira; 2) Área superior; 3) Área inferior; 4) Área anterior inteira; 5) Área posterior inteira; (Figura 8, página 13). Quando toda a área ao redor do IM foi analisada, uma ROI circular de 0,10 cm^2 foi usada ao redor do dispositivo. Quando apenas a área anterior ou posterior foi analisada, uma ROI semicircular de 0,05 cm^2 foi usada. Quando apenas metade do MI foi analisado, os números totais das fatias de todo o comprimento do MI foram obtidos usando o software e, a partir desse valor, a fatia que representa exatamente a metade do MI foi determinada. Todas as seleções de regiões de interesse foram obtidas com zoom 3x para o mesmo operador (F.M.C.).

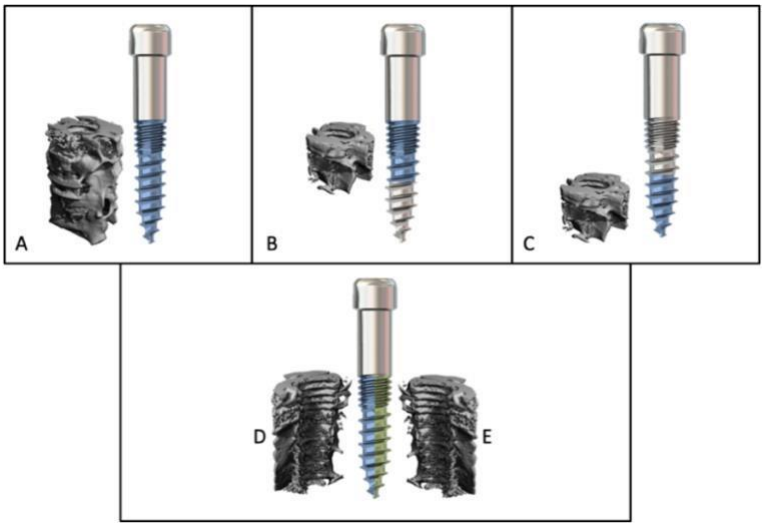

Figura 8. Cinco áreas de interesse (ROI) determinadas para a análise do osso trabecular: A) Área inteira; B) Área superior; C) Área inferior; D) Área anterior inteira; E) Área posterior inteira;

3.2.7 Análise estatística

A análise estatística foi realizada por meio do programa Statistical Package for Social Science (versão 21.0, SPSS Inc., EUA). A acurácia intraexaminador foi avaliada pelo coeficiente de correlação intraclasse (ICC) obtida a partir da repetição das medidas de 30% das amostras, com intervalo de uma semana entre as análises. A normalidade da amostra foi verificada pelo teste de Kolmogorov-Smirnov e a homogeneidade das variáveis pelo teste de Levene ($\alpha = 0,05$). O teste *ANOVA two way* com análise post-hoc de tukey ($\alpha = 0,05$) foi usado para avaliar os principais efeitos do tipo de inserção e ROI na microestrutura do osso trabecular. O efeito do tempo foi avaliado através do teste ANOVA-MR com correção de Bonferroni ($\alpha = 0,003$).

A análise qualitativa foi realizada para encontrar semelhanças e diferenças entre os grupos durante os tempos de ativação do dispositivo.

3.3 REVISÃO SISTEMÁTICA E META-ANÁLISE

A metodologia desta revisão sistemática foi baseada no guia PRISMA Statement (www.prisma-statement.org) (Moher et al., 2012).

3.3.1 Critério de Elegibilidade

O critério de seleção para esta revisão foi definido considerando os elementos da estratégia **PICO**, listados abaixo:

População (P): composta por pacientes de ambos os sexos, sem restrição de grupo socioeconômico, étnico ou idade, com diagnóstico de deficiência transversa da maxila;

Intervenção (I): inclui o uso da técnica *MARPE* (expansão rápida assistida por mini-implante) para tratar os pacientes com deficiência transversa da maxila;

Comparação (C): a técnica convencional de expansão rápida da maxila sem o uso de mini-implantes como ancoragem esquelética;

Desfecho (O): mudanças no osso alveolar vestibular (espessura e altura) avaliados por métodos tridimensionais. Não há desfechos secundários.

Os estudos foram considerados elegíveis caso apresentassem as seguintes características: ensaio clínico prospectivo, retrospectivo, randomizado ou não-randomizado; que avalie os parâmetros periodontais (efeitos colaterais) do *MARPE* e do expansor convencional, como perda óssea vestibular (altura e espessura).

Critérios de exclusão: relatos de casos; editoriais e opiniões; artigos de revisão; pacientes submetidos a outro tratamento - como tração reversa da maxila - antes ou durante a expansão rápida da maxila; pacientes

sistemicamente comprometidos, fissurados e sindrômicos e estudos que não utilizaram a disjunção convencional como grupo controle.

3.3.2 Estratégia de Busca e Seleção de Estudos

Pesquisas sistemáticas foram realizadas utilizando as seguintes bases de dados eletrônicas: Pubmed (MEDLINE), Scopus, Web of Science, The Cochrane Library, Virtual Health Library, Embase, Ovid, LIVIVO, CINAHL e banco de dados da literatura cinzenta (Portal de Periódicos da CAPES, Google Scholar e SIGLE). As palavras-chave foram selecionadas com a ajuda de um bibliotecário especializado em ciências da saúde (D.M.T.P.F.). A estratégia de pesquisa foi criada de acordo com as regras de sintaxe de cada banco de dados, usando termos MeSH e palavras de texto livre, e nenhuma restrição ou filtro foi usado em relação ao idioma e data da publicação.

Primeiramente, foi realizada uma triagem inicial de títulos e resumos selecionados na etapa anterior, e, os estudos foram selecionados apenas quando satisfizeram todos os critérios de inclusão e não apresentaram nenhum critério de exclusão. Assim, três revisores (F.M.C., G.M.V. e L.D.C.) realizaram uma avaliação completa dos resumos e se o consenso não fosse alcançado, um quarto avaliador era contatado (L.C.M.). Se o resumo não fornecesse informações suficientes, o texto completo era recuperado para análise posterior e/ou o autor era contatado. Uma pesquisa manual foi feita na lista de referências dos artigos principais elegíveis para selecionar possíveis artigos não selecionados na etapa anterior.

3.5.3 Análise de Qualidade e Risco de Viés

A análise de qualidade e risco de viés foi realizada durante a fase de extração de dados por dois avaliadores (F.M.C. e G.M.V.) e, quando houvesse discordância, um terceiro revisor (L.C.M.) era consultado. Foi utilizada a ferramenta Cochrane Collaboration para analisar o risco de viés, verificar a qualidade das evidências e classificar os estudos randomizados elegíveis (Higgins et. Al., 2011). O instrumento ROBINS-I (Risco de viés em estudos não-randomizados de intervenções) foi utilizado para analisar o risco de viés de estudos não-randomizados selecionados (Sterne et al., 2016).

A ferramenta Cochrane Collaboration, para estudos randomizados, avaliou detalhadamente os seguintes itens: 1) método utilizado para gerar a alocação e randomização; 2) cegamento da randomização onde ocorreu a avaliação do processo de ocultação da randomização antes ou durante a pesquisa; 3) cegamento dos participantes ou avaliadores de resultados para avaliar a eficácia de todos os métodos empregados, a fim de cegar qualquer participante ou pessoal envolvido no estudo; 4) dados de resultados incompletos, onde foi verificado a integridade dos dados dos resultados relatados, incluindo desgaste e perda de amostra; 5) relato de resultados seletivos, onde foi avaliado se os autores fizeram relatos de desfechos seletivos; 6) outras possíveis fontes de viés: avaliação de outras fontes não abordadas nos itens anteriores. Considerando estes 6 itens, o estudo foi classificado como: baixo risco de viés, se foi improvável que viés plausível alterasse significativamente seus resultados; risco claro de viés, viés plausível que levanta dúvidas sobre os resultados; e alto risco de viés, presença de algum fator que enfraqueceria seriamente os resultados.

A versão 2016 da ROBINS-I para estudos intervencionais não-randomizados funciona da seguinte forma: inclui sete domínios tais como viés devido à confundimento, a seleção de participantes para o estudo, classificação das intervenções, desvios de intervenções destinadas, falta de dados, medições de resultados, e seleção dos resultados reportados. Os dois primeiros domínios referem-se ao período de pré-intervenção, o terceiro ao período de intervenção propriamente dita e os quatro últimos referem-se ao período pós-intervenção. O risco de viés dentro de cada domínio é julgado respondendo às perguntas com “sim”, “provavelmente sim”, “provavelmente não” ou “não”. A resposta “sem informação” também pode ser escolhida se for necessário. Então, o risco de viés foi definido como “baixo”, “moderado”, “sério” ou “crítico”.

Uma vez que é impossível o cegamento do operador tanto na instalação do dispositivo (*MARPE* ou disjuntor convencional) quanto na análise dos dados, esses domínios não foram considerados chaves para qualificação dos artigos selecionados, ou seja, esses fatores exclusivamente não puderam impactar negativamente a avaliação dos artigos selecionados.

3.5.4 Extração de dados

Os seguintes dados foram extraídos dos estudos incluídos: (1) autor, ano de publicação e país onde o estudo foi realizado; (2) desenho do estudo; (3) dados relacionados aos participantes (tamanho da amostra, distribuição dos gêneros e idade média dos participantes) (4) design do expansor convencional; (5) design do expansor *MARPE*; (6) dados avaliados nos estudos; (7) períodos de avaliação; e, (8) resultados principais do estudo.

3.5.5 Meta-análise

A heterogeneidade clínica dos estudos incluídos foi avaliada pelo desenho do estudo, características dos participantes, protocolos de intervenção, metodologias de avaliação dos objetivos e qualquer outra fonte relevante de heterogeneidade.

As diferenças médias padronizadas (SMD) com seus respectivos intervalos de confiança de 95% (IC 95%) foram escolhidas como medidas de efeito. As meta-análises foram realizadas usando o método da variância inversa. O modelo de efeito fixo foi selecionado para avaliar todas as estimativas combinadas, com o objetivo de obter uma estimativa mais precisa da variância entre os estudos (Borestein, 2019)

Análises de subgrupos foram realizadas para avaliar o efeito do tipo de dente (1º pré-molar / 1º molar) e o lado maxilar (direito / esquerdo) na espessura óssea alveolar vestibular. Além disso, uma análise de sensibilidade foi pré-determinada para explorar diferenças quando os resultados relatados para raízes mésio-vestibulares ou disto-vestibulares de primeiros molares que foram incluídos na meta-análise. As análises foram realizadas no RevMan (versão 5.3.5; The Nordic Cochrane Centre, Copenhagen, Dinamarca) adotando um nível de significância de 5%.

3.5.6 Avaliação do nível de evidência

O nível de evidência final da Revisão Sistemática foi mensurado utilizando o *software Recommendations, Assessment, Development and Evaluation Pro* (Ferramenta de Desenvolvimento *GRADE pro Guideline*, disponível online no site classpro.org). Ele classifica a qualidade da evidência de uma Revisão

Sistemática em quatro níveis: muito baixo, baixo, moderado e alto. "Alta qualidade" sugere que o verdadeiro efeito está próximo da estimativa sugerida pelo trabalho. "Muito baixa qualidade" sugere que há muito pouca confiança na estimativa do efeito proporcionado pela Revisão Sistemática, e a estimativa relatada no trabalho pode ser substancialmente diferente da que foi medida (Balshem et. Al., 2011).

4 DESENVOLVIMENTO DA PESQUISA

4.1 ARTIGO 1

COPELLO FM; SILVEIRA, AM; CASTRO ACR; LOPES RT; KO F; SUMNER DR; SANT`ANNA EF. In-vitro trabecular bone damage following mono- and bicortical mini implants anchorage in mini-implant assisted rapid palatal expansion (MARPE). Publicado na revista ***International Orthodontics***, março de 2021.

4.2 ARTIGO 2

COPELLO FM; MARAÑÓN-VÁSQUEZ GA; BRUNETTO DP; CALDAS LD; MASTERSON D; MAIA LC; SANT'ANNA EF. Is the buccal alveolar bone less affected by mini-implant assisted rapid palatal expansion than by conventional rapid palatal expansion? - A systematic review and meta-analysis. Publicado na revista ***Orthodontics and Craniofacial Research***, agosto de 2020.

4.1 ARTIGO 1

To cite this article: Copello FM, et al. In-vitro trabecular bone damage following mono- and bicortical mini implants anchorage in mini-implant assisted rapid palatal expansion (MARPE). International Orthodontics (2021), https://doi.org/10.1016/j.ortho.2021.02.003

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Original article

In-vitro trabecular bone damage following mono- and bicortical mini implants anchorage in mini-implant assisted rapid palatal expansion (MARPE)

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Keywords
Palatal expansion technique
Orthodontic anchorage procedure
Orthodontic appliances
In vitro techniques
X-ray microtomography
Cancellous bone

Summary

Objectives > To assess in-vitro trabecular bone damage following mono- and bicortical mini-implant (MI) anchorage in mini-implant assisted rapid palatal expansion (MARPE).

Material and methods > Sixteen self-drilling MI (four MARPE appliances) were distributed in two groups according to bone insertion (monocortical and bicortical) in bovine rib. The device was activated five times (0.5 mm each). Trabecular bone damage was assessed using micro-CT scans made at baseline and after each activation by trabecular spacing parameter (Tb.Sp) (distance [mm] between the trabecular bone structure). These measurements were made in five different regions of interest (ROI) surrounding the screw (whole, superior, inferior, anterior and posterior). Two-way ANOVA with Tukey post-hoc analysis ($\alpha = 0.05$) was used to evaluate the effect of insertion type (monocortical vs. bicortical) and activation cycle (0–5) on trabecular damage. The time effect was evaluated using ANOVA-MR test effect with Bonferroni correction ($\alpha = 0.003$). The micro-CT images were also examined qualitatively.

Results > When analysing the individual ROIs, only the superior ROI had a significant difference ($P < 0.003$) beginning at the fourth activation cycle. For the monocortical group, trabecular spacing was affected when the whole ROI was analysed beginning at the fourth activation cycle, while for the superior ROI, this difference became apparent beginning with the third activation cycle ($P < 0.003$). For the qualitative analysis, it seems that only monocortical anchorage influences the trabecular bone in the superior area.

Conclusions > Monocortical anchorage is more susceptible to bone damage around the MIs, with the superior (cervical) region most strongly affected.

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Introduction

Maxillary transverse deficiency affects 20% of patients in mixed dentition [1]. Rapid maxillary expansion (RME) is the most popular treatment method for this dentofacial discrepancy. This technique opens the midpalatal suture to achieve upper dental arch amplitude [2] and prior studies describe the technique's success in treating maxillary transverse deficiency, particularly in younger patients [3–5]. However, the progressive calcification and interdigitation of circummaxillary sutures in older patients reduces the efficiency of RME [6].

When there is no potential to open the midpalatal suture with RME in adult patients, surgically assisted rapid palatal expansion (SARPE) may be an option [7,8]. Nevertheless, this technique is invasive and can lead to side effects, such as periodontium injuries, root resorption [9] and sinus infection [10].

Mini-implants (MIs) were used in the RME procedure for the first time in 2010 as an alternative to SARPE in adult patients [11] and continue to yield promising results. This technique is known as mini-implant assisted rapid palatal expansion (MARPE) and has been shown to expand maxillary efficiently in adolescents and adults [12–16].

Bicortical anchorage is recommended in cases where strong anchorage is desired and it is associated with the MI's stability improvement. This is achieved when the MI is inserted through the cortical plates of the hard palate facing the oral cavity and the nasal cavity [17–19]. Bicortical anchorage is not always achieved and, in this case, only the cortical plate facing the oral cavity is engaged (monocortical anchorage). However, virtual planning may improve the installation accuracy of these devices, aiming at the bicortical anchorage [20,21].

Taking the bone basic physiology into consideration, it is known that the process of drilling and implant placement may create stress and heat on the trabecular bone, associated with microcrack formation, and this microdamage may stimulate bone modelling or remodelling in the bone that supports the device [22].

While the stability of MIs is associated with bone stress around these devices [23,24], further investigation is needed to determine the relationship between the type of anchorage used in the MARPE technique and bone tissue close to the MI. This question should be addressed scientifically by laboratory studies. Therefore, this study aims to compare the effects of monocortical and bicortical anchorage on trabecular bone damage using micro-computed tomography (micro-CT).

Materials and methods

The project was approved by the Animal ethics committee of the Centre for health sciences of the Federal University of Rio de Janeiro before the study began, under number 01200.001568/2013-87.

Sample size calculation and groups division

According to a previous study [25], a power analysis was performed following the method outlined by Pandis [26], assuming α = 5% and study power = 80% using the trabecular space micro-CT parameter (Tb.Sp), minimum difference adopted was 0.08 mm with standard deviation of 0.04. The calculation for the difference between means suggested the use of seven samples per group. However, the MARPE appliance requires four MIs to perform the technique, leading to our sample size of eight MIs (two MARPE appliances per group). Thus, we consider each MI as an independent event in the experiment. Accordingly, two MARPE appliances were installed using monocortical anchorage, and the other two with bicortical.

Bone substrate

Four bone sections (3 cm × 5 cm) were removed from a bovine rib (Bos Taurus indicus, Nelore lineage) and stored at −20 °C [27]. All the specimens had approximately 1 mm of cortical bone (on the superior and inferior surfaces) with either 4 or 6 mm separating the two cortical bone areas, leading to bicortical and monocortical screw placement, respectively. A 1 mm thick slab of a rubber material (Angare – Carapicuiba, SP, Brazil) was attached with cyanoacrylate glue (SuperBonder– Sao Paulo, SP, Brazil) to the sample superficial's surface to simulate oral cavity soft tissue.

MARPE appliance installation

Each MARPE device (PECLAB® Sistema de Implantes Dentários, Brazil) was installed following the protocol stipulated by the manufacturer, using the PECLAB® mini-implant installation kit. Once the devices did not have tooth anchorage support, the prefabricated extensions were removed. The MIs used to install the MARPE device were from the same company (PECLAB® Sistema de Implantes Dentários, Brazil), made of Ti-6Al-4V alloy, cylindrical and self-drilling (7 mm length and 1.8 mm diameter).

The device was positioned over the bone substrate, and a cortical drill was used to break the upper cortical using a portable micromotor (Beltec LB100, Araraquara, Brazil) and contra-angle (KAVO 500, Charlotte, NC, USA). After the bone cortical rupture, the MIs were inserted (*figure 1*).

MARPE appliance activation and micro-CT image acquisition

Each activation opened 0.5 mm of the MARPE appliance (two ¼ turns each time). At the end of the five activation cycles, the device had a 2.5 mm opening. The activation process was done with a specific key for the PECLAB® MARPE device.

The acquisition of the micro-CT images of each time was obtained using the VTOMEX/m equipment (General Electric GE – Boston, Massachusetts, USA), under the following exposure parameters: 80 kV voltage, 280 µA current, and 24.23 µm pixel size. The files were obtained in DICOM format. A total of six

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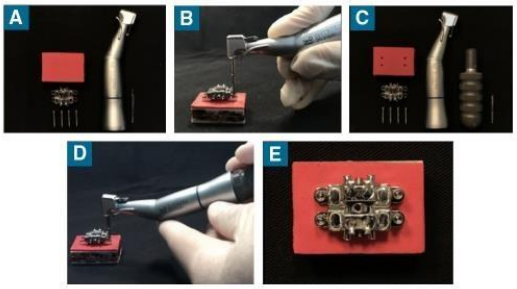

FIGURE 1

MARPE device installation. A. Bone sample, MARPE appliance, mini-implants, cortical bur and contra-angle. B. Cortical rupture. C. Sample with the cortical prepared to MI installation. D. MI installation. E. MARPE appliance prepared for activations

micro-CT files were obtained: T0 (before the first activation), T1 (after the first activation), T2 (after the second activation), T3 (after the third activation), T4 (after the fourth activation) and T5 (after the fifth activation). The samples were scanned in air, and this procedure was performed by the same operator (A.M. S.) and all the samples were positioned in the same position using a sample holder (*figure 2*).

Trabecular bone analysis

The DICOM files were converted to ISQ files and were analysed in the software µCT evaluation version 6.5-3 (Scanco Medical®, Brüttisellen, Switzerland). Trabecular bone micro-architecture was measured around the MIs to obtain trabecular number (Tb.N – 1/mm) and trabecular spacing (Tb.Sp – mm). The global threshold of segmented bone used in this study was 315 and 130 upper and lower, respectively. Five regions of interest (ROI) were determined for trabecular bone analysis:

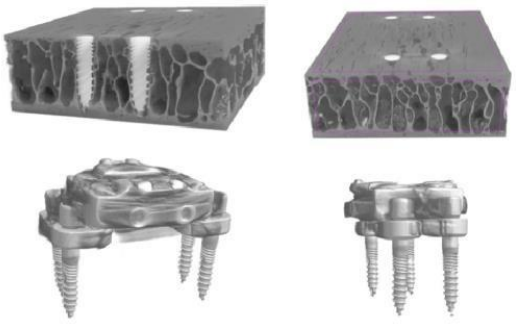

FIGURE 2

Sample micro CT images (bone substrate and MARPE appliance)

- whole area;
- superior area;
- inferior area;
- whole anterior area;
- and whole posterior area (*figure 3*).

When the whole area around the MI was analysed, a 0.10 cm^2 circular ROI was used around the device. When only the anterior or posterior area was analysed, a 0.05 cm^2 semi-circular ROI was used. When only half of the MI was analysed, the total slice numbers of the MI entire length were obtained using the software, and from this value, the slice representing exactly half of the MI was determined. All regions of interest selections were obtained with 3× zoom for the same operator (F.M.C.).

Data analysis

The statistical analysis was performed using the Statistical Package for Social Science program (version 21.0, SPSS Inc., USA). Intra-examiner accuracy was assessed by the intraclass correlation coefficient (ICC) obtained from the repetition of measurements of 30% of the samples, with a period of one week between the analyses. The normality of the sample was verified by the Kolmogorov–Smirnov test and the homogeneity of variances by the Levene test ($\alpha = 0.05$). Two-way ANOVA test with Tukey post-hoc analysis ($\alpha = 0.05$) was used to evaluate the main effects insertion type and ROI on trabecular bone architecture and the interaction terms were also examined. The time effect was evaluated using ANOVA-MR test effect with Bonferroni correction ($\alpha = 0.003$).

A qualitative analysis was performed to find similarities and differences between the groups during the device activation times.

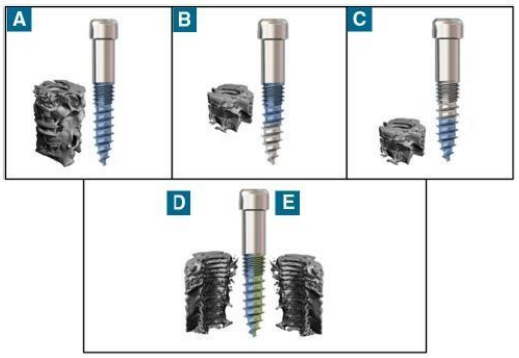

FIGURE 3

Regions of interest for the trabecular bone analysis. A. Whole area; B. Superior area; C. Inferior area; D. Whole anterior area; E. Whole posterior area

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TABLE I
Descriptive statistics for each activation time of trabecular space analysis

Area analysis	Type of insertion	Trabecular space (Mean ± SD)					
		T0	T1	T2	T3	T4	T5
Whole area	Monocortical	0.153 ± 0.007[a]	0.154 ± 0.008[a]	0.154 ± 0.007[a]	0.159 ± 0.005[a]	0.160 ± 0.008[a]	0.162 ± 0.004[a]
	Bicortical	0.150 ± 0.004[a]	0.152 ± 0.005[a]	0.154 ± 0.013[a]	0.155 ± 0.007[b]	0.154 ± 0.010[b]	0.154 ± 0.008[b]
Half top area	Monocortical	0.147 ± 0.008[a]	0.148 ± 0.009[a]	0.153 ± 0.010[a]	0.154 ± 0.012[a]	0.158 ± 0.009[a]	0.157 ± 0.009[a]
	Bicortical	0.151 ± 0.002[a]	0.149 ± 0.007[a]	0.151 ± 0.014[a]	0.150 ± 0.014[a]	0.150 ± 0.008[b]	0.151 ± 0.015[b]
Half bottom area	Monocortical	0.147 ± 0.008[a]	0.149 ± 0.007[a]	0.149 ± 0.007[a]	0.149 ± 0.005[a]	0.148 ± 0.005[a]	0.148 ± 0.006[a]
	Bicortical	0.153 ± 0.004[a]	0.154 ± 0.012[a]	0.154 ± 0.002[a]	0.153 ± 0.007[a]	0.152 ± 0.013[a]	0.153 ± 0.009[a]
Whole anterior area	Monocortical	0.149 ± 0.002[a]	0.150 ± 0.004[a]	0.152 ± 0.007[a]	0.151 ± 0.006[a]	0.149 ± 0.007[a]	0.150 ± 0.008[a]
	Bicortical	0.153 ± 0.004[a]	0.154 ± 0.012[a]	0.154 ± 0.002[a]	0.156 ± 0.007[a]	0.156 ± 0.003[a]	0.157 ± 0.009[a]
Whole posterior area	Monocortical	0.150 ± 0.004[a]	0.151 ± 0.012[a]	0.151 ± 0.002[a]	0.150 ± 0.007[a]	0.152 ± 0.023[a]	0.151 ± 0.009[a]
	Bicortical	0.149 ± 0.002[a]	0.150 ± 0.019[a]	0.150 ± 0.004[a]	0.151 ± 0.013[a]	0.150 ± 0.011[a]	0.150 ± 0.002[a]

[a]Different letters indicate statistically significant differences among groups (ANOVA/Tukey test) ($P < 0.05$).
[b]Indicate statistically significant differences among groups (ANOVA/Tukey test) ($P < 0.05$)

Results

The intraclass correlation coefficient was 92% for trabecular spacing and 95% for trabecular number.

No significant differences were observed when the trabecular number was analysed between the activation times ($P > 0.05$). Significant differences ($P < 0.05$) were observed between the monocortical and bicortical anchorage groups when Tb.Sp was analysed using the whole area ROI only after three times of activations (T3, T4 and T5), (monocortical: T0–0.153 ± 0.007/T3–0.159 ± 0.005/T4–0.160 ± 0.008/T5–0.162 ± 0.004; bicortical: T0–0.150 ± 0.004/T3–0.155 ± 0.007/T4–0.154 ± 0.010/T5–0.154 ± 0.008). When analysing the other ROIs, significant differences ($P < 0.003$) between groups were only found when the superior area was assessed after four activations (T4 and T5), (monocortical: T0–0.147 ± 0.008/T4–0.158 ± 0.009/T5–0.157 ± 0.009; bicortical: T0–0.151 ± 0.002/T4–0.150 ± 0.008/T5–0.151 ± 0.015). The Tb.Sp results for each time are displayed in *table I*.

About the effect of time, a significant difference ($P < 0.003$) was found for the monocortical group when the whole area was analysed between T0–T4 (−0.009 ± 0.004) and T0–T5 (−0.012 ± 0.008). For the superior area, significant difference ($P < 0.003$) was found ($P < 0.003$) for the monocortical group between T0–T3 (−0.089 ± 0.003), T0–T4 (−0.011 ± 0.008) and T0–T5 (−0.010 ± 0.006). *figure 4* shows the effect of time on Tb.Sp analysis. Descriptive statistics of Tb.Sp for the effect of

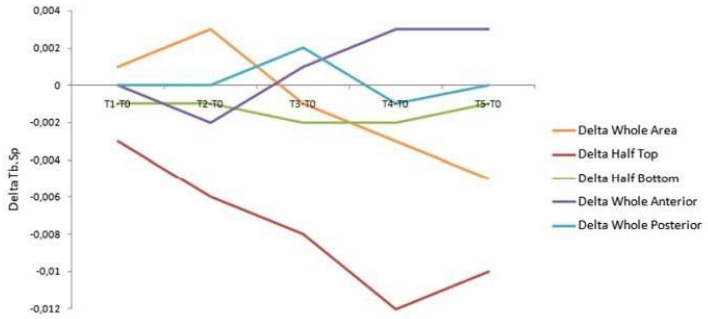

FIGURE 4
Graph showing the effect of the activations on the Tb.Sp analysis. Monocortical anchorage increases Tb.Sp after the activations when the whole area is analysed but the superior area (cervical area) is more susceptible to it when compared to the inferior area

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TABLE II
Descriptive statistics for the difference between times (ΔTb.Sp) of the trabecular space analysis

Area analysis	Type of insertion	Trabecular space (ΔTb.Sp)							
		T0–T1	T0–T2	T0–T3	T0–T4	T0–T5	T1–T2	T1–T3	T1–T4
Whole area	Monocortical	−0.001 ± 0.004	−0.007 ± 0.007	−0.006 ± 0.002	−0.009 ± 0.004*	−0.012 ± 0.008*	−0.386 ± 0.009	−0.005 ± 0.002	−0.006 ± 0.002
	Bicortical	−0.003 ± 0.001	−0.005 ± 0.002	−0.006 ± 0.008	−0.004 ± 0.006	−0.005 ± 0.005	−0.002 ± 0.003	−0.003 ± 0.007	−0.001 ± 0.007
Half top area	Monocortical	−0.001 ± 0.004	−0.006 ± 0.002	−0.089 ± 0.003*	−0.011 ± 0.008*	−0.010 ± 0.006*	−0.005 ± 0.007	−0.006 ± 0.003	−0.010 ± 0.001
	Bicortical	0.002 ± 0.005	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.002	0.000 ± 0.008	−0.002 ± 0.006	−0.001 ± 0.001	−0.001 ± 0.008
Half bottom area	Monocortical	0.001 ± 0.006	−0.003 ± 0.006	0.000 ± 0.001	−0.001 ± 0.007	−0.001 ± 0.004	−0.004 ± 0.005	−0.001 ± 0.008	−0.002 ± 0.009
	Bicortical	−0.001 ± 0.002	−0.001 ± 0.004	−0.006 ± 0.004	−0.007 ± 0.002	−0.009 ± 0.006	0.000 ± 0.006	−0.005 ± 0.005	−0.006 ± 0.001
Whole anterior area	Monocortical	−0.001 ± 0.008	−0.003 ± 0.003	−0.001 ± 0.003	0.003 ± 0.006	0.004 ± 0.002	−0.002 ± 0.002	0.000 ± 0.002	0.004 ± 0.005
	Bicortical	−0.001 ± 0.003	−0.001 ± 0.007	−0.006 ± 0.007	0.003 ± 0.004	−0.009 ± 0.003	0.000 ± 0.006	−0.005 ± 0.009	0.004 ± 0.006
Whole posterior area	Monocortical	−0.001 ± 0.003	−0.001 ± 0.006	0.000 ± 0.003	−0.002 ± 0.007	−0.001 ± 0.007	0.000 ± 0.009	0.001 ± 0.002	−0.001 ± 0.003
	Bicortical	−0.001 ± 0.006	−0.001 ± 0.005	−0.002 ± 0.003	−0.001 ± 0.002	−0.001 ± 0.004	0.000 ± 0.004	−0.001 ± 0.004	0.000 ± 0.005

* indicates statistical significance with the RMANOVA test with Bonferroni correction ($\alpha = 0.003$).

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TABLE III
Descriptive statistics for the difference between times (ΔTb.Sp) of the trabecular space analysis

Area analysis	Type of insertion	Trabecular space (ΔTb.Sp)						
		T1-T5	T2-T3	T2-T4	T2-T5	T3-T4	T3-T5	T4-T5
Whole area	Monocortical	−0.002 ± 0.007	0.003 ± 0.002	0.003 ± 0.002	0.002 ± 0.008	−0.001 ± 0.006	−0.003 ± 0.009	−0.002 ± 0.009
	Bicortical	−0.002 ± 0.004	−0.001 ± 0.005	0.001 ± 0.009	0.000 ± 0.002	0.002 ± 0.002	0.001 ± 0.001	−0.001 ± 0.008
Half top area	Monocortical	−0.009 ± 0.007	−0.001 ± 0.008	−0.005 ± 0.004	−0.004 ± 0.002	−0.004 ± 0.002	−0.003 ± 0.004	0.001 ± 0.004
	Bicortical	−0.002 ± 0.009	0.001 ± 0.006	0.001 ± 0.006	0.000 ± 0.007	0.000 ± 0.007	−0.001 ± 0.009	−0.001 ± 0.002
Half bottom area	Monocortical	−0.002 ± 0.007	0.003 ± 0.009	0.002 ± 0.006	0.002 ± 0.003	−0.001 ± 0.002	−0.001 ± 0.002	0.000 ± 0.008
	Bicortical	−0.008 ± 0.007	−0.005 ± 0.005	−0.006 ± 0.007	−0.008 ± 0.007	−0.001 ± 0.003	−0.003 ± 0.002	−0.002 ± 0.009
Whole anterior area	Monocortical	0.005 ± 0.007	0.002 ± 0.008	0.006 ± 0.009	0.007 ± 0.002	0.004 ± 0.007	0.005 ± 0.009	0.001 ± 0.008
	Bicortical	−0.008 ± 0.007	−0.005 ± 0.007	0.004 ± 0.007	−0.008 ± 0.007	0.009 ± 0.008	−0.003 ± 0.004	−0.012 ± 0.002
Whole posterior area	Monocortical	0.001 ± 0.009	0.001 ± 0.009	−0.001 ± 0.004	0.000 ± 0.002	−0.002 ± 0.007	−0.001 ± 0.004	0.001 ± 0.007
	Bicortical	0.000 ± 0.003	−0.001 ± 0.004	0.000 ± 0.008	0.000 ± 0.007	0.001 ± 0.008	0.001 ± 0.009	0.000 ± 0.004

* indicates statistical significance with the RMANOVA test with Bonferroni correction (α = 0.003).

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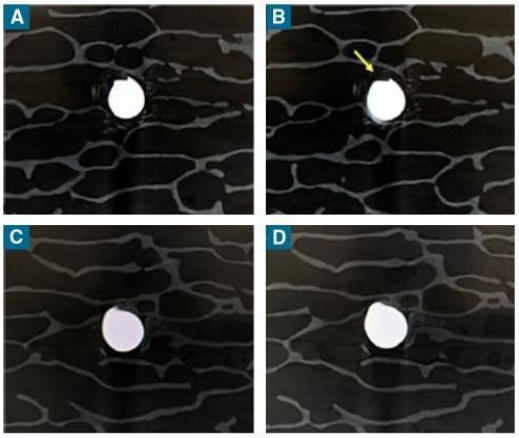

FIGURE 5

Trabecular bone qualitative analysis showing that the cervical area is more affected when the MIs are inserted with monocortical anchorage when compared to bicortical. A. Monocortical anchorage superior area in T0. B. Monocortical anchorage superior area in T6. The yellow arrow shows the space after the MI compression. C. Bicortical anchorage superior area in T0. D. Bicortical anchorage superior area in T6

time between the activations (ΔTb.Sp) is displayed in *tables II and III*.

When the slices were assessed qualitatively, there appeared to be more rupture of the trabeculae in the superior area when the MIs were inserted using monocortical anchorage when compared to bicortical (*figure 5*). For both types of anchorage, the inferior area seems not to be affected by the appliance activation.

Discussion

The MARPE technique has emerged as a potential treatment for transverse maxillary deficiency. This alternative treatment approach can avoid major periodontal side effects associated with an invasive surgically assisted maxillary expansion [10,28]. Nevertheless, MARPE is not always successful, motivating the present in-vitro study to examine alterations in bone around these devices. Some factors may be associated with the failure of these devices, such as the professional's ability during the mini-implant's installation, the design, manufacture, frequency of activation, patient hygiene, anatomy of the palate, systemic diseases, and bone structure and quality that is investigated in this study. We did find alterations in trabecular spacing, particularly in the monocortical group near the cervical aspect of the MI, suggesting that trabecular bone damage could be a failure mechanism and emphasising the importance of bicortical anchorage.

Bovine rib samples were chosen as the bone model for this study once they were already used in previous biomechanical studies [29–31]. Besides, the thickness of the bovine rib in selected areas allows the simulation of the two types of anchorage (monocortical and bicortical) performed in this study.

The micro-CT technique allows the acquisition of high-resolution 3-dimensional images of the bone sample [32] and micro-architectural properties [33–35], such as the trabecular number and trabecular spacing used in this study and one other study [25] using the same bovine model.

The study by Lee et al. [36], using finite element analysis, showed the presence of stress areas around the MIs when these devices received the activation force from the MARPE appliance. Besides that, a possible difference between areas of stress when compared to the monocortical and bicortical anchorage was observed in this study. It was then decided that different ROIs be adopted in this study. Due to the lack of studies that determined the strength of bone resistance when the device is activated, the present study decided to use a sample simulating the completely closed midpalatal suture, as it was performed in a previous study [36]. Thus, the force applied directly by the MIs was standardised when the MARPE device was activated. To make it possible to discuss this issue with numerical data, we decided to test a sample simulating an open midpalatal suture to determine the force placed on the MIs during each activation of the MARPE appliance.

In the present study, it was found that changes in the trabecular microarchitecture could be observed from the third activation of the MARPE appliance when the MI is inserted in monocortical anchorage. Studies have shown that overloading bone tissue around the MI may cause the loss of the primary stability of these devices [23]. The study by Lee et al. [36] using finite element analysis showed that there is higher stress around the devices inserted in monocortical anchorage. These findings are consistent with the results of the present study, which showed a greater change in trabecular micro-architecture around devices inserted with monocortical anchorage.

The stress in the cervical area of the MI is associated with the risk of loosening of these devices [24] and this is probably associated with inflammation response and bone remodelling after the device installation and/or activation. The present study showed that the superior area around the monocortical MIs was more damaged than the devices inserted using bicortical anchorage. Our studies are consistent with the idea that bicortical anchorage has a lower risk of loss of primary stability of mini-implants.

The present study is limited only to mechanical results, since it is an in-vitro and ex-vivo study. However, these are important results for orthodontists since, when using the MARPE technique, purely mechanical force is necessary to open the maxillary sutures. Because of the inherent limitations of the ex-vivo studies and in-vitro mechanical simulations, future studies using

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an in-vivo animal model, such as minipig, are needed to confirm our results. It is also suggested that a retrospective clinical study analysing the failure rate of MI associated with the MARPE technique be done to determine if the failure of these devices is associated with the type of insertion.

Conclusions

Besides the limitations of an in-vitro study, the following conclusions were drawn:

- bone microarchitecture around mini-implants may change when these devices receive force from the MARPE appliance screw;
- monocortical anchorage creates greater bone damage around the MIs when compared to bicortical anchorage;
- the cervical/superior region is most affected when bicortical anchorage cannot be achieved.

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4.2 ARTIGO 2

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REVIEW ARTICLE

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Is the buccal alveolar bone less affected by mini-implant assisted rapid palatal expansion than by conventional rapid palatal expansion?—A systematic review and meta-analysis

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Abstract

Objective: To systematically review the existing literature comparing mini-implant assisted rapid palatal expansion (MARPE) and conventional rapid palatal expansion (RPE) regarding the effect on the buccal alveolar bone thickness (BT) and marginal bone level (BL).

Methods: PubMed/MEDLINE, Scopus, Web of Science, The Cochrane Library, Virtual Health Library, Embase, Ovid, LIVIVO, CINAHL, the *Portal de Periódicos da CAPES*, Google Scholar and SIGLE were searched up to January 2020. Risk of bias (RoB) assessments were performed using the Cochrane Collaboration and ROBINS-I tools. Fixed-effects meta-analysis of standardized mean differences (SMD) was implemented to assess the pooled estimates for the BT outcome. The analyses were performed adopting a significance level of 5%. A narrative synthesis was performed to summarize the results on the BL. The GRADE tool was used to assess the quality of the evidence.

Results: Three randomized clinical trials and one retrospective study were included. Only one study was rated as with low RoB, while the others were scored as with moderate to serious RoB. Limited evidence indicated that patients using conventional RPE had a greater loss of the BT compared to patients using MARPE (SMD = 0.55; 95% CI: 0.29-0.80; $P < .0001$). Subgroup analyses showed that differences were significant in both premolars' regions, right (SMD = 0.75; 95% CI: 0.24-1.25; $P = .004$) and left (SMD = 1.05; 95% CI: 0.52-1.57; $P < .0001$), and these were not significant for the molars' regions ($P > .05$) (Low quality of evidence).

Limitations: Limited amount of selected papers, methodological issues that could lead to bias and high clinical heterogeneity among the studies. Due to the statistical model applied for the quantitative synthesis of the results, no generalization to any other population is recommended.

Registration: The protocol of this systematic review was registered in PROSPERO (CRD42014007510). This was updated twice after the first registration.

Conclusions: Limited evidence suggests that MARPE could decrease the loss of the buccal alveolar bone when compared to conventional RPE.

KEYWORDS
alveolar bone loss, meta-analysis, orthodontic anchorage procedures, palatal expansion technique, systematic review

1 | INTRODUCTION

Rapid palatal expansion (RPE) is the procedure routinely used for correction of the transverse maxillary deficiency.[1] On this therapy, heavy forces exceeding the necessary limits for orthodontic movement are applied to the anchorage teeth inducing hyalinization of their periodontal ligament; this allows the transmission of loading to the maxilla, promoting opening of the midpalatal suture.[2] Although, in general, RPE has been recognized as a safe and reliable treatment in growing patients,[3] it causes lateral flexion of the alveolar processes and buccal tipping of the involved teeth,[4-6] favouring the appearance of periodontal side effects such as loss of the buccal bone thickness and marginal bone level.[7-9]

Because of the increase in skeletal resistance of the midpalatal suture in the late adolescence[10,11] and the possible greater dental/periodontal effect that RPE could produce, the feasibility and predictability of this therapy on mature patients remains controversial.[12-14] Surgically assisted rapid maxillary expansion (SARME) was advocated as the treatment of choice for these cases[15-17]; however, the increased morbidity and cost issues result in poor patients' acceptability. More recently, mini-implant assisted rapid palatal expansion (MARPE) was proposed as a procedure with the ability to obtain skeletal transverse correction without severe periodontal side effects on the anchorage teeth[18] and without biological trauma caused by SARME.[19] When MARPE is used, loading is directly distributed on the palate with less rotation and tipping of the maxillary complex, and stress on the supporting tissues.[20]

Two systematic reviews with different methodologies and conflicting results about dental and/or skeletal effects of MARPE were previously published.[21,22] While one concluded that this procedure and conventional RPE result in the same dentoskeletal outcome,[21] the other one demonstrated advantages of bone-borne or hybrid tooth-bone-borne RPE in terms of increased sutural opening and reduced tooth tipping.[22] This last review also evaluated the adverse effects of this procedure, including those that occur on the periodontium. The authors suggest based on two selected studies[23,24] that MARPE may cause less loss of buccal alveolar bone thickness than conventional RPE. However, in that review, studies with missing full text and with retrospective designs were not included for the synthesis of results. Besides that, the authors did not include studies assessing the marginal alveolar bone level, and only a brief narrative description of the results was made. Thus, the present systematic review aimed to assess more extensively the existing literature to answer the following focused question (PICO strategy): In subjects with transverse maxillary deficiency (P), are the buccal alveolar bone thickness and marginal bone level (O) less affected by MARPE (I) than by conventional RPE protocols (C)? The null hypothesis tested was that there was no difference between both techniques regarding the effect on the buccal alveolar bone.

2 | MATERIALS AND METHODS

2.1 | Protocol and registration

This review was conducted with the guidance of the Cochrane Handbook for Systematic Reviews of Interventions[25] and reported according to the PRISMA statement guideline (www.prisma-statement.org)[25] The protocol of this systematic review was initially registered in PROSPERO (CRD42014007510) on 8 April 2014. At that time, although formal search processes were finished, the conduction of the review was truncated. In 2019, the project was resumed following new methodology and reformulating the primary outcome. Thus, the protocol was updated on 1 May 2019. A last modification of the protocol was requested to PROSPERO on January 2020 because (a) the search process would be updated and new databases would be reviewed; (b) terminology adjustments would be made to avoid misunderstandings; and (c) the possibility of analyses (not informed in the previous versions) had to be reported, with the objective of being more specific in the description of the procedures that would be executed. All protocol versions are available in www.crd.york.ac.uk/prospero.

2.2 | Eligibility criteria

Studies in accordance with the following selection criteria were included:

Participants (P): patients of both sexes, without restriction on socio-economic classification, ethnicity or age, who were diagnosed with transverse maxillary deficiency.

Intervention (I): bone-borne or hybrid tooth-bone-borne RPE protocols using mini-implants (MARPE).

Comparison (C): conventional tooth-borne or tooth-tissue-borne RPE protocols no using mini-implants.

Outcome (O): changes in the buccal alveolar bone thickness and/or marginal bone level (bone dehiscence), assessed by

three-dimensional methods. No secondary outcomes were established for this review.

Study design (S): randomized or non-randomized clinical trials and retrospective studies.

Studies that combined RPE protocols with another treatment (ie reverse facemask), or applied MARPE protocols that used surgical procedures to assist the opening of the midpalatal suture were not included. On the other hand, studies that assessed systemically comprised or cleft/syndromic patients were excluded. Review articles, case reports, case series, editorials and experts' opinions were not selected for the present systematic review.

2.3 | Information sources, search strategy and study selection

Systematic searches were performed using the following electronic databases: PubMed (MEDLINE), Scopus, Web of Science, The Cochrane Library, Virtual Health Library, Embase, Ovid, LIVIVO and CINAHL. Searches on grey literature were performed in Google Scholar, the *Portal de Periódicos da CAPES* (Brazil) and the System for Information on Grey Literature on Europe (SIGLE). To retrieve the eligible studies, the search strategy was firstly developed for PubMed, and then, it was adapted according to the syntax rules of the other databases, using MeSH terms when possible, and free text words (see terms and complete search strategy in Table S1). This process was assisted by a senior health science's specialized librarian (DFM). No restrictions on language or date were applied.

An initial screening on titles and abstracts was performed. At the beginning, three reviewers (FMC, GMV and LDC) independently selected all the studies they considered satisfied the eligibility criteria. Subsequently, a consensus meeting was held to make the final decision. The participation of a fourth evaluator (LCM) was requested to resolve any discrepancy between the reviewers. For the abstracts not providing enough information, full texts were retrieved for analysis or the author was contacted for further clarifications. It was planned to send e-mails once a week for a period of four consecutive weeks until the corresponding authors of the selected studies answered. If no responses were obtained after this period, we would decide not to include the data in quantitative synthesis.

The final selection was performed by comprehensive reading of the studies. Additionally, a hand search in the reference list of the selected papers was performed. Experts in the subject of interest were contacted to retrieve ongoing studies or unpublished research. The search was performed until March 2019 and updated until January 2020.

2.4 | Quality assessment and risk of bias

An independent quality assessment was performed by two reviewers (FMC and GMV) with the intervention of a third one (LCM) when disagreement occurred. The Cochrane Collaboration's tool was used to assess the risk of bias and quality of evidence of the randomized trials.[25] On the other hand, the ROBINS-I (Risk of bias in non-randomized studies of interventions) tool was used for non-randomized/retrospective studies.[27]

2.5 | Data extraction

The following data were extracted from the included studies: (a) author, year of publication and country where the study was performed; (b) study design; (c) participants-related data (sample size, genders distribution and mean age of participants); (d) conventional expander design; (e) MARPE design; (f) outcomes assessed; (g) periods of evaluation; and (h) main study results.

2.6 | Meta-analysis

Clinical heterogeneity of the included studies was assessed by the examination of the trial design, participants' characteristics, intervention protocols, outcomes' assessment methodologies and any other relevant source of heterogeneity.

The standardized mean differences (SMD) with their correspondent 95% confidence intervals (95% CI) were chosen as effect measures. Meta-analyses were performed using the inverse variance method. The fixed-effect model was selected to assess all pooled estimates.[28] Subgroup analyses were performed to explore the effect of the tooth type (1st premolar/ 1st molar) and the maxillary side (right/ left) on the buccal alveolar bone thickness. Besides that, a sensitivity analysis was pre-determined to explore differences when reported results for mesiobuccal or distobuccal roots of first molars are included in meta-analysis. The analyses were performed in RevMan (version 5.3.5; The Nordic Cochrane Centre) adopting a significance level of 5%.

Since, according to the statistical model used (fixed-effects model), the estimate of variance between the studies is zero, the prediction interval as a measure of dispersion between them was not calculated.[28]

2.7 | Evaluation of the certainty of evidence

The evidence level was measured using the Grading of Recommendations, Assessment, Development and Evaluation Pro software (GRADEpro Guideline Development Tool, available online at gradepro.org.). It grades the quality of evidence in four levels: very low, low, moderate and high. 'High quality' suggests that the true effect lies close to the estimate of the effect. 'Very low quality' suggests that there is very little confidence in the effect estimate, and the estimate reported can be substantially different from what was measured. This tool considers five aspects for rating the quality of evidence: risk of bias, inconsistency, indirectness, imprecision and other considerations.[29]

3 | RESULTS

3.1 | Study selection and characteristics

The flow chart of the search selection procedures, according to the PRISMA guideline, is shown in Figure 1. Of the 3335 articles initially retrieved, 2926 remained after the removal of duplicates. A total 2912 records were excluded after title and abstract screening. Fourteen articles were finally assessed for eligibility; ten were excluded after full-text reading (reasons for exclusion are shown in Figure 1). Four studies[23,24,30,31] were included for qualitative synthesis: 3 randomized prospective studies[23,24,31] and 1 non-randomized retrospective study.[30]

3.2 | Risk of bias within studies

The risk of bias assessment for the randomized studies classified one of them as with low risk of bias,[23] and the other two studies were judged as with serious risk of bias.[24,31] The main factors contributing to the risk of bias were the lack of clarity/quality in the randomization processes and the lack of information on the evaluators' blindness (Figure 2). Regarding to the non-randomized study,[30] it was judged as with moderate risk of bias. This judgment was mainly attributed to the possible bias in classification of interventions and measurement of outcomes (Figure 3).

3.3 | Results of individual studies

Three of the selected studies were identified as randomized clinical trials,[23,24,31] and one was a retrospective study.[30] Two of them evaluated growing patients (adolescents),[23,24] one evaluated patients in the final stage of growth (late adolescents),[30] and one did not detail the sample age.[31] Regarding to the design of the conventional RPE appliances, all studies used the Hyrax expansion screw; three of them with bands in the first premolars and first molars,[24,30,31] and one of them using an occlusal coverage for the posterior teeth.[23] There was greater variability on the design of the MARPE appliances used between the studies. Although with some differences (design and the number of mini-implants used for anchorage), three studies performed exclusive bone-borne RPE.[23,30,31] The other used a hybrid tooth-bone-borne RPE.[24]

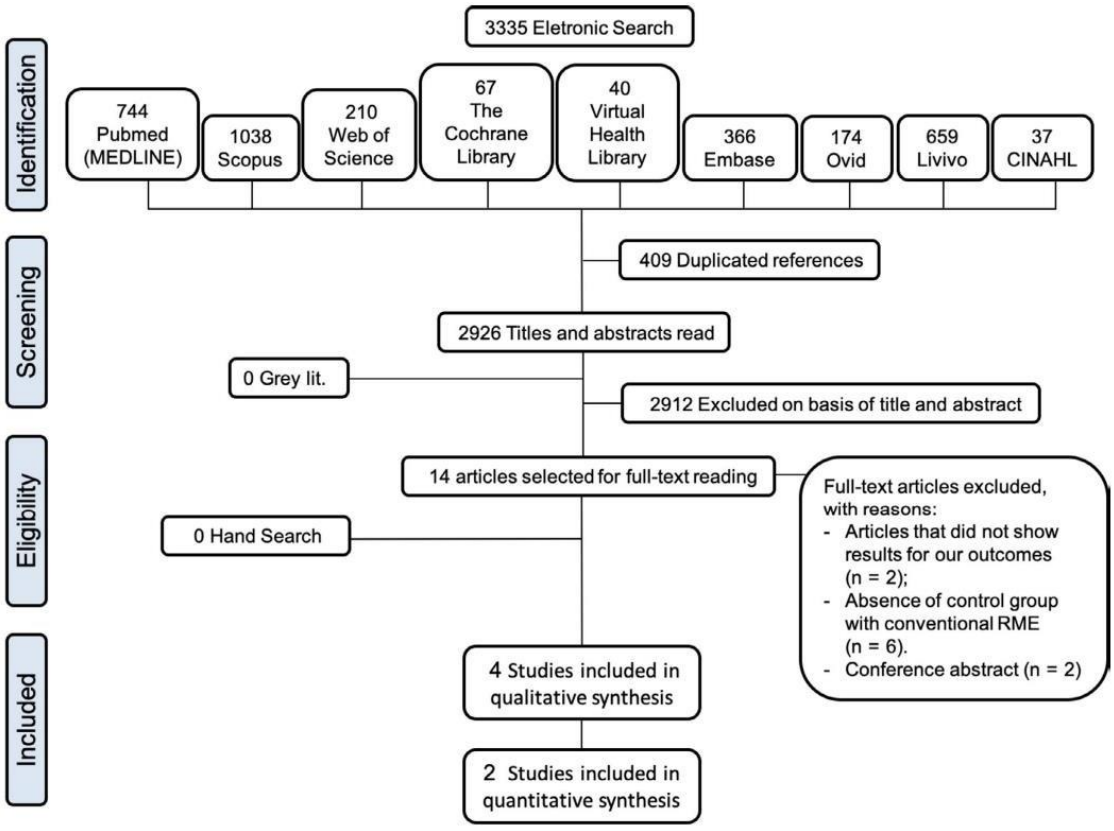

FIGURE 1 PRISMA flow diagram for the studies selection procedure

Two studies assessed the buccal alveolar bone thickness as outcome.[23,24] One of them showed that there is less decrease in the alveolar bone thickness for MARPE in both the premolar and molar regions, following six months of passive retention.[23] The other study showed similar results only for the premolar region on one side (left side), after three months of follow-up.[24] The other two studies evaluated changes in the marginal bone level.[30,31] Although they had different follow-up times (three and six months), both studies showed differences between the two types of procedures. One of them demonstrated that there is less vertical bone loss in the premolar region when MARPE is used.[30] For the other study,[31] although the authors concluded that the amount of bone loss was not clinically significant for any of the groups, a statistical difference was found between them for the first right premolar region. However, the results are unclear as to which intervention has less or more bone loss. Attempts were made to contact the authors of this study. Because no responses were obtained, this paper[31] was excluded from meta-analysis. Positive results were achieved in attempts to contact the authors of the other three included studies[23,24,30] (see Acknowledgement section).

A summary of the description of the studies included and evaluated is presented in Table 1.

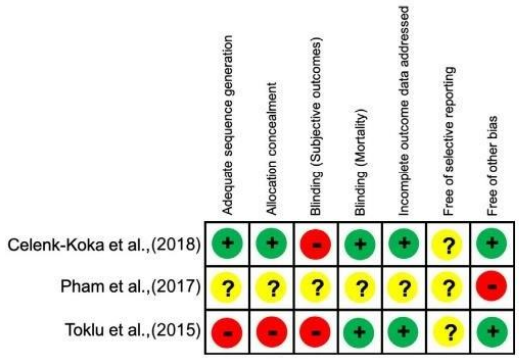

FIGURE 2 Risk of bias assessment for the included randomized studies, according to Cochrane Collaboration's tool

3.4 | Meta-analysis and certainty of evidence

The meta-analysis showed that patients using the conventional expansion technique (n = 33) had a greater loss of the buccal alveolar bone thickness by 0.55 standardized measurement units (SMD = 0.55; 95% CI: 0.29-0.80; $P < .0001$) compared to patients using MARPE (n = 32). Subgroup analyses evidenced that these differences were significant in both premolars' regions, right (SMD = 0.75; 95% CI: 0.24-1.25; $P = .004$) and left (SMD = 1.05; 95% CI: 0.52-1.57; $P < .0001$), and these were not significant for the molars' regions ($P > .05$) (Figure 4). Considering that Toklu et al[24] reported results for the mesial and distal first molar roots regions, sensibility analyses were performed in both conditions, evidencing similar patterns for the overall effects measurements. Meta-analysis including data of the distal root region reported by Toklu et al[24] is presented in the Figure A1.

Certainty of the evidence was low and very low for the effect stated for the buccal alveolar bone thickness and marginal bone level, respectively (Table 2). Risk of bias and inconsistency items were categorized as serious because the low quality and clinical heterogeneity of the studies included. For the bone marginal level outcome, imprecision was additionally rated as serious because only a narrative synthesis was conducted and the estimates are not precise.

4 | DISCUSSION

MARPE has been advocated as a suitable therapy for correction of the transverse maxillary deficiency in patients in whom the midpalatal suture is partially or fully fused.[18,22] Because stress is more distributed on the hard palate instead of the anchorage teeth, this procedure is supposed to cause less negative effects on the supporting alveolar bone when compared to the conventional RPE.[20] To the best of our knowledge, this review systematically assessed the whole existing literature that supports these assumptions or not, with methodological rigour and high standard very well established criteria. The results suggest that, despite the limited amount of evidence selected, MARPE could produce less loss of buccal alveolar bone than conventional RPE protocols, thereby rejecting the

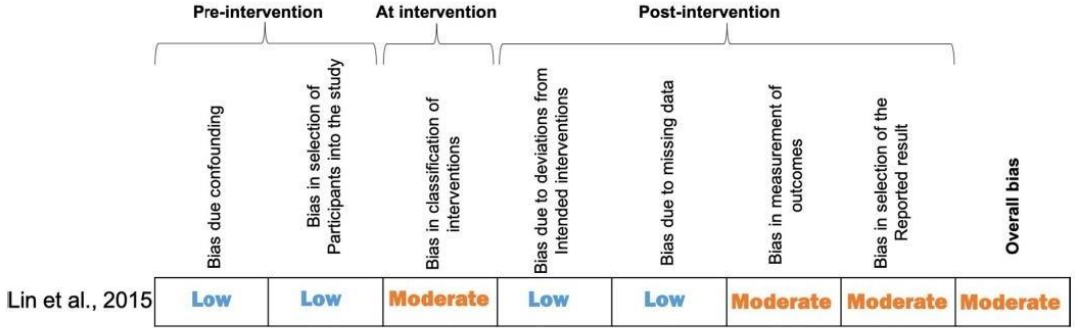

FIGURE 3 Risk of bias assessment for the included non-randomized study, according to ROBINS-I tool

TABLE 1 Characteristics of the included studies

Author/ Year/ Country	Study design	Participants-related data		Conventional expander design	MARPE design
		Sample size/ Gender	Mean age		
Celenk-Koka et al/ 2018/ Turkey	RCT	40 patients (20 conventional RME [12 female and 8 male]) and 20 Miniscrew-supported RME [13 female and 7 male])	Conventional RME: 13.84 ± 1.36 y; Miniscrew-supported RME: 13.81 ± 1.23 y	Hyrax expansion screw with occlusal coverage of premolars and first molar (and extension for second molar) (tooth-borne expansion)	Hyrax expansion screw individually fitted and supported by 4 mini-implants (1.8 mm × 9 mm, Orlus, Ortholution Co, Seoul, Korea) inserted into the palatal alveolar bone between the roots of first and second premolars, and between second premolars and first molars (bone-borne expansion)
Toklu/ 2015/ Turkey	RCT	25 patients (13 tooth-borne expansion [8 female and 5 male] and 12 tooth-bone-borne expansion [6 female and 6 male])	Tooth-borne expansion: 14.3 ± 2.3 y; tooth-bone-borne expansion: 13.8 ± 2.2 y	Hyrax expansion screw with bands on first premolars and first molars (tooth-borne expansion)	Hyrax expansion screw with bands on the first molars and additionally supported by 2 mini-implants (1.8 mm × 9 mm, Total Anchor, Trimed, Ankara, Turkey) inserted at the level of the right and left first premolars, next to the midpalatal suture (tooth-bone-borne expansion)
Lin et al/ 2015/ Korea	Retrospective	28 female patients (13 tooth-borne expansion and 15 bone-borne expansion [C-expander])	Tooth-borne expansion: 17.4 ± 3.4 y; bone-borne expansion: 18.1 ± 4.4 y	Hyrax expansion screw with bands on first premolars and first molars (tooth-borne expansion)	C-expander (acrylic resin connecting the expansion screw with the mini-implants) supported by 4 mini-implants (1.8 mm × 8.5 mm, C-Implant Co, Seoul, Korea) placed 8 mm beneath the alveolar ridge: two between canines and first premolars and two between the second premolars and first molars (bone-borne expansion)
Pham & Lagravère/ 2017/ Canada	RCT	62 patients (20 tooth-anchored expansion, 21 bone-anchored expansion and 21 controls/ no treatment)	---	Hyrax expansion screw with bands on first premolars and first molars (tooth-borne expansion)	Non-detailed bone-anchored maxillary expander placed on each side between the projection of the first permanent molars and second premolar roots, and 6 mm from the midpalatal suture (bone-borne expansion)

established null hypothesis. However, due to methodological limitations and the small number of included studies, no generalization to any other population is recommended.

Two of the selected studies evaluated the buccal alveolar bone thickness.[23,24] Celenk-Koka et al[23] demonstrated that although MARPE also causes a slight decrease in the buccal bone thickness (first premolars: −0.04 mm; first molars: −0.10 mm), this loss is significantly lower than the occurred with conventional RPE (first premolars: −0.29 mm; first molars: −0.24). On the other hand, Toklu et al[24] showed that there is a significant decrease in the buccal alveolar bone thickness in both premolars and molars in the conventional RPE group, while in the MARPE group, there is only loss in the molar region. When both groups were compared, there was a difference only for one of the first premolars. The loss was significant for the conventional RPE group (−0.80 mm), while it was maintained in the MARPE group for this tooth (−0.009 mm).

Both the study by Celenk-Koka et al[23] and by Toklu et al[24] were randomized controlled trials. The first one was categorized as with low risk of bias, while the second one was rated as with serious risk of bias. There were methodological differences between both studies, especially regarding the difference in the designs of appliances and follow-up periods. A meta-analysis was attempted using a fixed-effects model. The raw data for the right and left sides from the study by Celenk-Koka et al[23] were solicited to perform subgroup analysis for each anchorage tooth stratifying this by the side. The implemented meta-analysis demonstrated that MARPE significantly decreased the loss of buccal alveolar bone thickness, mainly at the first premolar region, when compared to the conventional RPE. However, the quality of evidence for this effect was graded as low because the serious risk of bias of the study by Toklu et al,[24] and a serious inconsistency caused by clinical heterogeneity of the studies included in the analyses. It is important to enphasize that this pooled estimate should be restricted for studies included in the analysis and not generalized to other populations.

The other two selected studies evaluated the marginal bone level (bony dehiscence).[30,31] Lin et al[30] demonstrated that vertical bone loss is significantly greater at the first premolar region

Outcome	Evaluation periods	Results
Buccal alveolar bone width: measurement from the outermost point of the bone to the roots at the level of the bifurcation and trifurcation of the maxillary first premolars and maxillary first molars, respectively.	Pre-treatment (T1) and 6 mo (T2) following passive retention period using the same appliances	Both groups showed decreases in buccal bone width at the level of first premolars (conventional RME: −0.29mm; bone-borne RME: −0.04mm) and first molars (conventional RME: −0.24mm; bone-borne RME: −0.10mm). However, the bone-borne RME group experienced significantly less buccal bone loss than the conventional RME group for both the premolars (P = .003) and molars (P = .046)
Buccal bone plate thickness: distance between the external border of the buccal cortical plate to the centre of the buccal aspect of the first premolar root or first molar mesiobuccal or distobuccal roots (right and left sides)	Pre-treatment (T1) and at the end of 3 mo of retention (T2)	Significant difference was found in the buccal bone thickness in the left first premolar (P < .001) when tooth-borne and tooth-bone-borne expansion groups were compared. The tooth-bone-borne group experienced less buccal bone loss (−0.009 mm) than the conventional tooth-borne group (−0.80 mm)
Buccal alveolar bone dehiscence: measurement from the cementum-enamel junction to the alveolar crest on buccal side, on premolars and molars (right and left sides)	Pre-treatment (T1) and 3 mo after expansion (T2)	For both groups, vertical alveolar bone loss was significantly increased at the first premolar area compared with other posterior teeth (P < .001). On the other hand, a difference in buccal dehiscences at the first premolar was obvious between both groups (P < .001). The tooth-borne group showed greater buccal dehiscences (>5 mm) when compared to the MARPE group (<0.20 mm)
Buccal alveolar bone level: measurement from cusp to bone margin on premolars and first molars (mesial and distal roots)	Pre-treatment (T1) and at the removal of the appliance, 6 mo since appliance insertion (T2)	When the bone-borne group was compared to the conventional tooth-borne group, there was a significant difference between measurements from the cusp tip to the buccal bone margin at the level of first premolars (mean difference 1.122 mm)

in patients using conventional RPE (right side: 5.16 mm; left side: 5.06 mm) when compared to the loss occurred in patients in the MARPE group (right side: 0.11 mm; left side: 0.09 mm). There was no difference in the vertical bone loss for the other teeth evaluated between the tooth-borne (<0.6 mm) and bone-borne groups (<0.2 mm). This study was rated as with moderate risk of bias. On the other hand, the study by Pham & Lagravère[31] concluded that there is no difference in the marginal bone level of the posterior teeth between conventional RPE and MARPE groups, except for the right first premolar (difference of 1,122 mm between the groups). The results are unclear as to which intervention has less or more bone loss. The authors stated that the amount of bone loss was not clinically significant for any of the groups (<1 mm). This study was categorized as having a serious risk of bias. The quality of the evidence on this outcome is very low due to the moderate and serious risk of bias in the studies, inconsistency caused by clinical heterogeneity of them, and imprecision for being a narrative synthesis (absence of meta-analysis due to lack of access to the raw data corresponding to one of the studies).[31]

Regarding this outcome (marginal bone level), there was a difficulty in terms of information related to the data presented by the study of Pham & Lagravère.[31] The authors only reported the mean difference between the measures of marginal bone level in the pre (T1) and post-treatment (T2), and not the means for each of the evaluation periods independently. Considering that the way of reporting the mean difference is not equal among the studies (this may be T1 minus T2, or T2 minus T1), it can only be concluded with high degree of certainty that there was a difference between the groups for this outcome. However, the direction of the effect for each intervention was not possible to define. This issue was consulted with the authors of each selected paper; however, for this study, no response was obtained. Thus, because the synthesis of the results for this outcome could be ambiguous, such information should be evaluated with caution.

Decreased buccal alveolar bone thickness and the presence of bone dehiscences have been findings commonly reported after conventional RPE.[7,8,32] They are caused by the osteoclastic resorption that occurs as the teeth move through the buccal plate.[33,34]

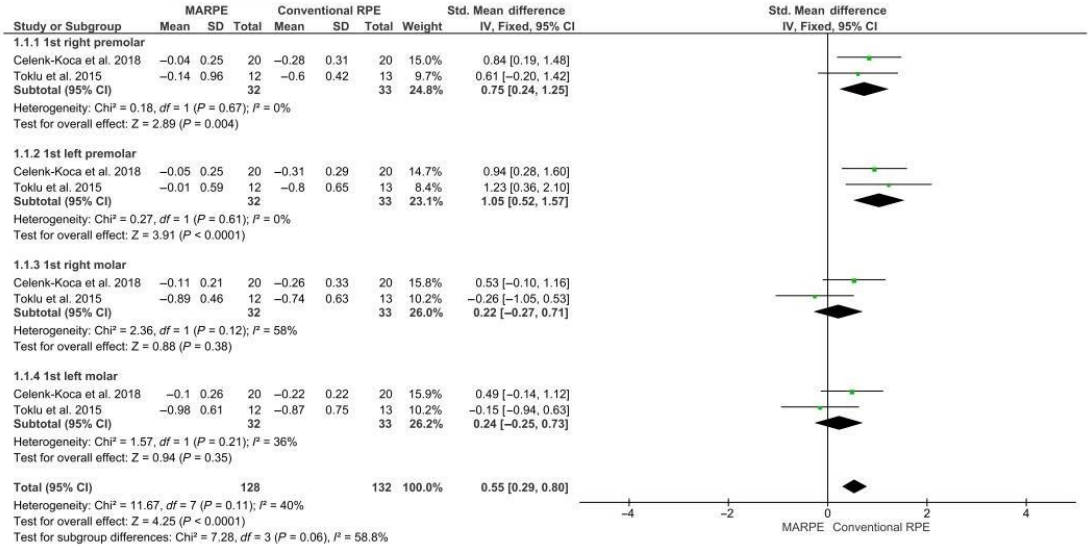

FIGURE 4 Forest plot of fixed-effects meta-analysis performed

Garib et al[7] showed that periodontal changes take place mainly in the anchorage teeth. In the studies by Celenk-Koka et al[23] and Lin et al[30] in which the MARPE appliances had no dental anchorage, there was a smaller buccal alveolar bone loss than in the conventional RPE group. In the study by Toklu et al,[24] the difference in bone loss was significant only for the premolar region because the absence of anchorage on these teeth. The design of the MARPE device included only anchoring in the first molars, which could have caused buccal displacement of these teeth and consequent bone resorption. On the other hand, anatomically, the first premolars are located in a region that becomes narrower upwards. Garib et al[7] stated that in this area, when there is buccal movement of the teeth, the root can perforate the alveolar bone much more easily. Additionally, a previously published systematic review stated that less premolar inclination is likely to occur with hybrid tooth-bone-borne appliances than with conventional RPE (moderate level of evidence).[22] All these findings would explain the best results for this region when MARPE is used.

Even for the bone-borne appliances, there was a slight loss of buccal alveolar bone thickness and presence of bone dehiscences,[23,30] indicating that these outcomes are not caused exclusively by loading applied on teeth. It has been reported that almost half of the expansion obtained at the alveolar level after a RPE procedure is due to an alveolar bending towards the buccal aspect.[35] The same goes for MARPE, and the maxillary halves show buccal rotation, with the rotational centre located near the frontonasal suture.[36] Therefore, buccal tooth tipping and alveolar bending occur. Lin et al[30] evaluated the ratio between these two outcomes. The authors showed that in the bone-borne group the changes in the tooth axis within their alveolar housing were minimal, which would mean that changes in the buccal alveolar bone could be due to the alveolar flexion.

4.1 | Limitations

Synthesis of the results must be interpreted carefully and taking into account that the review presents several limitations related mainly to the reduced number of selected studies, high clinical heterogeneity between them and low level of certainty of evidence. Although an attempt was made to cover a large number of bases, the amount of retrieved articles that responded to the established review question and eligibility criteria was small. To reduce the possibility of omitting the selection of desired articles, an additional evaluator was included for the selection process (PROSPERO update of May 1, 2019). The established primary outcomes could have reduced the breadth of the search. Secondary outcomes such as gingiva clinical condition, presence of inflammatory markers, development of gingival recession, among others, could have retrieved articles showing additional outcomes on the effect of the interventions studied on the periodontal tissues. Reviews including these outcomes could complement our findings. Likewise, systematic reviews including studies that applied MARPE and perform before/after comparisons, instead of having a control group (conventional RPE), could broaden the search range. SARME could also be the comparator group in future research.

The quantitative synthesis for the bone thickness outcome should be carefully evaluated due to the minimum number of included studies. Since the random-effects model would be untenable for this condition, with an inaccurate estimate of the between-study variance, we opted to perform a fixed-effects meta-analysis.[28] Although this selected model allowed us to report SMD and confidence interval for the studies included in the analysis, no generalization to any other population is recommended.[28] Besides that, dispersion of the true effects across the studies was not calculated.

TABLE 2 Quality of evidence on the assessed outcomes

Certainty assessment							No of patients				
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Bone-borne rapid palatine expansion	Conventional rapid palatine expansion	Effect (95% CI)	Certainty	Importance
Buccal alveolar bone thickness											
2	Randomized trials	Serious[a]	Serious[b]	Not serious	Not serious	None	128 teeth (32 patients)	132 (33 patients)	MARPE group presented lower loss of the buccal alveolar bone thickness by 0.55 standardized measurement units (95% CI: 0.29-0.80) when compared to RPE.	⨁⨁◯◯ LOW	IMPORTANT
Buccal alveolar bone level (bone dehiscence)											
2	1 Randomized trial and 1 Retrospective study	Serious[c]	Serious[b]	Not serious	Serious[d]	None	---	---	There are differences in the buccal alveolar bone level at the first premolar region between MARPE and conventional RPE.	⨁◯◯◯ VERY LOW	IMPORTANT

Abbreviations: CI, confidence interval.

[a]Serious risk of bias for one of the studies (Tokiu et al).[24]

[b]Design of the expander devices and follow-up periods were different for both included studies.

[c]Serious risk of bias for one of the studies (Pham & Lagravère)[25] and moderate risk for the other one (Lin et al).[23]

[d]Narrative synthesis was conducted, and the estimates are not precise.

It has been stated that for the random-effects model, the prediction interval is considered as reasonable to report heterogeneity, if it is based on enough data (minimum number of studies needed to compute useful prediction interval should be at least 10). This does not apply to the fixed-effects model, where the estimate of variance between the studies is zero; consequently, there is no conceptual basis for discussing the extent of dispersion when working with this model.[28]

Furthermore, and as already mentioned, the selected studies presented some limitations in their methodological designs. For the bone thickness outcome, one of the two selected studies[24] presented certain deficiencies in the randomization process, not guaranteeing similarity in the distribution of possible confounding factors among the groups assigned for each intervention. In relation to the bone level outcome, one of the studies[30] had two main methodological limitations related to (1) the risk of bias in the classification of interventions due to the retrospective nature of the study and (2) the lack of blinding of the assessments and consequent risk of judgment bias. The other study[31] presented several deficiencies in its execution and uncertainty in the reported information.

Other methodological aspects could also have contributed to the risk of bias. Although three studies[23,24,30] reported baseline data related to the sex distribution and mean age of their groups, none reported data related to the complexity of the malocclusion or the severity of the maxillary transverse deficiency of these. Besides that, only one study[24] reported the activation time and mean amount of screw opening for each intervention group. Of the other studies selected, one indicated only how far the activation was performed (relationship between upper or lower cusps),[23] another reported that 20% overcorrection was reached,[31] and the other one that more than 7 mm activation was realized. If the transversal deficiency severity or planned amount of screw opening was not considered at the time of randomization or data analysis, these variations could be a great source of bias. In relation to the sample size, while the two studies selected for the bone thickness outcome[23,24] performed power estimations, the studies that evaluated the bone level outcome[30,31] did not perform any calculation to determine the number of individuals needed for each group. Of the prospective studies, two reported no dropouts during the study,[23,31] while in the other,[24] one participant was lost for one of the study groups, not reaching the planned sample size.

In addition to the above, high clinical heterogeneity among the studies was identified. The difference in the ages of the samples could have influenced the responses to the interventions applied. Both studies assessing the alveolar bone thickness[23,24] included adolescents that respond favourably to RPE. On the other hand, Lin et al[30] recruited late adolescents in whom it is known that there is probably total or partial fusion of the midpalatal suture[10,11] and the effect of this procedure have a greatly decreased predictability.[37] This could explain greater differences for the bone dehiscences between the groups in this study. Pham and Lagravère[31] did not report the age of the subjects included. Besides that, there is also heterogeneity in relation to the diagnostic criteria established for maxillary transverse deficiency. Consequently, different conditions could have been evaluated. Only Lin et al[30] considered the maturation stage of the suture as a selection criterion. The authors included individuals with a partially or completely fused suture. None of the studies specified information on the symmetry of malocclusions, which could have produced variations in the outcomes assessed between right and left sides. Additionally, the studies lack information regarding oral hygiene status, follow-up controls including prophylaxis and periodontal diagnosis at the baseline. It has been shown that in patients with greater quantity of the buccal alveolar bone at the baseline, the degree of loss of the alveolar bone with both MARPE and conventional RPE would be lower.[7,38]

Different designs of MARPE appliances were used probably influencing the outcomes assessed. Toklu et al[24] used a hybrid tooth-bone-borne expander. This was the only appliance supported by mini-implants close to the midpalatal suture avoiding loading transmission to the alveolar processes and consequent bone bending. Pham and Lagravère,[31] although they did not detail the type of anchoring device used (mini-implants or ONPLANTS), these were placed six millimetres from the palatal suture; however, the entire design of the devices is unclear. Regarding to the conventional RPE appliances, all studies used exclusively dental anchorage.[23,24,30,31] It was claimed that tooth-borne expanders have poor anchorage because they transmit loading only to the periodontium.[39] Garib et al[7] demonstrated that tooth-borne RPE produces more bone dehiscences in the buccal alveolar bone of the anchorage teeth (mainly premolars) than the tooth-tissue-borne expanders. In the study by Celenk-Koka et al,[23] an occlusal coverage was used on the posterior teeth instead of bands, which exerts a load away from the centres of skeletal and dental resistance, favouring worse periodontal effect in the conventional RPE group.

The activation protocols for MARPE appliances were also different. Two studies performed two activations per day,[23,24] while the other two performed 1 activation per day.[30,31] In addition, in two of the studies the screw opening started after a healing period of seven days after insertion of the anchorage devices.[24,31] On the other hand, probably because the severity of the maxillary transverse deficiency at the baseline could have been different between the studies, varying amounts of screw opening (MARPE appliances) were performed. Lin et al[30] reported above 7 mm aperture for all cases, Celenk-Koka et al[23] openings above 8 mm and Toklu et al[24] approximate 10 mm aperture. The amount of screw opening for the study of Pham and Lagravère[31] was not reported.

In relation to the follow-up periods, two studies carried out their evaluations three months after the transversal correction,[24,30] while the other two conducted them at six months.[23,31] The lack of long-term follow-up could be considered a limitation of the studies, since it was already suggested that there is recovery of the periodontal component after the orthodontic treatment in individuals who underwent RPE.[4,32,40] Similarly, Lim et al[38] demonstrated in a group of patients using MARPE that the loss of the buccal alveolar bone thickness in the anchorage teeth is reduced during the follow-up period (one year). The same occurs with the

alveolar crest level; however, this loss remains significant for the first premolar region (>1 mm).

4.2 | Clinical implications

Although, apparently, MARPE causes less damage to the buccal alveolar bone than conventional RPE, a slight bone loss during its use exists in the anchorage teeth of hybrid tooth-bone-borne appliances. It is important to emphasize that, clinically, no recessions are observed because there is no migration of the epithelium or loss of connective attachment after the apical displacement of the buccal alveolar crest.[41-43] What happens is the formation of a long connective attachment, which will only be damaged in the presence of inflammation or mechanical brushing trauma.[44,45] Therefore, it is recommended that patients receive periodic hygiene follow-up after performing this procedure.

5 | CONCLUSION

The existing literature suggests that MARPE could produce less loss of the buccal alveolar bone thickness and marginal bone level in the region of first premolars than the conventional RPE. However, the low and very low quality of evidence, respectively, make these statements not conclusive. For these reasons, the authors of the present systematic review suggest that these results should be evaluated with caution because the evidence is scarce, heterogeneous and methodologically poor. We encourage researchers to conduct new studies, preferably randomized clinical studies using powerful samples, and longitudinal designs with longer follow-up time to identify what the long-term changes are. Furthermore, standardization of the assessment methods regarding teeth and regions evaluated, as well as diversification and replication of research in relation to the population evaluated (adolescents or adults), severity of transverse maxillary deficiency and design of the devices used are also recommended.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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APPENDIX

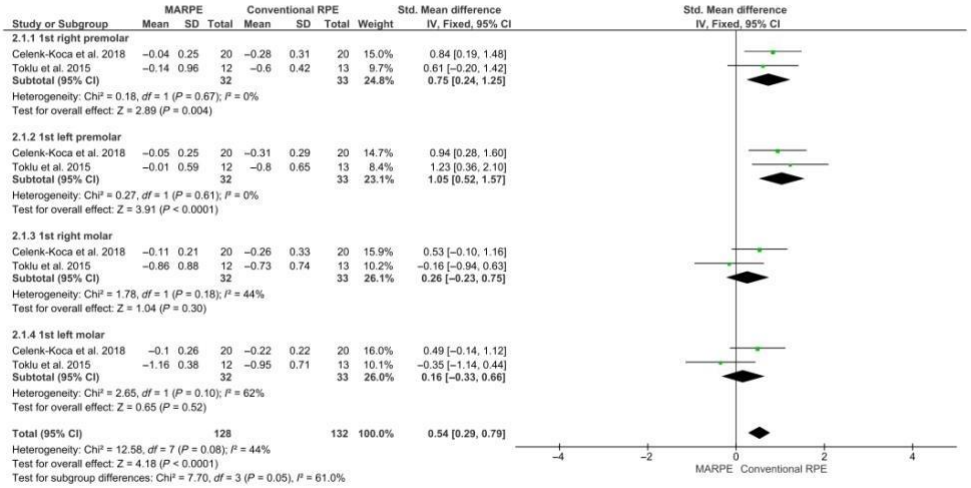

FIGURE A1 Alternative forest plot of fixed-effects meta-analysis performed

5 CONCLUSÃO

5.1. Os resultados do estudo *in vitro* indicam que:

5.1.1. A microarquitetura óssea ao redor dos mini-implantes utilizados na técnica *MARPE* pode sofrer alterações quando estes dispositivos recebem forças laterais provenientes do parafuso disjuntor;

5.1.2. A ancoragem monocortical causa maior dano ósseo em torno dos mini-implantes quando comparado com os dispositivos inseridos em ancoragem bicortical;

5.1.3. A região óssea superior (cervical) é a mais afetada quando a ancoragem bicortical não é alcançada.

5.2. Os resultados da revisão sistemática e meta-análise sugerem que:

5.2.1. A técnica *MARPE* produz menos perda de espessura e altura do osso alveolar vestibular na região dos primeiros pré-molares quando comparado com a técnica de expansão rápida da maxila convencional.

6. RECOMENDAÇÕES

6.1. A amostra utilizada no estudo *in vitro,* composta por animais em estado ex vivo, sem simulação de tecido sutural, não permite conclusões concisas e não podem ser fortemente comparadas a dados clínicos em seres humanos. Outros estudos são necessários para fortalecer as evidencias mostradas no presente estudo. Sugere-se a confecção de estudos com modelo *in vivo,* como *mini-pig*, utilizando o dispositivo da técnica *MARPE* em diferentes tipos de inserção (mono e bicortical), associado a coleta de material biológico pós-ativação do disjuntor em diferentes áreas como proposto no presente estudo. Sendo assim, a avaliação da presença de marcadores inflamatórios em diferentes áreas ao redor dos mini-implantes, nos dois tipos de inserção, esclareceria a possibilidade de maior chance de perda de estabilidade do dispositivo. Assim como o mapeamento histológico ao redor destes mini-implantes seria importante para uma visualização qualitativa, e, comparação com os resultados do presente estudo.

6.2. A literatura existente sugere que a técnica *MARPE* poderia produzir menos perda de espessura e altura do osso alveolar vestibular na região dos primeiros pré-molares quando comparada com as técnicas de expansão convencionais. No entanto, os níveis de qualidade de evidencia encontrados nos estudos buscados na revisão sistemática fazem essas afirmações não

conclusivas. Por essas razões, recomenda-se que esses resultados sejam avaliados com cautela porque as evidências são escassas, heterogêneas e metodologicamente pobres. É necessária a condução de novos estudos, de preferência os clínicos randomizados usando amostras maiores, longitudinais com maior tempo de acompanhamento para identificar quais são as mudanças a longo prazo. Além disso, é importante a padronização dos métodos de avaliação em relação aos dentes e regiões avaliadas, a população estudada (adolescentes ou adultos), gravidade da deficiência maxilar e design dos dispositivos usados.

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8 ANEXOS

8.1 Parecer do Comitê de Ética de Pesquisa em Animais.

UNIVERSIDADE FEDERAL DO RIO DE JANEIRO – UFRJ
Centro de Ciências da Saúde - CCS

Rio de Janeiro, 14 de junho de 2018

Prezado Professor Eduardo Franzotti Sant'Anna

A Comissão de Ética no Uso de Animais (CEUA) em Experimentação Cientifica do Centro de Ciências da Saúde da Universidade Federal do Rio de Janeiro registrada no Conselho Nacional de Controle de Experimentação Animal (CONCEA) sob o número de processo 01200.001568/2013-87 certifica que o projeto intitulado: **"Expansão rápida de maxila apoiada em mini-implantes (MARPE): Influência da ancoragem bicortical na resistência dos mini-implantes e análise micro-estrutural do tecido ósseo.", protocolo n° 071/18**, sob sua responsabilidade que envolve a produção, manutenção e/ou utilização de animais para fins de pesquisa científica (ou ensino) encontra-se de acordo com os preceitos da Lei n°11.794, de 8 de outubro de 2008, do Decreto n°6.899, de 15 de julho de 2009, e com as normas editadas pelo Conselho Nacional de Controle da Experimentação Animal (CONCEA), foi aprovado por esta comissão de ética, em reunião do dia **13/06/2018**.

Finalidade	**( ) Ensino (X) Pesquisa Científica**
Vigência do Projeto	**Até 02/02/2022**
Espécie/linhagem	***Bos taurus indicus*/ Nelore**
N° de animais	**1 animal**
Peso/idade	**250kg/ 24 meses**
Sexo	**Macho**
Origem	**Frigorífico Landim Ferreira - Valença - RJ** **CNPJ: 896.421.8000-178**

Atenciosamente;

Prof. Marcel Frajblat
Coordenador da Comissão de Ética no Uso de Animais - CCS

CEUA - UFRJ: Av. Carlos Chagas Filho, 373 Prédio do Centro de Ciências da Saúde, Bloco K, 2° andar - sala 19 - Cidade Universitária - CEP 21941-590 – Rio de Janeiro – Brasil
Tel: (21) 39386490 - https://www.ccs.ufrj.br/conteudos/ceua

8.2 Registro na plataforma PROSPERO da revisão sistemática

PROSPERO
International prospective register of systematic reviews

NHS National Institute for Health Research

Efficiency and periodontal effects of the bone-borne compared to the tooth-borne rapid maxillary expansion: a systematic review

Flávio Copello, Daniel Brunetto, Guido Marañón-Vásquez, Luciana Caldas, Danielle Masterson, Lucianne Maia, Eduardo Sant`Anna

Citation

Flávio Copello, Daniel Brunetto, Guido Marañón-Vásquez, Luciana Caldas, Danielle Masterson, Lucianne Maia, Eduardo Sant`Anna. Efficiency and periodontal effects of the bone-borne compared to the tooth-borne rapid maxillary expansion: a systematic review. PROSPERO 2014 CRD42014007510 Available from:
http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42014007510

Review question

Is bone-borne rapid maxillary expansion more efficient than tooth-borne rapid maxillary expansion?
Are the periodontal collateral effects of the bone-borne rapid maxillary expansion less severe than those of the tooth-borne rapid maxillary expansion?

Searches

The following electronic databases will be searched: PubMed, Scopus, Virtual Health Library, Ovid, Web of Science, LILACS, BBO, Cochrane Library and the System for Information on Grey Literature on Europe (SIGLE). The keywords will be selected with the assistance of a health sciences specialized librarian and no restrictions will be added concerning the publication language and date.

Types of study to be included

Included designs: randomized clinical trials, nonrandomized clinicas trials and prospective studies with large sample (>15).Excluded designs: case reports, case series (<15), editorials and opinions and review articles.

Condition or domain being studied

Posterior cross bite and constricted maxilla are very common malocclusions . If they are not treated at the right time, they may worsen and become irreversible conditions.

Participants/population

Individuals that have a malocclusion that justifies the treatment with rapid maxillary expansion (RME), tooth-borne or bone-borne, will be eligible for this systematic review. Patients subjected to another treatment – such as reverse facemask - prior to or during the RME, that are systemically compromised, cleft or syndromic will be excluded from the study.

Intervention(s), exposure(s)

The traditional tooth-borne rapid maxillary expansion (RMEtb) has been utilized in orthodontics for many decades to correct transversal maxillary discrepancies in growing patients. However, the force generated on the device is applied to the anchorage teeth and may hinder their periodontal health. In order to avoid these problems, a new maxillary expansion technique has been proposed. It utilizes mini-implants fixed at the hard palate as auxiliary anchorage points, and therefore eliminates the horizontal force that is applied to the teeth in the traditional technique.

Comparator(s)/control

The comparison will be made directly between tooth-borne and bone-borne rapid maxillae expansion.

Context

Main outcome(s)

The primary outcome consists of the periodontal collateral effects of both treatments. These measures are done through CBCT images and the results are reported by mean and median.