PONTIFÍCIA UNIVERSIDADE CATÓLICA DO PARANÁ

ESCOLA DE SAÚDE E BIOCIÊNCIAS

PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

ÁREA DE CONCENTRAÇÃO ORTODONTIA

RENATA MACHADO MARANGON

AVALIAÇÃO DAS TENSÕES NO MINI-IMPLANTE E NO OSSO CIRCUNDANTE DE ACORDO COM VARIAÇÕES DA ESPESSURA DA CORTICAL ÓSSEA E COMPOSIÇÃO DO MINI-IMPLANTE: UMA ANÁLISE PELO MÉTODO DOS ELEMENTOS FINITOS

Curitiba

2015

RENATA MACHADO MARANGON, CD

AVALIAÇÃO DAS TENSÕES NO MINI-IMPLANTE E NO OSSO CIRCUNDANTE DE ACORDO COM VARIAÇÕES DA ESPESSURA DA CORTICAL ÓSSEA E COMPOSIÇÃO DO MINI-IMPLANTE: UMA ANÁLISE PELO MÉTODO DOS ELEMENTOS FINITOS

Dissertação apresentada ao Programa de Pós-Graduação em Odontologia da Pontifícia Universidade Católica do Paraná, como parte dos requisitos para obtenção do título de Mestre em Odontologia, Área de Concentração em Ortodontia

Orientador: Prof. Dr. Orlando Tanaka

Curitiba
2015

Dados da Catalogação na Publicação
Pontifícia Universidade Católica do Paraná
Sistema Integrado de Bibliotecas – SIBI/PUCPR
Biblioteca Central

Marangon, Renata Machado
M311a Avaliação das tensões no mini-implante e no osso circundante de acordo
2015 com variações da espessura da cortical óssea e composição do mini-implante : uma análise pelo método dos elementos finitos / Renata Machado Marangon ; orientador, Orlando Tanaka. – 2015.
61 f. : il. ; 30 cm

Dissertação (mestrado) – Pontifícia Universidade Católica do Paraná, Curitiba, 2015
Inclui bibliografias
Texto em português e inglês

1. Odontologia. 2. Implantes dentários. 3. Método dos elementos finitos. 4. Ortodontia. I. Tanaka, Orlando Motohiro. II. Pontifícia Universidade Católica do Paraná. Programa de Pós-Graduação em Odontologia. III. Título.

CDD 20. ed. – 617.6

Pontifícia Universidade Católica do Paraná
Escola Saúde e Biociências
Programa de Pós-Graduação em Odontologia

TERMO DE APROVAÇÃO

RENATA MACHADO MARANGON

AVALIAÇÃO DAS TENSÕES NO MINI-IMPLANTE E NO OSSO CIRCUNDANTE DE ACORDO COM VARIAÇÕES DA ESPESSURA DA CORTICAL ÓSSEA E COMPOSIÇÃO DO MINI-IMPLANTE: UMA ANÁLISE PELO MÉTODO DOS ELEMENTOS FINITOS

Dissertação apresentada ao Programa de Pós-Graduação em Odontologia da Pontifícia Universidade Católica do Paraná, como parte dos requisitos parciais para a obtenção do Título de **Mestre em Odontologia**, Área de Concentração em **Ortodontia**.

Orientador(a): Prof. Dr. Orlando Tanaka
Programa de Pós-Graduação em Odontologia, PUCPR

Prof. Dr. Odilon Guariza Filho
Programa de Pós-Graduação em Odontologia, PUCPR

Prof. Dr. José Rino Neto
Programa de Pós-Graduação em Ciências Odontológicas, USP

Curitiba, 25 de março de 2015.

Aos meus queridos pais Roberto Marangon e Rosane Machado Marangon,

Por sempre primarem pela minha educação,

Por sempre me incentivarem a lutar pelos meus objetivos,

Por sempre me apoiarem, me compreenderem e estarem ao meu lado em todos os momentos,

Por serem pessoas e profissionais exemplares que me inspiram a me tornar uma pessoa melhor a cada dia,

Por tornarem realidade este sonho.

Aos meus irmãos Guilherme Machado Marangon e Gustavo Machado Marangon e ao meu namorado Renan Fiori,

Pelo amor, carinho, incentivo e compreensão com que me apoiaram nesta caminhada.

Dedico.

Ao Professor Dr. Orlando Tanaka pelo exemplo de organização, dedicação e competência com que coordena o programa. Pelos ensinamentos e dedicação durante todo o mestrado. Por não medir esforços para orientação e realização deste trabalho.

Muito Obrigada!

AGRADECIMENTOS

À Deus pela Vida, pela minha saúde e pela fé que me acompanha.

Ao Professor Armando Saga pela coorientação e fundamental contribuição para a realização deste trabalho.

Ao Professor Key Fonseca de Lima pela coorientação deste trabalho. Pelos conhecimentos de Engenharia. Pela realização da parte laboratorial dessa pesquisa. Por suas contribuições na banca de qualificação.

Ao Professor Odilon Guariza Filho e a Professora Dra. Elisa Souza Camargo pelo carinho e pelos ensinamentos e contribuições à minha vida profissional.

Ao Professor Paulo Couto Souza pelas fundamentais contribuições e correções na banca de qualificação.

Ao Victor Paese Nissen aluno de Engenharia Mecânica da PUCPR, pela realização da parte laboratorial dessa pesquisa junto ao Professor Key Fonseca de Lima.

À Pontifícia Universidade Católica do Paraná - PUCPR - pela oportunidade e acolhimento para a realização do Mestrado.

Ao Diretor do Programa de Pós-Graduação em Odontologia da PUCPR, Prof. Dr. Sérgio Roberto Vieira pela competência na administração do programa.

À CAPES pela bolsa de estudos do mestrado.

À Neide Borges dos Reis e à Flavia Beuting funcionarias da secretaria do Programa de Pós-Graduação da PUCPR, pelo carinho, atenção e serviços prestados.

Aos colegas de turma do mestrado por todo carinho e por todos os momentos especiais divididos em especial à Estephany Gordillo Yepez pela amizade e parceria de sempre.

À todos meus familiares pelo incentivo, carinho e amor.

Aos meus amigos pelo apoio e compreensão nestes dois anos que não estive tão presente.

À todos que de alguma maneira contribuíram para realização deste trabalho, ou que simplesmente torceram pelo meu sucesso.

Muito obrigada.

SUMÁRIO

ARTIGO EM PORTUGUÊS

Página título

Avaliação das tensões no mini-implante e no osso circundante de acordo com variações da espessura da cortical óssea e composição do mini-implante: uma análise pelo método dos elementos finitos

Renata Machado Marangon

Mestranda, Programa de Pós-Graduação em Odontologia, Área de Concentração em Ortodontia,

Escola de Saúde e Biociências,

Pontifícia Universidade Católica do Paraná, Curitiba, PR, Brasil.

E-mail: remarangon@hotmail.com

Orlando Tanaka (Autor correspondente)

Professor Titular, Programa de Pós-Graduação em Odontologia, Área de Concentração em Ortodontia,

Escola de Saúde e Biociências,

Pontifícia Universidade Católica do Paraná, Curitiba, PR, Brasil.

R. Imaculada Conceição, 1155 - Prado Velho

80215-901 Curitiba-Pr - Brasil

Tel: 55 (41) 3271-1637

Fax: 55 (41) 3271-1405

E-mail: tanakaom@gmail.com

Resumo

Introdução: O objetivo deste trabalho foi analisar pelo método de elementos finitos (MEF) as tensões geradas no mini-implante (MI) e no osso circundante pela aplicação de uma força perpendicular ao MI, considerando variações de espessura de cortical óssea e composição do MI. **Material e métodos:** Mini-implante com propriedades mecânicas referentes ao aço inoxidável e a liga de titânio, inseridos em blocos ósseos com duas variações de cortical (1 mm e 2 mm) foram modelados tridimensionalmente via CAD (C*omputer Aided Design*) e estudados pelo MEF. Uma força de 3,5 N, perpendicular ao longo eixo do MI, foi aplicada em 4 ensaios mecânicos: EM1– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 1 mm e MI de aço inoxidável; EM2– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 1 mm e MI de titânio; EM3– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 2 mm e MI de aço inoxidável; EM4– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 2 mm e MI de titânio. **Resultados e conclusões:** As distribuições de tensões em todos os ensaios mecânicos se concentraram no MI, principalmente na região em contato com a cortical óssea. A maior tensão von Mises foi obsevada no EM2, seguido pelo EM1, EM4 e EM3. A concentração maior de tensões ocorre, portanto, em espessura de osso cortical de 1 mm quando comparado a de 2 mm e no MI de titânio quando comparado ao MI de aço inoxidável na mesma espessura de cortical óssea.

Palavras-chave: Implantes Dentários, Procedimentos de Ancoragem Ortodôntica, Análise de Elementos Finitos.

Introdução

O controle de ancoragem é um requisito fundamental para o sucesso do tratamento ortodôntico de diversos tipos de maloclusões. A resistência de fixação da ancoragem deve ser maior do que a do dente que será movimentado ortodonticamente, este fator segue o conceito de que “ação e reação” são iguais e opostas. Respeitando estes conceitos e exercendo este controle de ancoragem é possível maximizar o movimento desejado e diminuir os efeitos colaterais indesejados. Existem algumas classificações quanto a ancoragem. Esta pode ser do tipo A ou "absoluta”, quando não ocorre movimentação dos dentes de ancoragem; tipo B quando há movimentação dos dois segmentos dentários, tanto posterior quanto anterior, um em direção ao outro; e o tipo C que ocorre quando há a movimentação apenas dos dentes de ancoragem, ou seja, perda total da ancoragem.[1] Diversos fatores colaboram para que ocorra esta perda de ancoragem, entre eles a colaboração e o comprometimento do paciente no uso de dispositivos de ancoragem. Em busca de obter essa ancoragem absoluta sem necessitar da colaboração do paciente, os MI foram desenvolvidos e têm sido amplamente utilizados, com este objetivo, para a realização de diversos tipos de movimento dentário.[2-8]

O MI ortodôntico utilizado como ancoragem temporária apresenta muitas vantagens tais como maior facilidade e o menor trauma durante o procedimento de inserção e remoção, maior versatilidade, a possibilidade de carga imediata após a colocação e baixos custos.[3,9] Existe uma grande variação de relatos encontrados para a taxa de sucesso do MI utilizado como ancoragem, como uma baixa taxa em 50% e, também, resultados mostrando altas taxas como 89%.[10,11] Alguns fatores identificados como causas de insucesso incluem a inflamação, infecção, inserção em regiões de mucosas não queratinizadas e o tamanho reduzido do MI.[3,12,13]

Outro fator que provavelmente pode influenciar o potencial de ancoragem dos MI é a quantidade e a qualidade do osso em que eles são instalados, pois, não são osseointegráveis e necessitam de retenção mecânica.[7,14]

A estabilidade primária de um MI pode ser afetada, basicamente, por fatores relacionados ao parafuso e ao paciente. Características morfológicas como diâmetro e o comprimento são alguns fatores relacionados ao MI. A qualidade e quantidade do osso onde o MI é inserido referem-se à fatores do paciente. A espessura do osso cortical é um fator relacionado ao hospedeiro que pode interferir na estabilidade primária do MI. A estabilidade primária será melhor quanto maior for a quantidade de osso cortical pela essencial dependência da interface metal-osso. As áreas consideradas mais estáveis para colocação de MI são aquelas que apresentam o osso cortical mais espesso. Esta espessura assim como a densidade podem variar de acordo com o indivíduo e região que receberá o MI.[6-8,15]

A importância da localização e da angulação do MI para a resistência e estabilidade da ancoragem pode ser questionável devido a falta de estudos científicos , assim como das tensões que são geradas nos tecidos adjacentes ao MI sob carga.[14] A reabsorção no osso circundante ao MI pode ser ativada por diversos fatores tais como trauma cirúrgico, infecção bacteriana ou até mesmo por sobrecarga na interface osso-implante.[16,17]

Sobrecarga na região peri-implantar óssea pode gerar como consequência altas concentrações de tensões, e algumas hipóteses[18] sugerem que os campos de deformação relacionados devem estimular uma reabsorção óssea na região comprometendo assim, a eficácia do implante.[16] A avaliação da distribuição das tensões no osso possibilita a investigação da eficácia dos implantes endósseos e revela os riscos de insucesso do implante.[19]

O MEF é um método numérico computacional que pode ser utilizado para simular sistemas biomecânicos e prever as tensões e deslocamentos gerados dentro deste sistema.[20,21] Alguns estudos relataram a distribuição das tensões no osso circundante ao MI, porém poucos estudos avaliaram a distribuição das tensões no próprio MI.

O maior conhecimento acerca das regiões do MI que apresentam maior concentração tensão é também importante para o desenvolvimento de design de MI que apresente menor risco de fratura, aumentando o índice de sucesso do tratamento ortodôntico, bem como a minimização de riscos para o paciente.

Assim o objetivo deste trabalho foi analisar pelo MEF as tensões geradas no MI e no osso circundante pela aplicação de uma força perpendicular ao MI de acordo com variações de:

a) Espessura da cortical óssea (1 mm e 2 mm) e,

b) Composição do mini-implante (liga de titânio e aço inoxidável).

Material e Métodos

O MI selecionado para a realização deste estudo foi da marca Morelli (número de referência 37.10.102) com comprimento de 8 mm, diâmetro de 1,5 mm e perfil transmucoso de 1 mm (Figura 1). O MI foi introduzido em blocos ósseos de 9 mm de altura, 8 mm de largura e 8 mm de profundidade, formado pelos ossos cortical e trabecular. Neste estudo são avaliadas duas variações de cortical, uma com espessura de 1 mm e outra com 2 mm. Tanto o MI quanto os blocos ósseos foram simulados através da modelagem sólida geométrica com um aplicativo de CAD (Computer Aided Design) chamado de DS Solidworks® 2013. (Figura 2A). Foram atribuídas propriedades mecânicas dos materiais do MI referente ao aço inoxidável (ASTM F138) e liga de titânio (Ti6Al-4V) (Tabela 1) .

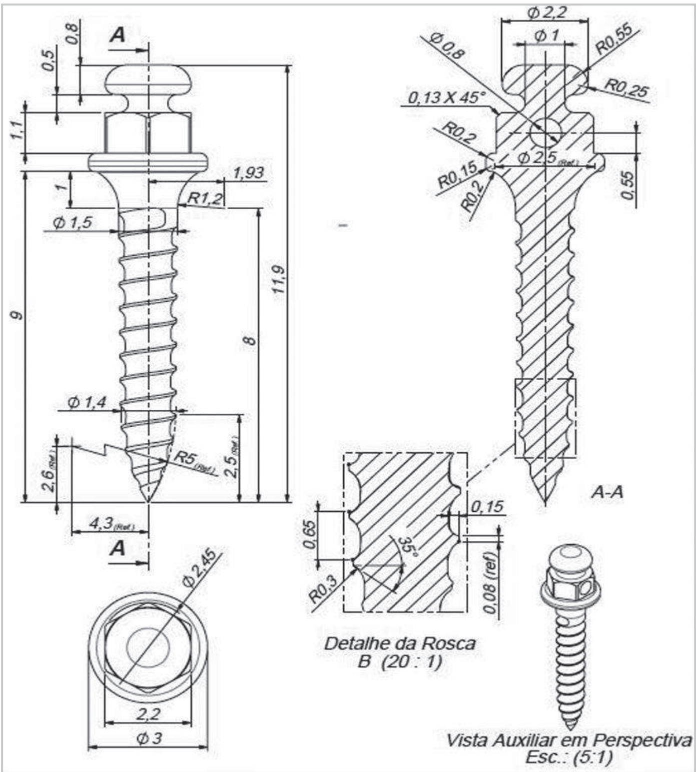


Fig 1. Dimensões do mini-implante.

Os modelos computacionais do MI inserido no bloco ósseo foram exportados para o programa Autodesk Simulation Multiphysics® 2013. Nesta etapa foram geradas as malhas de elementos finitos (Figuras 2A, 2B, 2C e 2D), introduzida as propriedades mecânicas (módulo de Young e coeficiente de Poisson) de todos os componentes que formam o modelo sólido (Osso e MI). As propriedades dos materiais adotadas para a simulação estão descritas na Tabela 1 e a força aplicada foi de 3,5 N na cabeça do MI em sentido perpendicular.

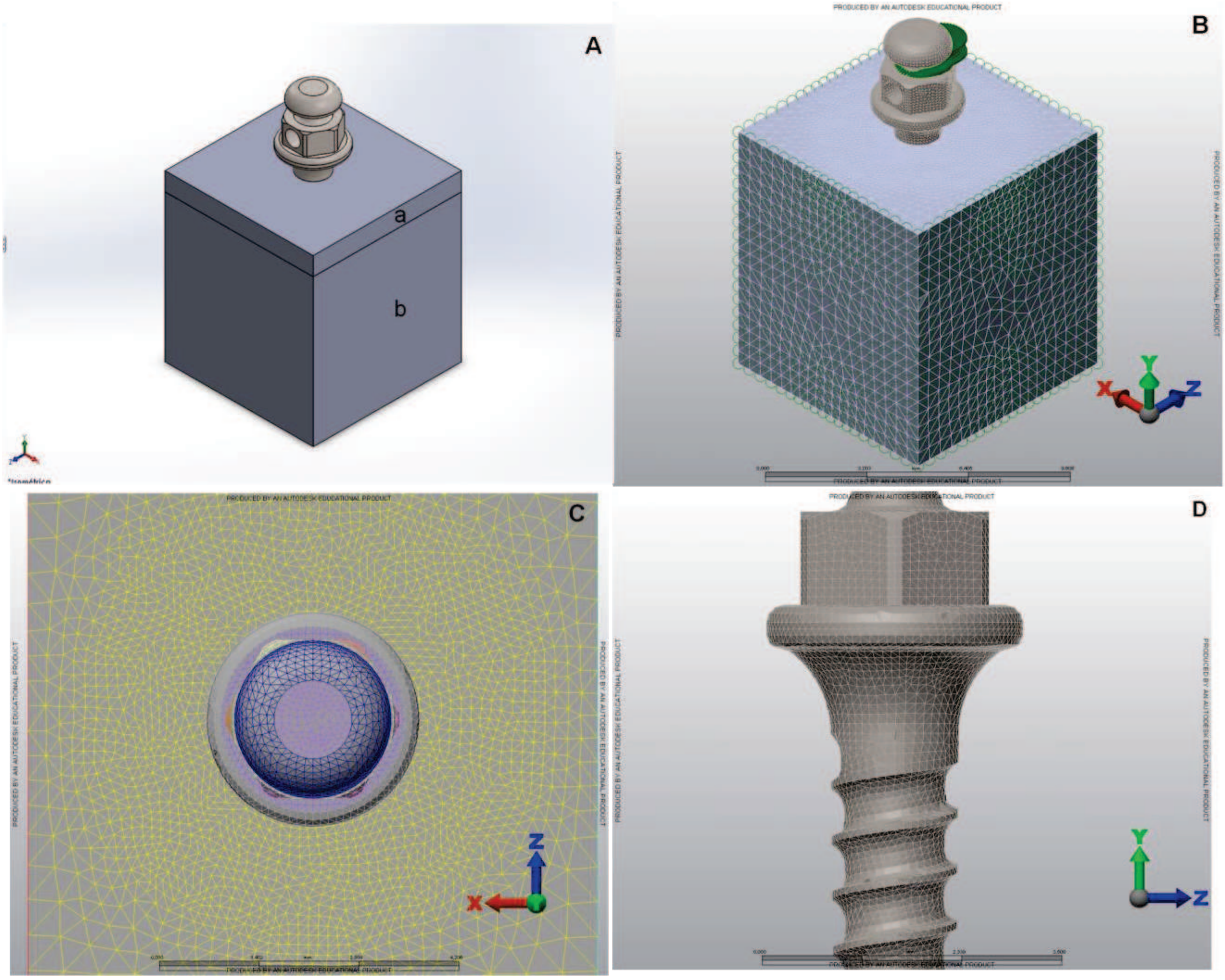


Fig 2. A, Modelagem tridimensional do MI inserido no bloco ósseo utilizada para as simulações mecânicas **a)** Espessura correspondente ao osso cortical. **b),** Espessura correspondente ao osso trabecular. **B**, Condições de contorno vista tridimensional. **C**, Detalhe da malha vista superior. **D,** Detalhe da malha do MI.

Tabela 1. propriedades do osso e dos mini-implantes utilizados nos modelos		
Material	Módulos de Young (Mpa)	Coeficiente de Poisson
Titânio	110.000	0,33
Aço Inoxidável	205.000	0,29
Osso Cortical	138.000	0,26
Osso Trabecular	345	0,31

Foram realizados quatro ensaios mecânicos com as seguintes combinações de espessura de cortical e material do MI:

- EM1– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 1 mm e MI de aço inoxidável
- EM2– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 1 mm e MI de titânio

- EM3– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 2 mm e MI de aço inoxidável
- EM4– Modelo sólido geométrico de bloco ósseo com espessura de cortical de 2 mm e MI de titânio

Nas faces laterais do cuboide, como condições de contorno, foram restringidas as translações nas direções x, y, z, representadas por círculos verdes na Figura 2B. Estas condições fazem-se necessárias para simular o restante do osso. O carregamento de 3,5 N foi aplicado na cabeça do mini-implante na direção do eixo z, representados por linhas verdes na cabeça do MI (Figura 2B). Esta magnitude representa uma força real que é aplicada clinicamente.[2]

Após uma análise de convergência do campo de tensões definiu-se a malha para realização das análises de MEF.[22] Os comprimentos das arestas dos elementos resultantes desta análise variam entre 0,375 mm e 0,500 mm. O maior refino de malha ocorreu na região do osso circundante ao MI (Figura 2C). A malha final para EM1 e EM2 é formada por 416.889 elementos tetraédricos lineares e 81.421 nós e a malha para EM3 e EM4 é composta por 499.882 elementos tetraédricos lineares e 96.753 nós. O modelo de elementos finitos dos ossos cortical e trabecular e dos MI foram considerados homogêneos, isotrópicos e com comportamento elástico linear. O campo de tensões sobre o modelo de elementos finitos, é avaliado de acordo com a teoria da energia de distorção para materiais dúcteis, também conhecido como critério de falha de von Mises. Estas duas tratativas vem sendo utilizadas no campo da Ortodontia.[16,23-25]

O sistema de coordenadas estabelecido para avaliação dos resultados foram os três eixos (x, y, z) determinados no programa Autodesk Simulation Multiphysics® 2013. Dessa maneira a força foi aplicada na direção z em sentido negativo (da direita para esquerda).

Resultados

A distribuição das tensões no osso e no MI foram avaliadas por meio de uma escala de cores que vai da cor azul que representa as tensões baixas até a cor vermelha que representa as tensões mais altas.

As regiões com tensões maiores na interface do osso e do MI em todos os ensaios mecânicos se concentraram na região do MI em contato com a cortical óssea (Fig 3, 4, 5 e 6). O valor mais alto das tensões foi encontrado no EM2 (53,09 MPa), seguido pelo EM1(43,64 MPa), EM4 (36,12 MPa) e EM3 (33,29 MPa) (Tabela 2).

Tabela 2.	Valores máximos de Stress Von Mises para os 4 ensaios mecânicos (MPa)
	Máximo
EM1	43,64
EM2	53,09
EM3	33,29
EM4	36,12

Em todos os carregamentos foi observado tensões na região do MI localizado fora do osso acima da cortical óssea e no osso trabecular próximo ao osso cortical quando a espessura de cortical foi de 1 mm. Nos ensaios mecânicos com espessura de cortical de 2 mm a concentração de tensões ocorreu dentro da cortical apenas, não se estendendo para o osso trabecular (Figuras 3E, 4E, 5E e 6E).

No corte perpendicular as maiores tensões se apresentaram na parte externa do MI e coplanares com o plano de aplicação da força em todos os ensaios mecânicos (Figura 3B, 4B, 5B e 6B)

No corte transversal com deflexão a distribuição das tensões se comportou da mesma maneira em todos os ensaios mecânicos. A maior deflexão como esperado, se concentrou na cabeça do MI em todos os ensaios mecânicos (Figura 3D, 4D, 5D e 6D). O EM2 foi o que apresentou maior deflexão (0,00464), seguido pelo EM1 (0,00337), EM4 (0,00331) e EM3 (0,00238).

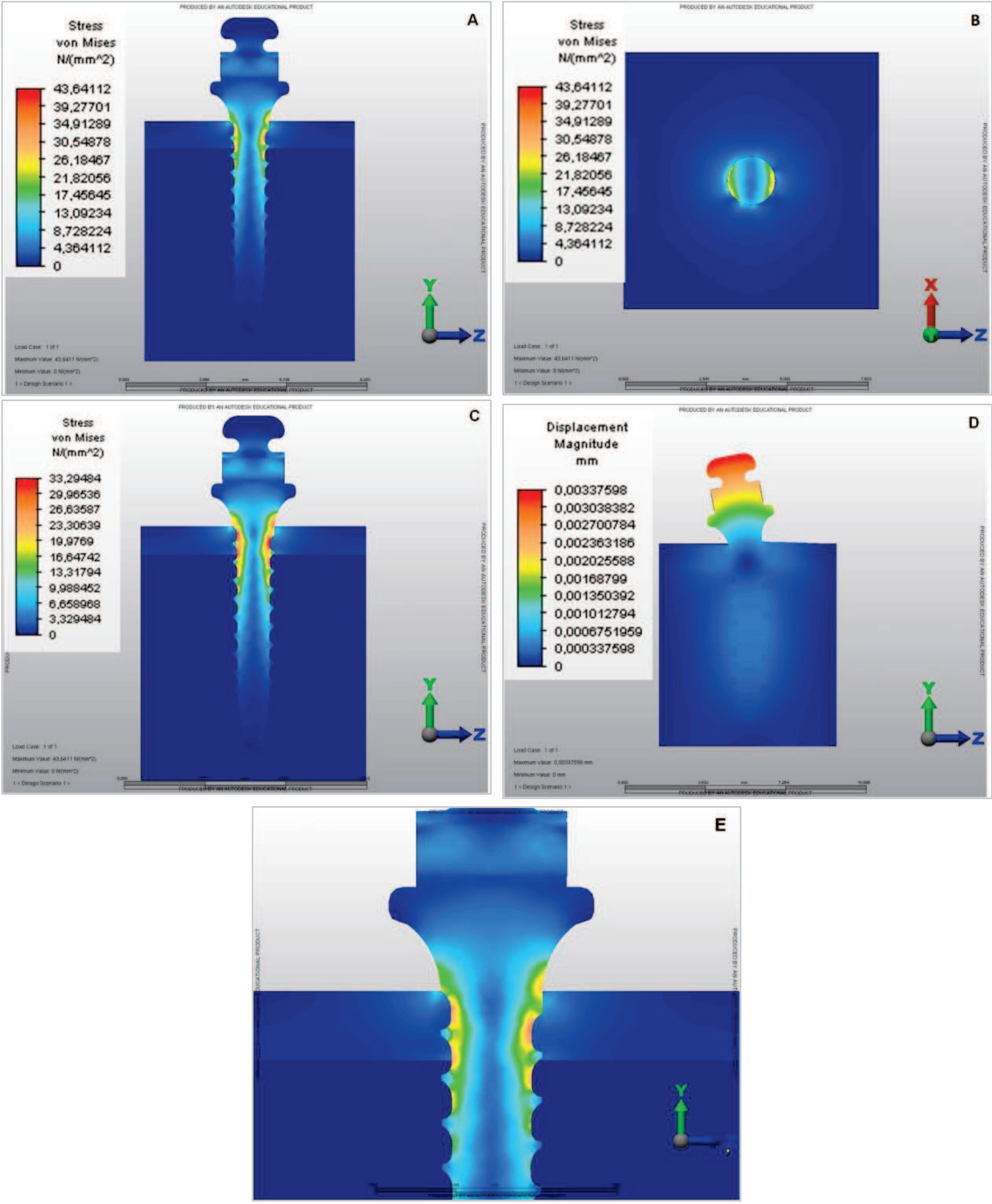


Fig 3. Distribuição das tensões para EM 1. **A–** Corte transversal. **B–** Corte perpendicular. **C–** Corte transversal com a menor escala dos valores máximos encontrados em todos ensaios mecânicos. **D–** Corte transversal com deflexão (escala: magnitude de deflexão). **E-** Detalhe da distribuição das tensões na região da espessura correspondente à cortical óssea.

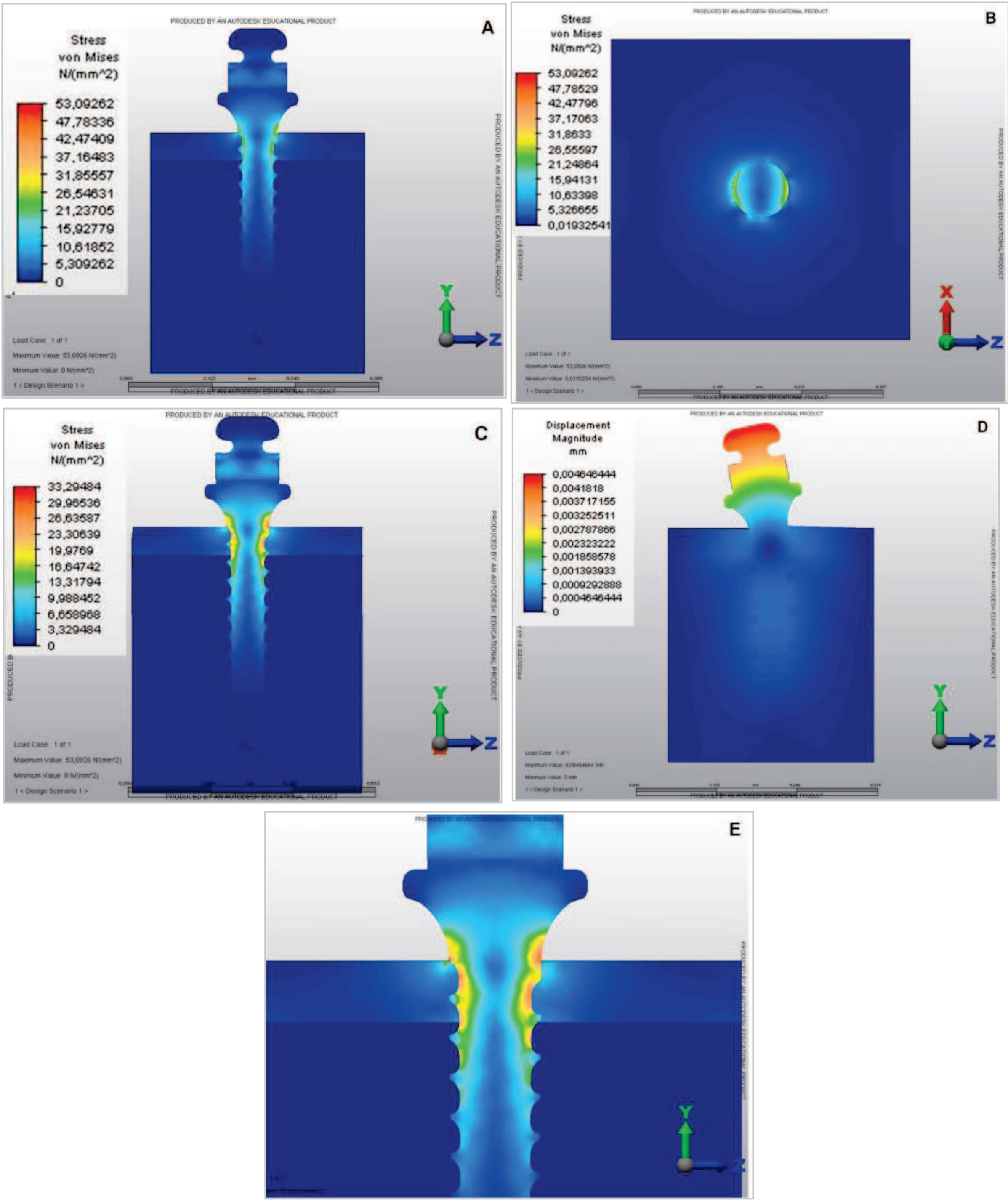


Fig 4. Distribuição das tensões para EM2. **A–** Corte transversal. **B–** Corte perpendicular. **C–** Corte transversal com a menor escala dos valores máximos encontrados em todos ensaios mecânicos. **D–** Corte transversal com deflexão (escala: magnitude de deflexão). **E-** Detalhe da distribuição das tensões na região da espessura correspondente à cortical óssea.

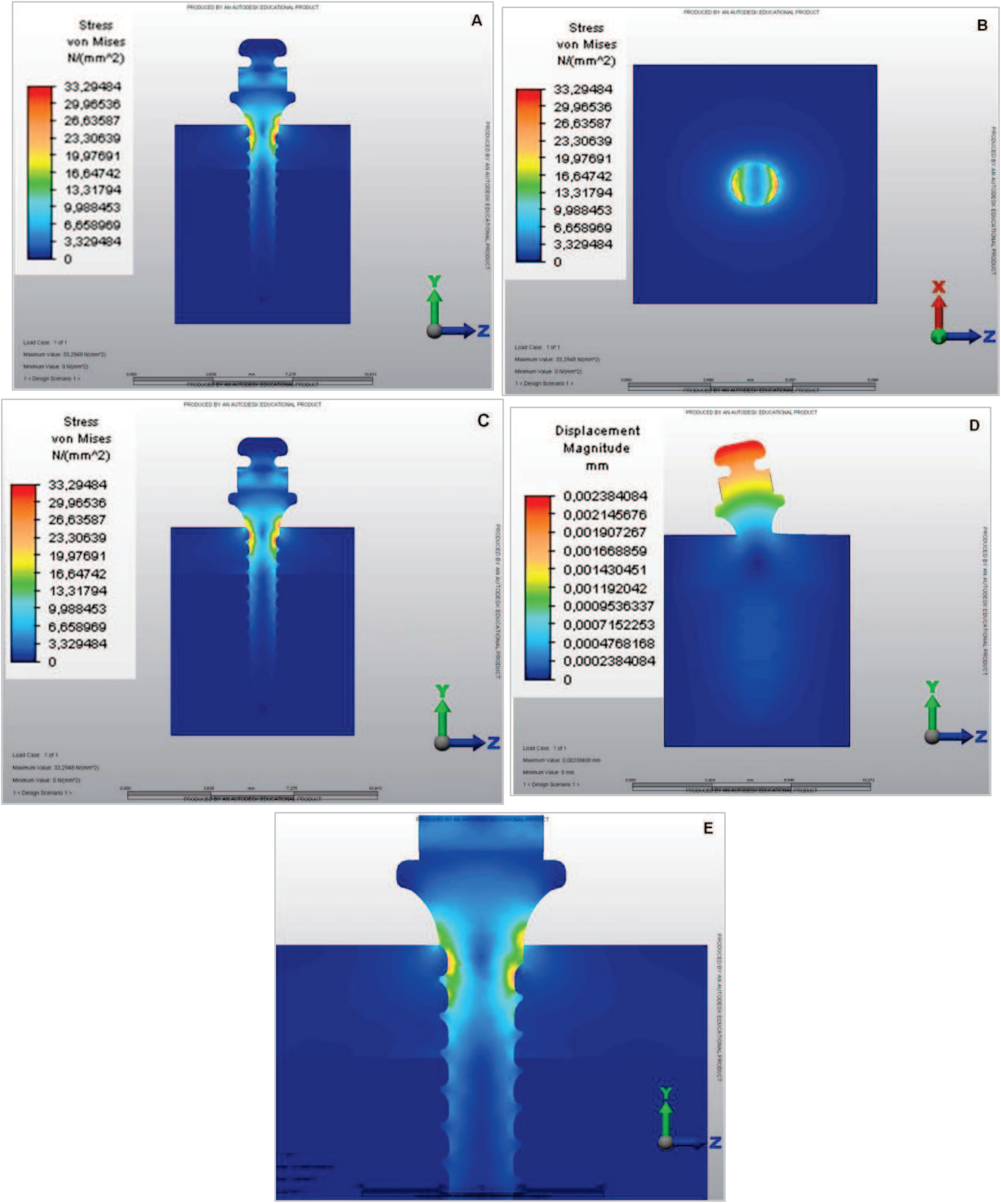


Fig 5. Distribuição das tensões para EM3. **A–** Corte transversal. **B–** Corte perpendicular. **C–** Corte transversal com a menor escala dos valores máximos encontrados em todos ensaios mecânicos. **D–** Corte transversal com deflexão (escala: magnitude de deflexão). **E-** Detalhe da distribuição das tensões na região da espessura correspondente à cortical óssea.

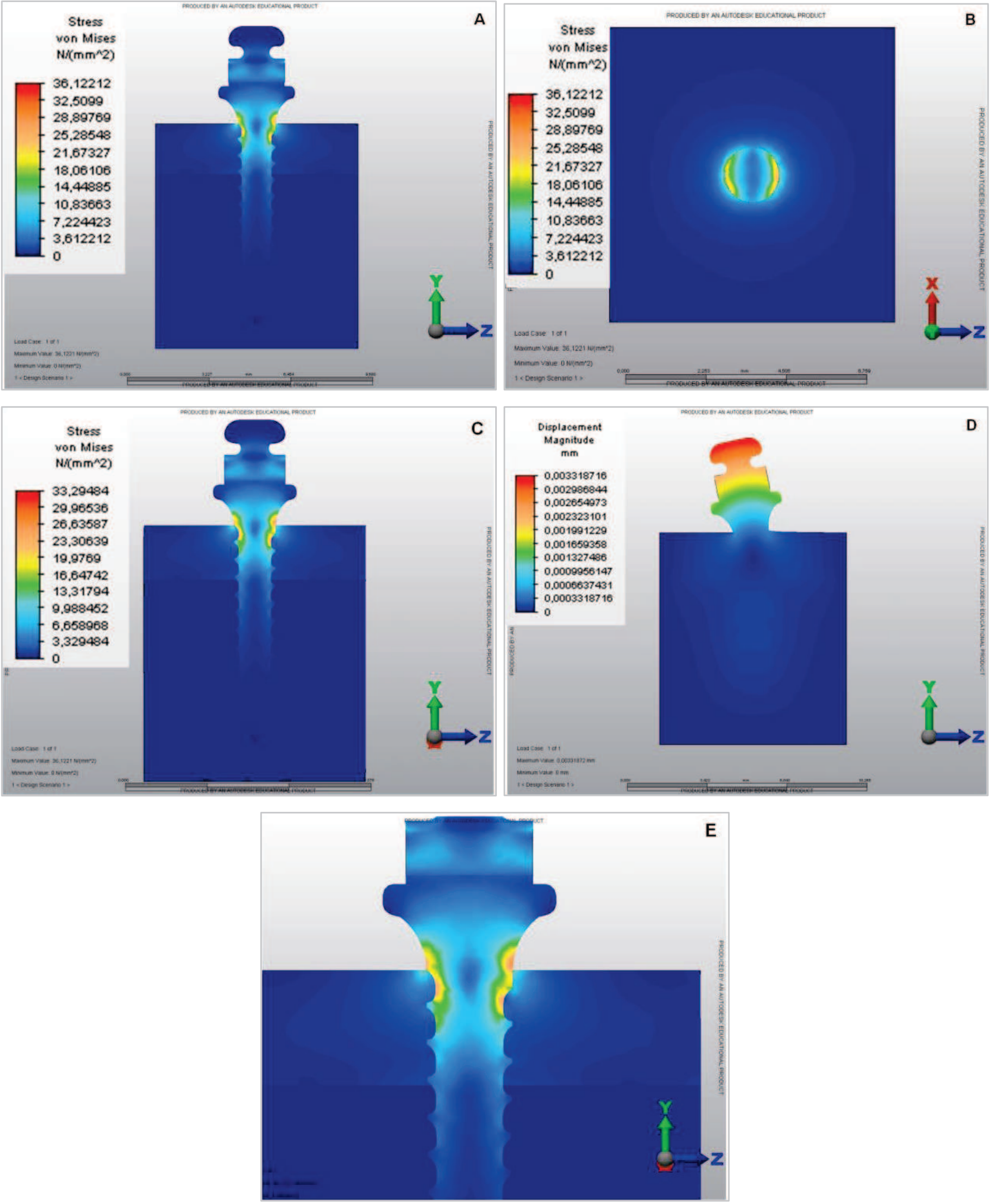


Fig 6. Distribuição das tensões para EM4. **A–** Corte transversal. **B–** Corte perpendicular. **C–** Corte transversal com a menor escala dos valores máximos encontrados em todos ensaios mecânicos. **D–** Corte transversal com deflexão (escala: magnitude de deflexão). **E-** Detalhe da distribuição das tensões na região da espessura correspondente à cortical óssea.

Discussão

Este estudo avaliou a distribuição e magnitude das tensões no osso e no MI induzido por uma carga ortodôntica aplicada ao MI. Os resultados forneceram informações que contribuem na compreensão de algumas reações advindas de um sistema de forças aplicado ao MI variando a espessura da cortical óssea.

A utilização de modelos animais para a avaliação e estudo da biomecânica ortodôntica é limitada, pois este método apresenta problemas na transferência dos resultados obtidos para humanos e estudos prospectivos realizados em humanos acabam sendo dificultados. O MEF é um método que surgiu com o desenvolvimento da engenharia computacional e tem permitido a realização de pesquisas nas áreas de ciências biológicas e da saúde sem o envolvimento de seres vivos. Este motivo tem sido muito utilizado na Odontologia, pois além de trazer vantagens por não utilizar seres humanos e animais na realização da pesquisa, permite a avaliação de biomecânicas e dessa maneira a busca pela solução de problemas relacionados a este tipo de situação. Na Ortodontia este método vem sendo utilizado para avaliar a magnitude e distribuição das tensões em diversos movimentos ortodônticos.

Alguns estudos que utilizaram o MEF mostraram que quando uma força de sentido lateral é aplicada no MI a maior parte das tensões irá se concentrar nas áreas de cortical óssea.[20,26] O presente estudo encontrou resultados semelhantes, as maiores concentrações de tensões foram observadas no MI na região de osso cortical. Estudos anteriores realizados com o objetivo de buscar melhor estabilidade primária do MI direcionaram o foco para a anatomia óssea relacionada com a espessura da cortical óssea e não com a qualidade do trabeculado ósseo.[1]

Os resultados do presente estudo mostraram maiores valores de tensões nos ensaios mecânicos com espessura de cortical óssea de 1 mm independente do material do MI. Nestes ensaios com espessura de cortical de 1 mm houve concentração de tensões no MI fora do osso, acima da espessura referente a cortical óssea e no MI na região do osso trabecular logo abaixo a espessura referente ao osso cortical. Na espessura de cortical de 2 mm essa concentração de tensões ocorreu fora do osso acima da espessura referente a cortical óssea e no MI dentro da espessura referente ao osso cortical e não se estendeu ao MI na região do osso trabecular.

A estabilidade primária, fator fundamental para a retenção adequada do dispositivo de ancoragem, pode ser influenciada também pelo torque de inserção além da qualidade e quantidade do osso. Com o objetivo de alcançar diferentes locais de inserção e de obter maior estabilidade primária os cirurgiões-dentistas lançam mão de diversos tamanhos e formatos de MI. Incidentes como deformações e fraturas dos MI podem ser evitados através de uma melhor compreensão da influência dessas variações nas suas propriedades mecânicas.

Trabalho realizado por Pithon et al. 2013[27] avaliou a influência do comprimento dos MI sobre suas propriedades mecânicas, o torque de inserção necessário para diversas espessuras de osso cortical e o torque de inserção necessário para fratura do dispositivo. Observaram que o comprimento do MI tem influência sobre o torque de inserção idependente da espessura do osso cortical, assim como relatado por Lim et al. 2008[28] utilizando uma espessura de osso cortical de 1,5 mm. No estudo realizado por Pithon et al. 2013[27] os maiores torques de inserção foram obtidos em cortical óssea mais espessa independente do MI em concordância com os resultados obtidos por Pithon et al. 2011[29] O torque de inserção pode ser influenciado também pelo formato do MI, dispositivos cônicos requerem maior torque de inserção quando comparados aos com formato cilíndrico Pithon et al. 2011[29]

O eixo de aplicação de força sobre o MI mais utilizado nas mecânicas ortodônticas é o eixo perpendicular ao dispositivo e por este motivo a deflexão do MI deve ser avaliada através da aplicação da força neste sentido assim como foi realizado no presente estudo.[27] A maior deflexão foi observada na região da cabeça do MI e os dispositivos de aço inoxidável apresentaram maiores valores de deflexão quando comparados ao dispositivos de titânio.

Foram selecionados MI de dois materiais diferentes para a realização do presente estudo, sendo eles aço inoxidável e liga de titânio. Os aços inoxidáveis utilizados para implantes utilizados em tecidos humanos, especialmente, na cavidade oral devem ser resistentes á corrosão pela exposição aos fluídos corpóreos pois esse tipo de corrosão pode trazer prejuízos ao paciente e ao tratamento por exemplo pela fratura do dispositivo. As ligas de titânio utilizadas para fabricação de implantes apresentam vantagens que são a alta resistência e seu baixo módulo de elasticidade que os tornam duas vezes mais resistentes do que as ligas de aço inoxidável além de apresentarem uma resistência à fadiga cerca de 30% maior.[30-32] A magnitude do campo de tensões é maior no mini-implante fabricado com liga de titânio porque a sua rigidez é aproximadamente 47 % menor que a do mini-implante do aço inoxidável 316. Para carregamento de flexão a rigidez está diretamente relacionada com o modulo de Young.[33] Os resultados obtidos por este estudo apresentaram maiores valores de tensões e maior deflexão nos MI de titânio quando comparados com os MI de aço inoxidável.

O MI na cavidade oral utilizado para ancoragem encontra-se inserido em osso e em tecido mole, porém é a porção óssea que exerce a força necessária contra as forças ortodônticas. Estudos realizados com o auxílio da engenharia computacional através do MEF permitem uma visualização da distribuição das tensões em simulações mecânicas e com isso auxiliam a utilização de mecânicas ortodônticas com maior segurança e previsibilidade.

Conclusão

O presente estudo recriou um modelo tridimensional de um MI inserido em um bloco ósseo com duas variações da espessura da cortical óssea e através do MEF forneceu um esboço da distribuição das tensões no MI e no osso adjacente, geradas pela aplicação de uma força perpendicular ao MI. Os resultados obtidos por esta simulação permitiram concluir que:

1) As distribuições das tensões se concentraram no MI em todos os ensaios mecânicos, principalmente na região em contato com o osso cortical;
2) As maiores concentrações de tensões ocorreram em espessura de osso cortical de 1 mm quando comparados a espessura de osso cortical de 2 mm;
3) Os MI de liga de titânio apresentaram maior concentração de tensões e maior deflexão quando comparados aos MI de aço inoxidável na mesma espessura de cortical óssea.

Referências

1. Hoste S, Vercruyssen M, Quirynen M, Willems G. Risk factors and indications of orthodontic temporary anchorage devices: a literature review. Aust Orthod J 2008;24:140-148.

2. Proffit WR, Fields H, Sarver D. Contemporary Orthodontics. Mosby 2007;5th Edition:768.

3. Liu TC, Chang CH, Wong TY, Liu JK. Finite element analysis of miniscrew implants used for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2012;141:468-476.

4. Kanomi R. Mini-implant for orthodontic anchorage. J Clin Orthod 1997;31:763-767.

5. Park HS, Kwon OW, Sung JH. Micro-implant anchorage for forced eruption of impacted canines. J Clin Orthod 2004;38:297-302.

6. Deguchi T, Takano-Yamamoto T, Kanomi R, Hartsfield JK, Jr., Roberts WE, Garetto LP. The use of small titanium screws for orthodontic anchorage. J Dent Res 2003;82:377-381.

7. Huja SS, Litsky AS, Beck FM, Johnson KA, Larsen PE. Pull-out strength of monocortical screws placed in the maxillae and mandibles of dogs. Am J Orthod Dentofacial Orthop 2005;127:307-313.

8. Salmoria KK, Tanaka OM, Guariza-Filho O, Camargo ES, de Souza LT, Maruo H. Insertional torque and axial pull-out strength of mini-implants in mandibles of dogs. Am J Orthod Dentofacial Orthop 2008;133:790 e715-722.

9. Cope JB. Temporary anchorage devices in orthodontics. A paradigm shift. Seminars in Orthodontics 2005.

10. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. American Journal of Orthodontics and Dentofacial Orthopedics 2003;124:373-378.

11. Cheng H, Yen E, Chen L, Lee S. The analysis of failure cases using Orthoanchor K1 mini-implant system as orthodontic anchorage. J Dent Res 2003;82.

12. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2003;124:373-378.

13. Crismani AG, Bertl MH, Celar AG, Bantleon HP, Burstone CJ. Miniscrews in orthodontic treatment: review and analysis of published clinical trials. Am J Orthod Dentofacial Orthop 2010;137:108-113.

14. Brettin BT, Grosland NM, Qian F, Southard KA, Stuntz TD, Morgan TA et al. Bicortical vs monocortical orthodontic skeletal anchorage. Am J Orthod Dentofacial Orthop 2008;134:625-635.

15. Ansell RH, Scales JT. A study of some factors which affect the strength of screws and their insertion and holding power in bone. J Biomech 1968;1:279-302.

16. Baggi L, Cappelloni I, Maceri F, Vairo G. Stress-based performance evaluation of osseointegrated dental implants by finite-element simulation. Simulation Modelling Practice and Theory 2008;16:971-987.

17. Roos-Jansaker AM, Renvert H, Lindahl C, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part III: factors associated with peri-implant lesions. J Clin Periodontol 2006;33:296-301.

18. Carter DR, Van Der Meulen MC, Beaupre GS. Mechanical factors in bone growth and development. Bone 1996;18:5S-10S.

19. Natali AN, Pavan PG. A comparative analysis based on different strength criteria for evaluation of risk factor for dental implants. Comput Methods Biomech Biomed Engin 2002;5:127-133.

20. Cattaneo PM, Dalstra M, Melsen B. The finite element method: a tool to study orthodontic tooth movement. J Dent Res 2005;84:428-433.

21. Farah JW, Craig RG, Sikarskie DL. Photoelastic and finite element stress analysis of a restored axisymmetric first molar. J Biomech 1973;6:511-520.

22. Logan D. A first course in the finite element method. Cengage Learning; 2011.

23. Suzuki A, Masuda T, Takahashi I, Deguchi T, Suzuki O, Takano-Yamamoto T. Changes in stress distribution of orthodontic miniscrews and surrounding bone

evaluated by 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2011;140:e273-280.

24. Lin TS, Tsai FD, Chen CY, Lin LW. Factorial analysis of variables affecting bone stress adjacent to the orthodontic anchorage mini-implant with finite element analysis. Am J Orthod Dentofacial Orthop 2013;143:182-189.

25. Largura LZ, Argenta MA, Sakima MT, Camargo ES, Guariza-Filho O, Tanaka OM. Bone stress and strain after use of a miniplate for molar protraction and uprighting: a 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2014;146:198-206.

26. Cha JY, Kil JK, Yoon TM, Hwang CJ. Miniscrew stability evaluated with computerized tomography scanning. Am J Orthod Dentofacial Orthop 2010;137:73-79.

27. Pithon MM, Figueiredo DSF, Oliveira DD. Mechanical evaluation of orthodontic mini-implants of different lengths. Journal of Oral and Maxillofacial Surgery 2013;71:479-486.

28. Lim S-A, Cha J-Y, Hwang C-J. Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length. The Angle Orthodontist 2008;78:234-240.

29. Pithon M, Nojima M, Nojima L. In vitro evaluation of insertion and removal torques of orthodontic mini-implants. International journal of oral and maxillofacial surgery 2011;40:80-85.

30. Buss GD, K.S; Vicente M.G. Utilização de aços inoxidáveis em implantes. Boletim Informativo de Tecnovigilância 2011:1-6.

31. Askeland DR. The science and engineering of materials. Boston: PWS Pub.; 1998.

32. Jesuíno G, Ribeiro L, Nakazato R, Codaro E, Hein LdO. Propriedades mecânicas e resistência à corrosão da liga Ti-4Al-4V obtida da reciclagem da liga Ti-6Al-4V. Materials Research 2001;4:63-69.

33. Popov EP. Engineering Mechanics of Solids. Prentice Hall; 1998.

ARTIGO EM INGLÊS

TITLE PAGE

Evaluation of stress in the miniscrew and surrounding bone according to variations in the cortical bone thickness and composition of the miniscrew: an analysis by the finite element method

Renata Machado Marangon, DDS

Graduate Program in Orthodontics

School of Health and Biosciences

Pontifical Catholic University of Paraná, Curitiba, Brazil

E-mail: remarangon@hotmail.com

Orlando Tanaka, DDS, PhD (Correspondig author)

Professor, Graduate Program in Orthodontics

School of Health and Biosciences

Pontifical Catholic University of Paraná, Curitiba, Brazil

R. Imaculada Conceição, 1155 - Prado Velho

80215-901 Curitiba-Pr - Brazil

Fone: 55 (41) 3271-1637

Fax: 55 (41) 3271-1405

E-mail: tanakaom@gmail.com

Abstract

Introduction: The aim of this study was to analyze the finite element method (FEM) tensions generated in the miniscrew (MS) and surrounding bone upon applying a force perpendicular to MS according to variations in the cortical bone thickness and MS composition. **Methods:** Miniscrews with stainless steel or titanium alloy mechanical properties that were inserted in bone blocks with cortical bone of varying thickness (1 mm and 2 mm) were modeled three-dimensionally using computer aided design (CAD) and studied by FEM. A 3.5-N force perpendicular to the long axis of the MS was applied in the four mechanical tests: EM1, solid geometric bone block model, 1-mm cortical thickness, and stainless steel MS; EM2, solid geometric model, 1-mm thickness, and titanium MS; EM3, solid geometric model, 2-mm thick, and stainless steel MS; and EM4, solid geometric model, 2-mm thick, and titanium MS. **Results and Conclusions:** The stress distributions in all mechanical tests were highest at the MS, especially at the MS-cortical bone interface. EM2 showed the highest von Mises voltage, followed by EM1, EM4, and EM3. Stress concentration was higher at a cortical bone thickness of 1 mm compared with 2 mm, and in titanium MS compared with stainless steel MS at the same cortical bone thickness.

Keywords: Dental implants, Orthodontic anchorage procedures, Finite element analysis

Introduction

Anchorage control is a key requirement for successful orthodontic treatment of a variety of malocclusions. The holding strength of the anchor must be greater than the orthodontic tooth being moved; this follows the principle of an equal and opposite "action-reaction." Using his principal, anchorage control can be used to maximize the desired motion and decrease unwanted side effects. There are several types of anchoring: type A, or absolute anchoring, occurs when there is no movement of the anchor teeth, type B occurs when there is movement of the two tooth segments toward one another, and type C occurs when only the anchor tooth is handled or a total loss of anchorage occurs.[1] Several factors contribute to a loss of anchorage, including the interaction between the dental structures and the patient adherence to using the anchoring devices. In searching for absolute anchorage that does not require patient adherence, miniscrews (MS) have been developed and widely used to produce different types of tooth movement.[2-8]

Orthodontic treatment using a temporary anchorage MS has many advantages compared with conventional dental implants, including simplicity, less traumatic insertion and removal, minimal anatomical contraindications, the potential for instant loading after placement, and low cost.[3,9] Numerous studies have examined the success rate of MS anchors and report rates as low as 50% and as high as 89%.[10,11] Causative factors for failure include inflammation, infection, insertion into non-keratinized mucosa, and small MS size.[3,12,13] The amount and quality of bone in which MS are installed is another influential factor, as the implant can fail to osseointegrate and requires mechanical retention.[7,14]

The primary stability of a MS is affected mostly by factors related to the screw and the patient. Morphological characteristics, such as the screw diameter and length, are among the factors related to the MS. The quality and quantity of the bone where the MS is to be inserted are among the patient factors. The thickness of the cortical bone is a patient factor that can interfere with the primary stability of the MS. Primary stability improves as the amount of bone increases, highlighting the importance of the metal-bone interface. Areas with thicker cortical bone are considered more stable for MS placement. This bone density and thickness may vary between individuals and MS regions.[6-8,15]

The importance of location and the MS angle for the strength and stability of the anchor, as well as the stress generated in the tissues adjacent to the MS under load, is unclear due to the paucity of studies.[14] Dental implants cause resorption in the surrounding bone, primarily in the bone contacting the implant neck. Resorption can be triggered by several factors including surgical trauma, bacterial infection, or overload at the bone-implant interface.[16,17]

Overload on the peri-implant bone region can result from high concentrations of stress, and some studies[18] suggest that the deformation related fields stimulate bone resorption in the region, thereby undermining the effectiveness of the implant.[16] The evaluation of stress distribution in the bone enables investigation of the effectiveness of endosseous implants and reveals the risk of implant failure.[19]

The finite element method (FEM) is a numerical computation method that can be used to simulate and forecast biomechanical stress and displacement generated within a system.[20,21] Many studies have reported the stress distribution in the bone surrounding the MS, but few studies have evaluated the stress distribution in the domestic market itself.

A greater understanding of the MS regions experiencing the greatest voltage concentration is important in designing MS with a lessened risk of fracture, increased success rate of orthodontic treatment, and minimized risks to the patient.

The aim of this study was to analyze the stress generated using the FEM in MS and the surrounding bone by applying a force perpendicular to the MS according to variations in the cortical bone thickness (1 mm and 2 mm) and the miniscrew composition (titanium and stainless steel alloy).

Material and Methods

An 8-mm long, 1.5-mm diameter MS with a 1-mm transmucosal profile was selected for this study (Morelli, reference number 37.10.102; Figure 1). The MS was introduced into bone blocks measuring 9-mm high, 8-mm wide, and 8-mm deep comprising cortical and trabecular bone. Two cortical variants were evaluated, one measuring 1 mm and the other 2 mm. Both the MS and bone blocks were simulated by geometric solid modeling application using a computer aided design (CAD) program (SOLIDWORKS® DS 2013; Figure 2A). The MS was assigned the mechanical properties of stainless steel (ASTM F138) and titanium alloy (Ti6Al-4V) (Table 1).

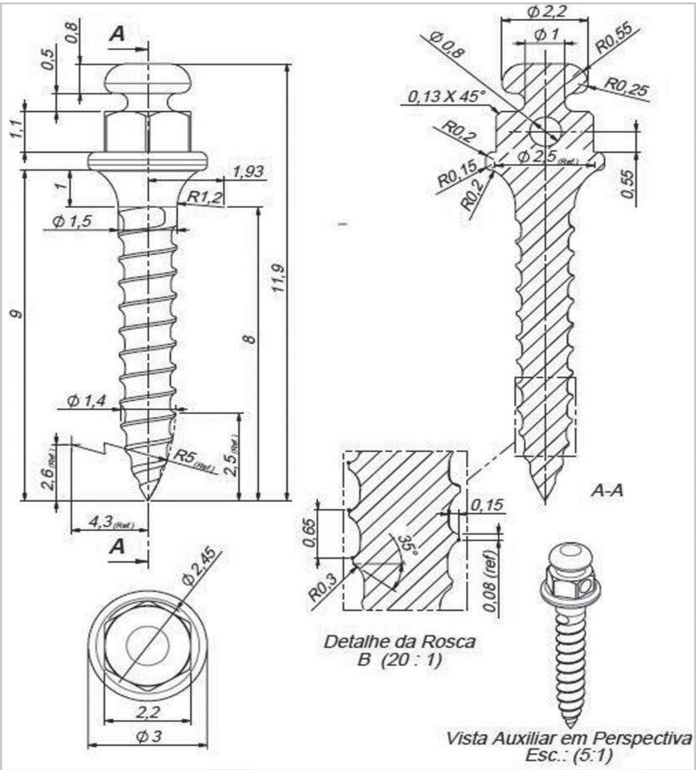


Fig 1. Miniscrew dimensions.

The computational models of the inserted MS-bone block was exported to the Autodesk Simulation program Multiphysics® 2013. The finite element meshes (Figures 2A–D) were generated, and the mechanical properties (Young's modulus and coefficient Poisson) of all components forming the solid model (bone and MS) were introduced. The properties of the materials used in the simulation are summarized in Table 1. A 3.5-N force was applied to the MS head in a perpendicular direction.

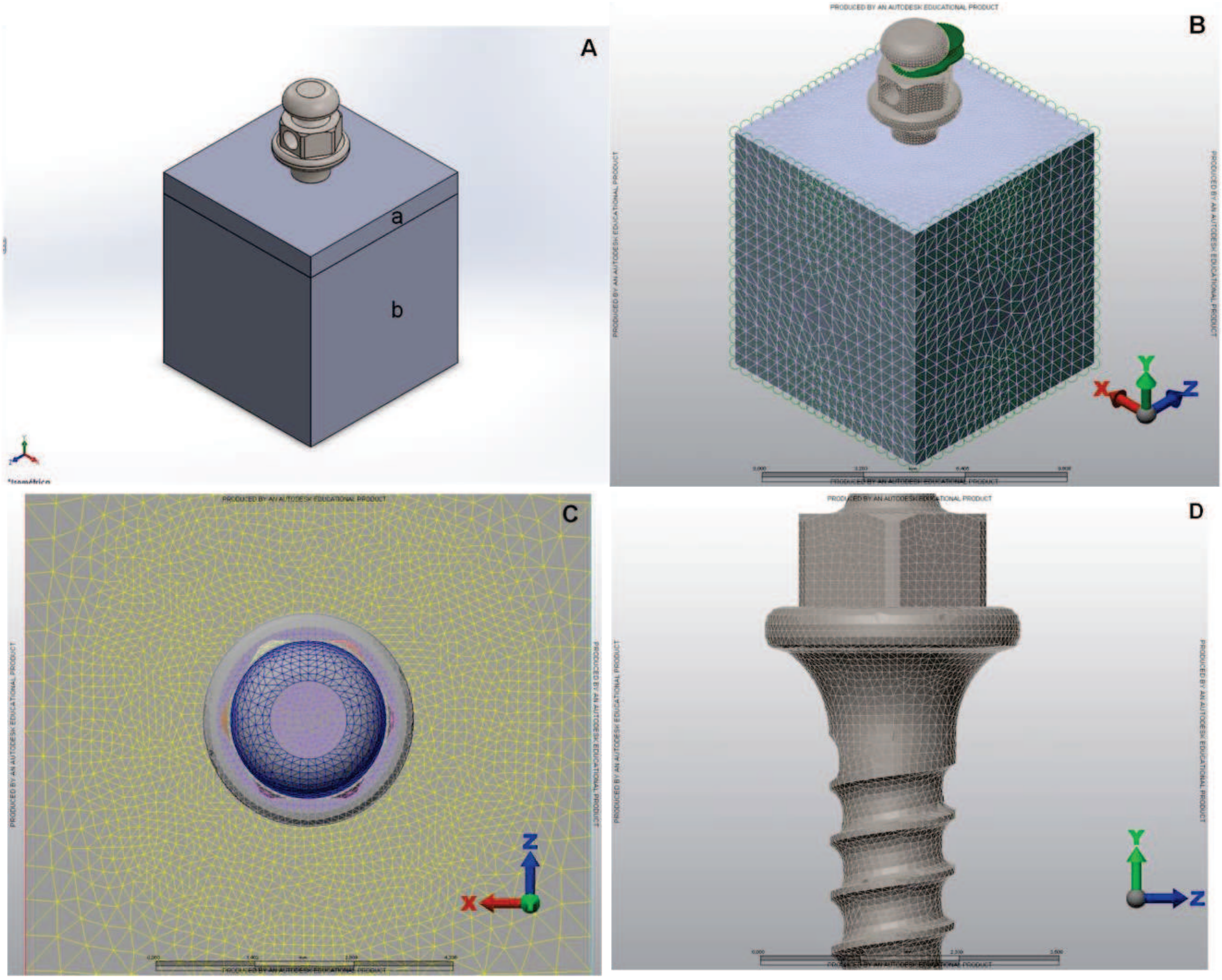


Fig 2. **A**, Three-dimensional modeling of the miniscrew (MS) inserted into a bone block in the mechanical simulations **a)** corresponding to the cortical bone thickness and **b)** trabecular bone thickness. **B**, Three-dimensional view of boundary conditions. **C**, Detailed top view. **D**, Detailed view of MI mesh.

Table 1. Bone and properties of miniscrews used in the models		
Material	Young´s modulus (MPa)	Poisson´s ratio
Titanium	110.000	0,33
Stainless Steel	205.000	0,29
Cortical Bone	138.000	0,26
Cancellous Bone	345	0,31

Four mechanical tests were performed using the following cortical thickness and MS material combinations:

• EM1: solid geometric bone block model, 1-mm thickness, and cortical stainless steel MS

• EM2: solid geometric bone block model, 1-mm thickness, and cortical titanium MS

• EM3: solid geometric bone block model, 2-mm thickness, and cortical stainless steel MS

• EM4: solid geometric bone block model, 2-mm thickness, and cortical titanium MS.

The translations on the side faces of the cuboid were restricted in the x-, y-, and z-directions as boundary conditions (Figure 2B, green circles). These conditions were necessary to simulate the remaining bone. The 3.5-N load was applied at the MS head along the z axis (Figure 2B, green lines). This magnitude is a realistic force that is applied clinically.[2]

After performing a convergence analysis of the stress field, the mesh was defined to perform the FEM analysis.[22] The lengths of the element edges in the analysis varied between 0.375 mm and 0.500 mm. The larger mesh refinement occurred in the region surrounding the bone-MS interface (Figure 2C). The final mesh for the EM1 and EM2 comprised 416,889 linear tetrahedral elements and 81,421 nodes, and the mesh for EM3 and EM4 comprised 499,882 linear tetrahedral elements and 96,753 nodes. The FEM of the cortical and trabecular bone, and MS were homogeneous, isotropic, and exhibited linear elastic behavior. The field stresses on the FEM were assessed according to the distortion energy theory for ductile materials, also known as failure von Mises criterion. These two parameters have been used in orthodontic studies.[16,23-25]

The coordinate system used to evaluate the results were the three axes (x, y, z) determined by the Autodesk Simulation Multiphysics® program 2013. Force was applied in the z-direction in the negative direction (from right to left).

Results

The stress distribution in the bone and MS were evaluated using a color scale, with blue representing a low voltage and red representing a high voltage.

In all four mechanical tests, the highest stress occurred at the bone and MS interface, particularly at the MS region in contact with the cortical bone. High stress was also observed along the MS region just above the cortical bone and in the trabecular bone near the cortical bone boundary when the cortical thickness was 1 mm (Fig. 3–6). The highest stress occurred in EM2 (53.0 MPa), followed by EM1 (43.6 MPa), EM4 (36.1 MPa), and EM3 (33.2 MPa) (Table 2).

Table 2.	Maximum values of Stress Von Mises for 4 mechanical tests (MPa)
	Maximum
EM1	43.64
EM2	53.09
EM3	33.29
EM4	36.12

In the mechanical tests employing a 2-mm thickness, stress was concentrated within the cortical bone only and did not extend into the trabecular bone.

In cross–section, the highest stress was present along the outside of the MS and was coplanar with the force application plane in all the mechanical tests (Figure 3B, 4B, 5B, and 6B).

In cross-section, deflection of the stress distribution behaved identically across all four mechanical tests. As expected, most of the deflection was concentrated at the MS head in all four mechanical tests (Figure 3D, 4D, 5D, and 6D). Stretching was greatest in EM2 (0.00464), followed by EM1 (0.00337), EM4 (0.00331), and EM3 (0.00238).

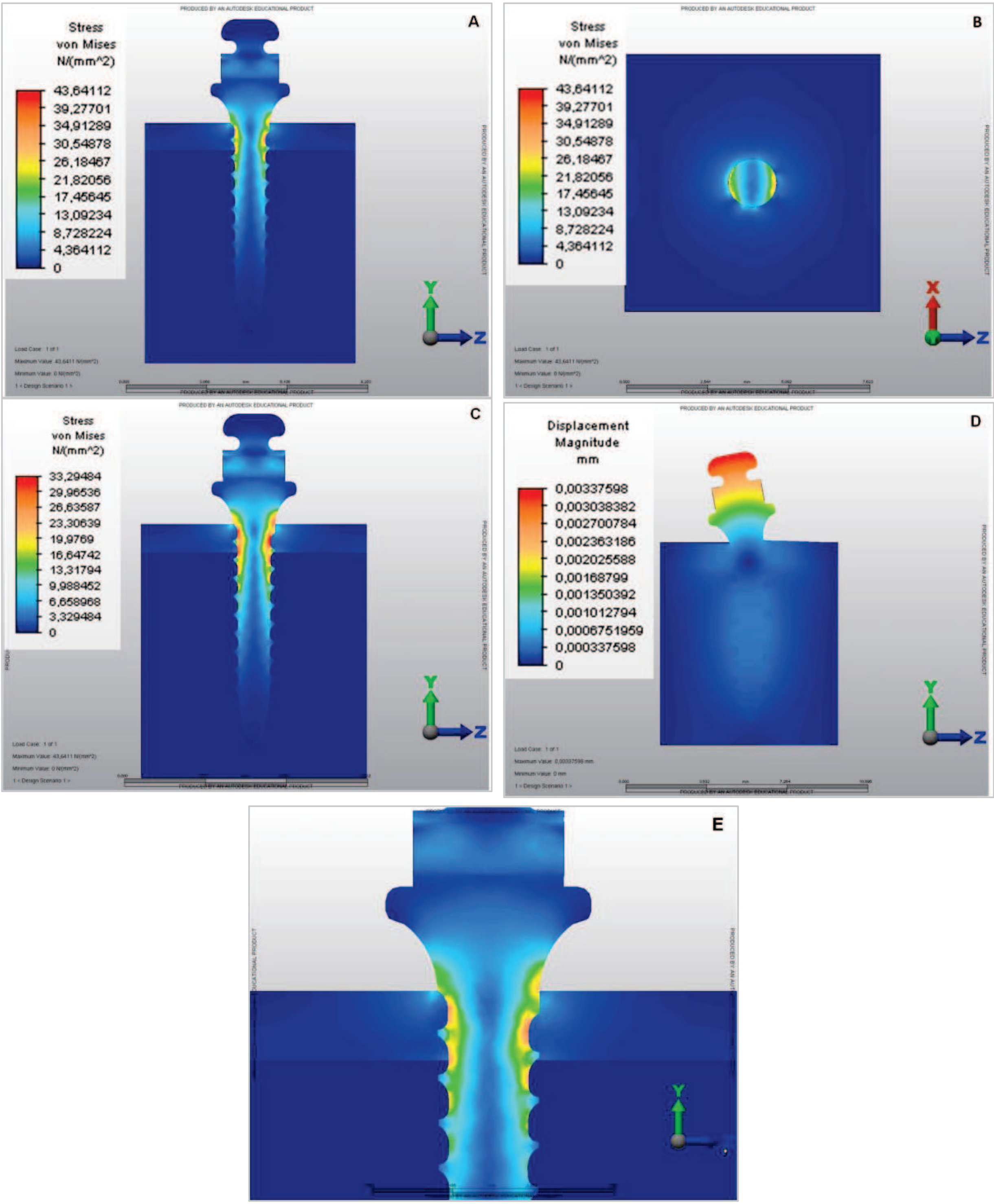
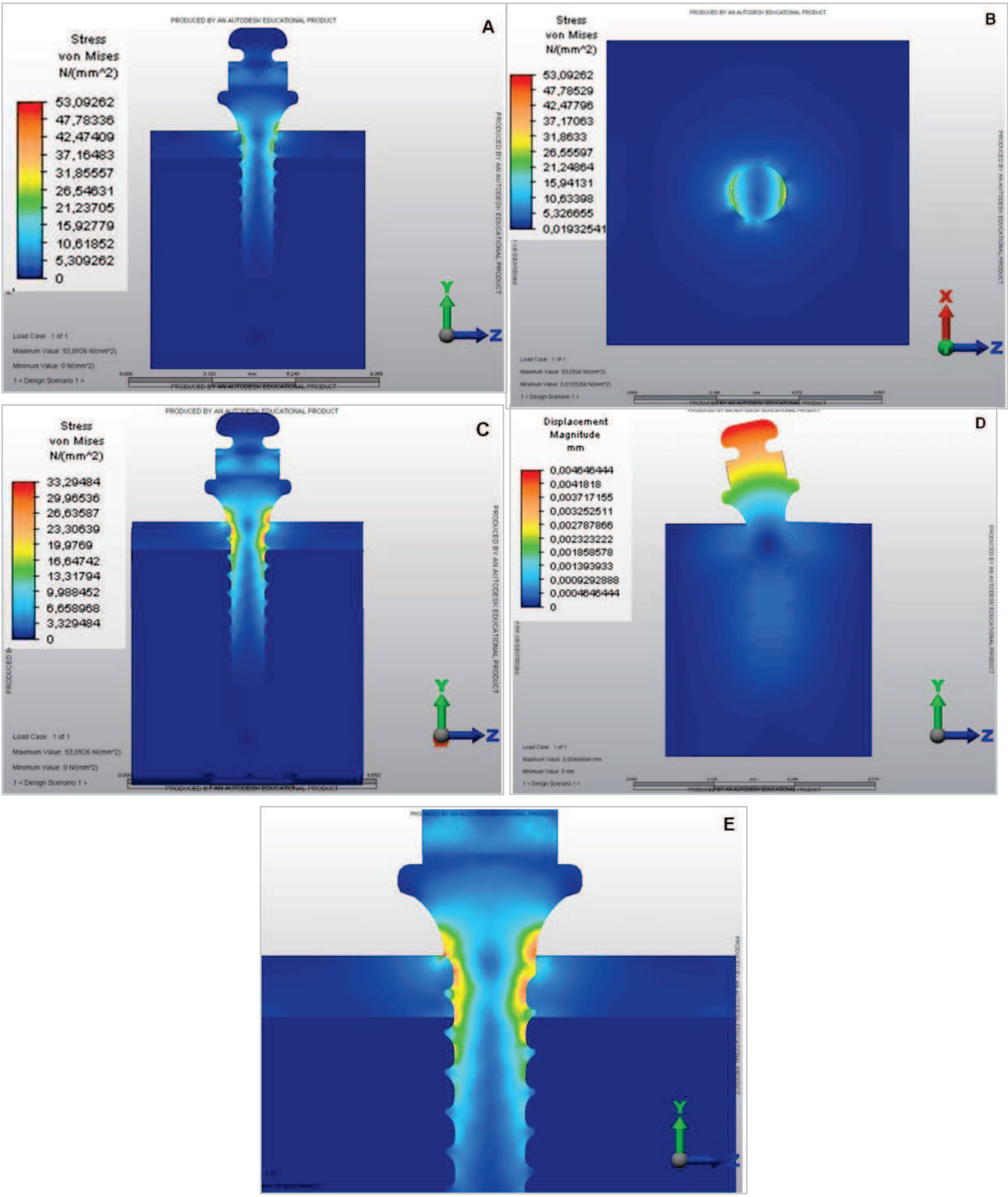


Fig 3. Stress distribution in EM1. **A-** Cross section. **B-** Perpendicular court. **C-** Cross section, the EM1 model had the lowest magnitude of stress among the mechanical test models. **D-** Cross section deflection (scale: magnitude of displacement). **E-** Stress distribuition in the region corresponding to the cortical bone

1



2

Fig 4. Stress distribution in EM2. **A-** Cross section. **B-** Perpendicular court. **C-** Cross section, the EM2 model had the lowest magnitude of stress among the mechanical test models. **D-** Cross section deflection (scale: magnitude of displacement). **E-** Stress distribuition in the region corresponding to the cortical bone

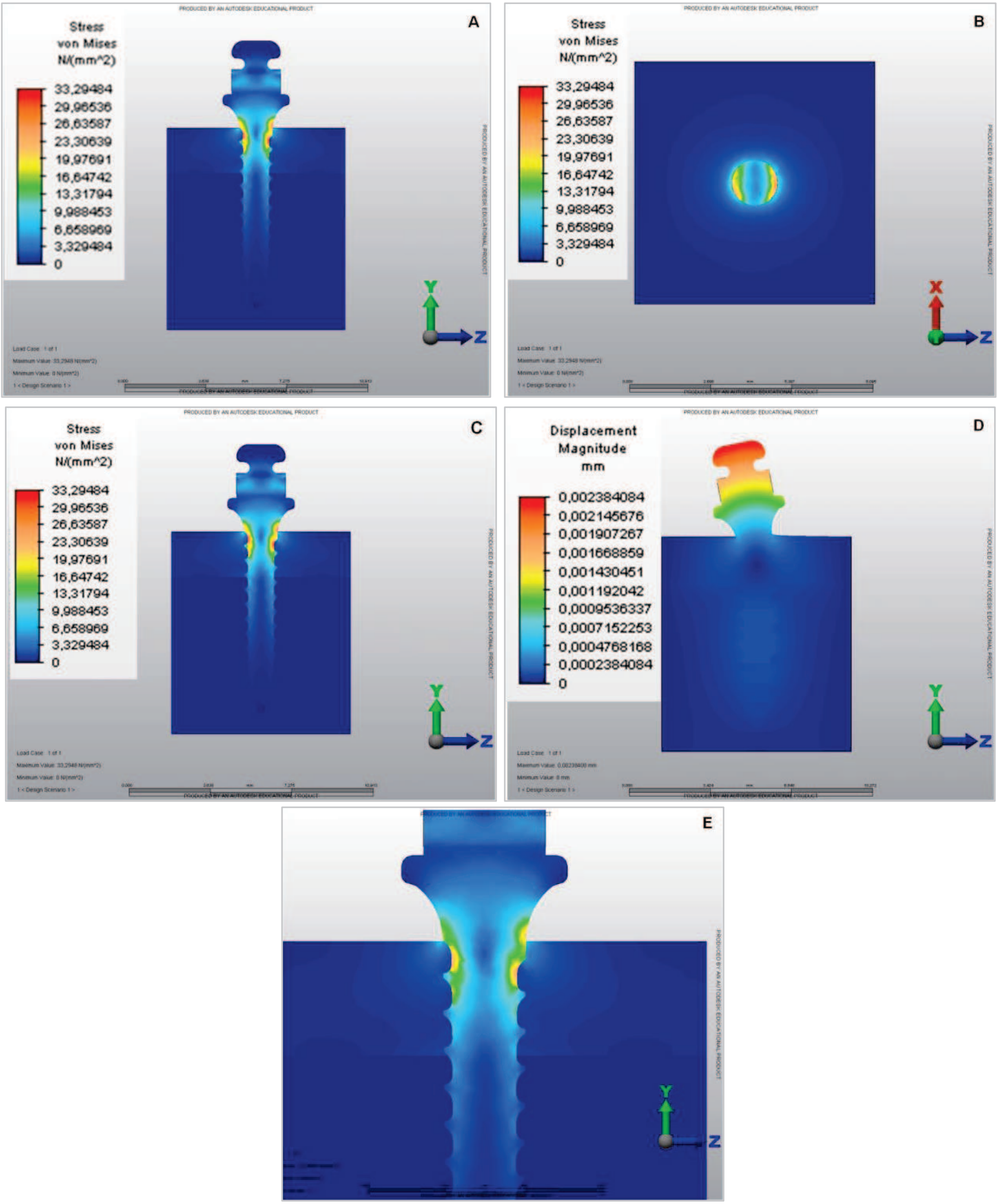


Fig 5. Stress distribution in EM3. **A-** Cross section. **B-** Perpendicular court. **C-** Cross section, the EM3 model had the lowest magnitude of stress among the mechanical test models. **D-** Cross section deflection (scale: magnitude of displacement). **E-** Stress distribuition in the region corresponding to the cortical bone

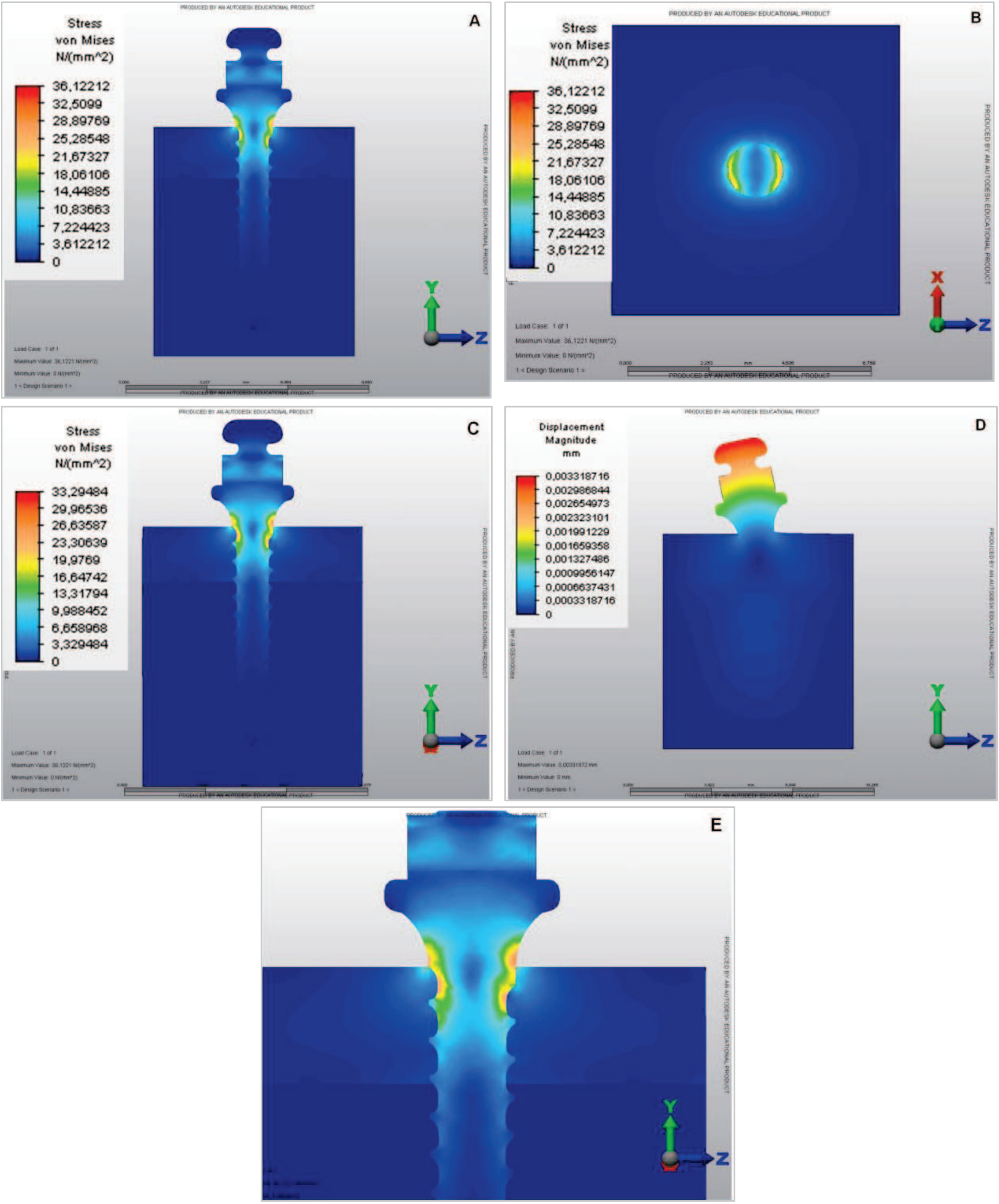


Fig 6. Stress distribution in EM4. **A-** Cross section. **B-** Perpendicular court. **C-** Cross section, the EM4 model had the lowest magnitude of stress among the mechanical test models. **D-** Cross section deflection (scale: magnitude of displacement). **E-** Stress distribuition in the region corresponding to the cortical bone

Discussion

This study evaluated the stress distribution and magnitude in the bone and MS induced by a load applied to an orthodontic MS. These results contribute to the understanding of the complex biological reactions resulting from the system of forces applied to the MS varied according to the cortical bone thickness.

The use of animal models to evaluate and study orthodontic biomechanics is limited by the difficulty of transferring the results to humans, which ultimately hampers prospective studies in humans. FEM has emerged with the development of computer engineering and enables research in life science and health without requiring living beings. This motif has long been used in dentistry. In addition to the benefits of avoiding human and animal research, FEM allows the assessment of biomechanical processes and the search for solutions to these particular clinical problems. In orthodontics, this method has been used to assess the magnitude and distribution of stress caused by various orthodontic movements.

Some FEM studies have shown that applying the force lateral to the MS causes most of the stress to concentrate in cortical bone areas.[26] The present study found similar results, as the highest stress concentrations were observed in the cortical bone-MS interface. Previous studies seeking to improve the primary stability of MS have focused on the bony anatomy, namely the thickness of the cortical bone, and not on the quality of the trabecular bone.[1]

The present results showed higher stress in the mechanical tests using a 1-mm cortical bone thickness, independent of the MS material. In the assays where the cortical thickness was 1 mm, stress concentrated 1-mm above the cortical bone and 1-mm below in the trabecular bone. In the 2-mm thick cortical bone, this stress concentration occurred within the entirety of the cortical bone and do not extend into the trabecular bone.

Primary stability is fundamental to the proper retention of the anchor and can be influenced by the insertion torque, as well as by the quality and quantity of the bone. In order to adapt MS to different insertion sites and achieve greater primary stability, dentists use various MI sizes and types. Deformation and MS fractures can be avoided through a better understanding of the influence of these factors on the mechanical properties of the implant.

Pithon et al. 2013[27] evaluated the influence of the MS length on its mechanical properties, specifically the insertion torque required for various thicknesses of cortical bone and the insertion torque required to fracture the device. They observed that the MS length influenced the insertion torque, independent of the cortical bone thickness, a finding also reported by Lim et al. 2008[28], who examined cortical bone measuring 1.5-mm thick. Pithon et al. 2013[27] obtained larger insertion torques in thicker cortical bone independent of the MS, consistent with their findings in a separate study.[29] The insertion torque is also influenced by the MS form, as tapered devices require greater insertion torque compared with the cylindrical device used by Pithon et al. 2011[29]

The force application axis used on the most MS in orthodontic mechanics is the axis perpendicular to the device. Therefore, the MS deformation should be evaluated by applying the force in this direction, as done in this study.[27] The largest deformation was observed in the MS head, and stainless-steel appliances had higher offset values compared with titanium devices.

Two different materials were selected for the MS in this study, stainless steel and titanium alloy. The stainless steel used for implants in human tissues, especially in the oral cavity, must resist corrosion caused by exposure to body fluids because this type of corrosion can harm the patient and promote device fracture and other forms of treatment failure. Titanium alloy implants have several advantages, including high strength and a low modulus of elasticity, that make these implants twice as resistant to corrosion as stainless steel alloys, as well as approximately 30% more resistant to fatigue apresetarem.[30-32] The present study revealed higher voltage and deflection in the titanium MS compared with the stainless steel MI. The magnitude of the stress field was higher in MS comprising titanium alloy because its rigidity is approximately 47% less than in the MS comprising stainless steel 316. The load bending stiffness is directly correlated with the magnitude of the Young's modulus.[33]

Although anchoring MI in the oropharynx is inserted into both the bone and soft tissue, it is the bone portion that maintains the necessary force against orthodontic forces. Studies aided by computer engineering using the FEM allow visualization of the stress distribution in mechanical simulations, thereby allowing clinicians to use orthodontic mechanics with greater certainty and predictability.

Conclusion

This study recreated a three-dimensional model of an MS inserted into a bone block at two cortical bone thicknesses and used FEM to predict the stress distribution in the adjacent bone and MS upon applying a force perpendicular to the MS. The simulation results showed the following:

1) The stress distribution concentrated at the MS in all mechanical tests, mainly at the interface with the cortical bone.

2) The greatest stress concentration occurred in cortical bone measuring 1-mm thick compared with cortical bone measuring 2-mm thick.

3) The titanium alloy MS showed higher stress and deflection voltages compared with the stainless steel MS at the same cortical bone thickness.

References

1. Hoste S, Vercruyssen M, Quirynen M, Willems G. Risk factors and indications of orthodontic temporary anchorage devices: a literature review. Aust Orthod J 2008;24:140-148.

2. Proffit WR, Fields H, Sarver D. Contemporary Orthodontics. Mosby 2007;5th Edition:768.

3. Liu TC, Chang CH, Wong TY, Liu JK. Finite element analysis of miniscrew implants used for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2012;141:468-476.

4. Kanomi R. Mini-implant for orthodontic anchorage. J Clin Orthod 1997;31:763-767.

5. Park HS, Kwon OW, Sung JH. Micro-implant anchorage for forced eruption of impacted canines. J Clin Orthod 2004;38:297-302.

6. Deguchi T, Takano-Yamamoto T, Kanomi R, Hartsfield JK, Jr., Roberts WE, Garetto LP. The use of small titanium screws for orthodontic anchorage. J Dent Res 2003;82:377-381.

7. Huja SS, Litsky AS, Beck FM, Johnson KA, Larsen PE. Pull-out strength of monocortical screws placed in the maxillae and mandibles of dogs. Am J Orthod Dentofacial Orthop 2005;127:307-313.

8. Salmoria KK, Tanaka OM, Guariza-Filho O, Camargo ES, de Souza LT, Maruo H. Insertional torque and axial pull-out strength of mini-implants in mandibles of dogs. Am J Orthod Dentofacial Orthop 2008;133:790 e715-722.

9. Cope JB. Temporary anchorage devices in orthodontics. A paradigm shift. Seminars in Orthodontics 2005.

10. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. American Journal of Orthodontics and Dentofacial Orthopedics 2003;124:373-378.

11. Cheng H, Yen E, Chen L, Lee S. The analysis of failure cases using Orthoanchor K1 mini-implant system as orthodontic anchorage. J Dent Res 2003;82.

12. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2003;124:373-378.

13. Crismani AG, Bertl MH, Celar AG, Bantleon HP, Burstone CJ. Miniscrews in orthodontic treatment: review and analysis of published clinical trials. Am J Orthod Dentofacial Orthop 2010;137:108-113.

14. Brettin BT, Grosland NM, Qian F, Southard KA, Stuntz TD, Morgan TA et al. Bicortical vs monocortical orthodontic skeletal anchorage. Am J Orthod Dentofacial Orthop 2008;134:625-635.

15. Ansell RH, Scales JT. A study of some factors which affect the strength of screws and their insertion and holding power in bone. J Biomech 1968;1:279-302.

16. Baggi L, Cappelloni I, Maceri F, Vairo G. Stress-based performance evaluation of osseointegrated dental implants by finite-element simulation. Simulation Modelling Practice and Theory 2008;16:971-987.

17. Roos-Jansaker AM, Renvert H, Lindahl C, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part III: factors associated with peri-implant lesions. J Clin Periodontol 2006;33:296-301.

18. Carter DR, Van Der Meulen MC, Beaupre GS. Mechanical factors in bone growth and development. Bone 1996;18:5S-10S.

19. Natali AN, Pavan PG. A comparative analysis based on different strength criteria for evaluation of risk factor for dental implants. Comput Methods Biomech Biomed Engin 2002;5:127-133.
20. Cattaneo PM, Dalstra M, Melsen B. The finite element method: a tool to study orthodontic tooth movement. J Dent Res 2005;84:428-433.
21. Farah JW, Craig RG, Sikarskie DL. Photoelastic and finite element stress analysis of a restored axisymmetric first molar. J Biomech 1973;6:511-520.
22. Logan D. A first course in the finite element method. Cengage Learning; 2011.
23. Suzuki A, Masuda T, Takahashi I, Deguchi T, Suzuki O, Takano-Yamamoto T. Changes in stress distribution of orthodontic miniscrews and surrounding bone evaluated by 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2011;140:e273-280.
24. Lin TS, Tsai FD, Chen CY, Lin LW. Factorial analysis of variables affecting bone stress adjacent to the orthodontic anchorage mini-implant with finite element analysis. Am J Orthod Dentofacial Orthop 2013;143:182-189.
25. Largura LZ, Argenta MA, Sakima MT, Camargo ES, Guariza-Filho O, Tanaka OM. Bone stress and strain after use of a miniplate for molar protraction and uprighting: a 3-dimensional finite element analysis. Am J Orthod Dentofacial Orthop 2014;146:198-206.
26. Cha JY, Kil JK, Yoon TM, Hwang CJ. Miniscrew stability evaluated with computerized tomography scanning. Am J Orthod Dentofacial Orthop 2010;137:73-79.
27. Pithon MM, Figueiredo DSF, Oliveira DD. Mechanical evaluation of orthodontic mini-implants of different lengths. Journal of Oral and Maxillofacial Surgery 2013;71:479-486.
28. Lim S-A, Cha J-Y, Hwang C-J. Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length. The Angle Orthodontist 2008;78:234-240.
29. Pithon M, Nojima M, Nojima L. In vitro evaluation of insertion and removal torques of orthodontic mini-implants. International journal of oral and maxillofacial surgery 2011;40:80-85.
30. Buss GD, K.S; Vicente M.G. Utilização de aços inoxidáveis em implantes. Boletim Informativo de Tecnovigilância 2011:1-6.
31. Askeland DR. The science and engineering of materials. Boston: PWS Pub.; 1998.
32. Jesuíno G, Ribeiro L, Nakazato R, Codaro E, Hein LdO. Propriedades mecânicas e resistência à corrosão da liga Ti-4Al-4V obtida da reciclagem da liga Ti-6Al-4V. Materials Research 2001;4:63-69.
33. Popov EP. Engineering Mechanics of Solids. Prentice Hall; 1998.

ANEXO 1 – Autorização do fabricante

Autorização para utilização dos desenhos dos mini-implantes fornecidos pelo fabricante Morelli

MORELLI ORTODONTIA

5 de Novembro de 2013

SAC Morelli Finalizado

Prezada

Renata Machado Marangon

Agradecemos seu contato bem como suas considerações sobre nossos produtos e serviços.

Segue abaixo os esclarecimentos sobre as SACs registradas na Morelli.

SAC	36775
Data	01/11/2013
Tipo de Atendimento	Contato do Site
Classificação	Solicitação
Tipo	Serviço
Serviço	Informações Técnicas
Descrição fornecida pelo Cliente	
Ocorrência	Sou estudante do mestrado de ortodontia da PUC Paraná. Meu orientador é o Professor Orlando Tanaka, e vamos começar uma pesquisa que será a minha dissertação com mini-implantes avaliados por elementos finitos. Pretendemos utilizar os MI Morelli de 8,0 mm de comprimento e com perfil transmucoso de 1,0 mm e outro de 8,0 mm de comprimento com perfil transmucoso de 2,0 mm. Pretendemos avaliar as tensões no Mi em relação a variação do perfil transmucoso. Gostaria de ver se há a possibilidade de me enviarem os desenhos ou fotos destes MI para que possamos realizar o trabalho com elementos finitos. Obrigada.
Resposta da Morelli	Prezada Dra. Renata, Agradecemos por nos consultar, e aproveitamos para lhe desejar todo sucesso possível no seu trabalho. Segue em anexo, os desenhos dos miniparafusos solicitados. Atenciosamente,

Atenciosamente,

SAC Morelli

ANEXO 2 – Normas para publicação

AMERICAN JOURNAL OF ORTHODONTICS & DENTOFACIAL ORTHOPEDICS

Information for Authors

Electronic manuscript submission and review

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

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

Rolf G. Behrents, Editor-in-Chief

E-mail: behrents@slu.edu

Send other correspondence to:

Chris Burke, Managing Editor

American Journal of Orthodontics and Dentofacial Orthopedics

University of Washington

Department of Orthodontics, D-569

HSC Box 357446

Seattle, WA 98195-7446

Telephone (206) 221-5413

E-mail:ckburke@aol.com

Before you begin

Ethics in publishing

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Human and animal rights

If the work involves the use of animal or human subjects, the author should ensure that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans http://www.wma.net/en/30publications/10policies/b3/index.html; EU Directive 2010/63/EU for animal experiments http://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm; Uniform Requirements for manuscripts submitted to Biomedical journals http://www.icmje.org. Authors should include a statement in the manuscript that informed consent was obtained for experimentation with human subjects. The privacy rights of human subjects must always be observed.

Conflict of interest

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

Submission declaration and verification

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/sharingolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. To verify originality, your article may be checked by the originality detection service CrossCheck http://www.elsevier.com/editors/plagdetect.

Contributors

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

Changes to authorship

This policy concerns the addition, deletion, or rearrangement of author names in the authorship of accepted manuscripts:

Before the accepted manuscript is published in an online issue: Requests to add or remove an author, or to rearrange the author names, must be sent to the Journal Manager from the corresponding author of the accepted manuscript and must include: (a) the reason the name should be added or removed, or the author names rearranged and (b) written confirmation (e-mail, fax, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed. Requests that are not sent by the corresponding author will be forwarded by the Journal Manager to the corresponding author, who must follow the procedure as described above. Note that: (1) Journal Managers will inform the Journal Editors of any such requests and (2) publication of the accepted manuscript in an online issue is suspended until authorship has been agreed.

After the accepted manuscript is published in an online issue: Any requests to add, delete, or rearrange author names in an article published in an online issue will follow the same policies as noted above and result in a corrigendum.

Copyright

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

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

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

Author rights

As an author you (or your employer or institution) have certain rights to reuse your work. For more information see http://www.elsevier.com/copyright.

Role of the funding source

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

Funding body agreements and policies

Elsevier has established a number of agreements with funding bodies which allow authors to comply with their funder's open access policies. Some authors may also be reimbursed for associated publication fees. To learn more about existing agreements please visit http://www.elsevier.com/fundingbodies.

Language (usage and editing services)

Please write your text in good English (American or British usage is accepted, but not a mixture of these). Authors who feel their English language manuscript may require editing to eliminate possible grammatical or spelling errors and to conform to correct scientific English may wish to use the English Language Editing service available from Elsevier's WebShop (http://webshop.elsevier.com/languageediting/) or visit our customer support site (http://support.elsevier.com) for more information.

Informed consent and patient details

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

Submission

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

Blinding

The *AJO-DO* uses a blind review process; the identity of the author and the location of the research are concealed from the reviewers, and the identities of the reviewers are concealed from the author. The following submission items are sent to reviewers during the review process and should not contain any identifying information.

Manuscript * Figures * Tables * Other Material

The title page, which should contain complete author information, is not sent to reviewers. In the manuscript, please pay special attention to Material and Methods and Acknowledgments sections; wherever author is mentioned, use the "hidden" format in Word to conceal it, or move it to the title page.

Guidelines for Original Articles

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

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

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

2. *Abstract.* Structured abstracts of 200 words or less are preferred. A structured abstract contains the following sections: Introduction, describing the problem; Methods, describing how the study was performed; Results, describing the

primary results; and Conclusions, reporting what the authors conclude from the findings and any clinical implications.

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

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

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

cells.

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

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

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

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

Guidelines for Systematic Reviews

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

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

Systematic Review and Meta-Analysis Guide for Authors

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

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

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

Guidelines for Randomized Clinical Trials

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

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

Guidelines for Miscellaneous Submissions

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

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

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

Checklist for Authors

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

____Abstract

____Article proper, including references and figure legends

____Figures, in TIF or EPS format

____Tables

____Copyright release statement, signed by all authors

____Photographic consent statement(s)

____ICMJE Conflict of interest statement

____Permissions to reproduce previously published material

Preparation

Double-blind review

This journal uses double-blind review, which means that both the reviewer and author name(s) are not allowed to be revealed to one another for a manuscript under review. The identities of the authors are concealed from the reviewers, and vice versa. For more information please refer to http://www.elsevier.com/reviewers/peer-review. To facilitate this, please include the following separately:

Title page (with author details): This should include the title, authors' names and affiliations, and a complete address for the corresponding author including an e-mail address.

Blinded manuscript (no author details): The main body of the paper (including the references, figures, tables and any Acknowledgements) should not include any identifying information, such as the authors' names or affiliations.

Article structure

Introduction

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

Material and Methods

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

Results

Results should be clear and concise.

Discussion

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

Conclusions

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

Essential title page information

• ***Title.*** Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.

• ***Author names and affiliations.*** Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.

• ***Corresponding author.*** Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. **Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.**

• ***Present/permanent address.*** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

Abstract

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

Graphical abstract

Although a graphical abstract is optional, its use is encouraged as it draws more attention to the online article. The graphical abstract should summarize the contents of the article in a concise, pictorial form designed to capture the attention of a wide readership. Graphical abstracts should be submitted as a separate file in the online submission system. Image size: Please provide an image with a minimum of 531 × 1328 pixels (h × w) or proportionally more. The image should be readable at a size of 5 × 13 cm using a regular screen resolution of 96 dpi. Preferred file types: TIFF, EPS, PDF or MS Office files. See http://www.elsevier.com/graphicalabstracts for examples.

Authors can make use of Elsevier's Illustration and Enhancement service to ensure the best presentation of their images and in accordance with all technical requirements: Illustration Service.

Highlights

Highlights are a short collection of bullet points that convey the core findings of the article. Highlights are optional and should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point). See http://www.elsevier.com/highlights for examples.

Acknowledgments

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

Artwork

Image manipulation

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

Electronic artwork

General points

• Make sure you use uniform lettering and sizing of your original artwork.

• Embed the used fonts if the application provides that option.

• Aim to use the following fonts in your illustrations: Arial, Courier, Times New

Roman, Symbol, or use fonts that look similar.

• Number the illustrations according to their sequence in the text.

• Use a logical naming convention for your artwork files.

• Provide captions to illustrations separately.

• Size the illustrations close to the desired dimensions of the published version.

• Submit each illustration as a separate file.

A detailed guide on electronic artwork is available on our website:

http://www.elsevier.com/artworkinstructions

You are urged to visit this site; some excerpts from the detailed information are given here.

Formats

If your electronic artwork is created in a Microsoft Office application (Word, PowerPoint, Excel) then please supply 'as is' in the native document format.

Regardless of the application used other than Microsoft Office, when your electronic artwork is finalized, please 'Save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):

EPS (or PDF): Vector drawings, embed all used fonts.

TIFF (or JPEG): Color or grayscale photographs (halftones), keep to a minimum of 300 dpi.

TIFF (or JPEG): Bitmapped (pure black & white pixels) line drawings, keep to a minimum of 1000 dpi.

TIFF (or JPEG): Combinations bitmapped line/half-tone (color or grayscale), keep to a minimum of 500 dpi.

Please do not:

• Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); these typically have a low number of pixels and limited set of colors;

• Supply files that are too low in resolution;

• Submit graphics that are disproportionately large for the content.

Color artwork

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

Figure captions

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

Tables

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

References

Citation in text

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

Reference links

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

Web references

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

References in a special issue

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

Reference style

Text: Indicate references by superscript numbers in the text. The actual authors can be referred to, but the reference number(s) must always be given.

List: Number the references in the list in the order in which they appear in the text.

Examples:

Reference to a journal publication:

1. Van der Geer J, Hanraads JAJ, Lupton RA. The art of writing a scientific article. Sci Commun 2010;16351-9.

Reference to a book:

2. Strunk Jr W, White EB. The elements of style. 4th ed. New York: Longman; 2000.

Reference to a chapter in an edited book:

3. Mettam GR, Adams LB. How to prepare an electronic version of your article. In: Jones BS, Smith RZ, editors. Introduction to the electronic age. New York: E-Publishing Inc; 2009. p. 281-304.

Note shortened form for last page number. e.g., 51-9, and that for more than 6 authors the first 6 should be listed followed by 'et al.' For further details you are referred to 'Uniform Requirements for Manuscripts submitted to Biomedical Journals' (J Am Med Assoc 1997;**277**:927–34) (see also http://www.nlm.nih.gov/bsd/uniform_requirements.html).

Video data

Elsevier accepts video material and animation sequences to support and enhance your scientific research. Authors who have video or animation files that they wish to submit with their article are strongly encouraged to include links to these within the body of the article. This can be done in the same way as a figure or table by referring to the video or animation content and noting in the body text where it should be placed. All submitted files should be properly labeled so that they directly relate to the video file's content. In order to ensure that your video or animation material is directly usable, please provide the files in one of our recommended file formats with a preferred maximum size of 50 MB. Video and animation files supplied will be published online in the electronic version of your article in Elsevier Web products, including ScienceDirect: http://www.sciencedirect.com. Please supply 'stills' with your files: you can choose any frame from the video or animation or make a separate image. These will be used instead of standard icons and will personalize the link to your video data. For more detailed instructions please visit our video instruction pages at http://www.elsevier.com/artworkinstructions. Note: since video and animation cannot be embedded in the print version of the journal, please provide text for both the electronic and the print version for the portions of the article that refer to this content.

Supplementary data

Elsevier accepts electronic supplementary material to support and enhance your scientific research. Supplementary files offer the author additional possibilities to publish supporting applications, high-resolution images, background datasets, sound clips and more. Supplementary files supplied will be published online alongside the electronic version of your article in Elsevier Web products, including ScienceDirect: http://www.sciencedirect.com. In order to ensure that your submitted material is directly usable, please provide the data in one of our recommended file formats. Authors should submit the material in electronic format together with the article and supply a concise and descriptive caption for each file. For more detailed instructions please visit our artwork instruction pages at http://www.elsevier.com/artworkinstructions.

3D Models

You can enrich your online articles by providing 3D models (optional) in PLY, OBJ or U3D format, which will be visualized using the interactive viewer next to the article. Each 3D model will have to be zipped and uploaded to online submission system via the "3D models" submission category. Please be advised that the recommended model size before zipping is 50-100 MB. Multiple models can be submitted. Please provide a short informative description for each model by filling in the “Description” field when uploading a dataset. Note: all datasets will be available for download from the online article on ScienceDirect. If you have concerns about your data being downloadable, please provide a video instead. For more information see http://www.elsevier.com/about/content-innovation/obj-ply-models and http://www.elsevier.com/about/content-innovation/u3d-models.

Submission Checklist

The following list will be useful during the final checking of an article prior to sending it to the journal for review. Please consult this Guide for Authors for further details of any item.

Ensure that the following items are present:

One author has been designated as the corresponding author with contact details:

• E-mail address

• Full postal address

• Phone numbers

All necessary files have been uploaded, and contain:

• All figure captions

• All tables (including title, description, footnotes)

Further considerations

• Manuscript has been 'spell-checked' and 'grammar-checked'

• References are in the correct format for this journal

• All references mentioned in the Reference list are cited in the text, and vice versa

• Permission has been obtained for use of copyrighted material from other sources (including the Web)

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

Permissions

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

After Acceptance

Use of the Digital Object Identifier

The Digital Object Identifier (DOI) may be used to cite and link to electronic documents. The DOI consists of a unique alpha-numeric character string which is assigned to a document by the publisher upon the initial electronic publication. The assigned DOI never changes. Therefore, it is an ideal medium for citing a document, particularly 'Articles in press' because they have not yet received their full bibliographic information. Example of a correctly given DOI (in URL format; here an article in the journal *Physics Letters B*):

http://dx.doi.org/10.1016/j.physletb.2010.09.059

When you use a DOI to create links to documents on the web, the DOIs are guaranteed never to change.

Proofs

One set of page proofs (as PDF files) will be sent by e-mail to the corresponding author (if we do not have an e-mail address then paper proofs will be sent by post) or, a link will be provided in the e-mail so that authors can download the files themselves. Elsevier now provides authors with PDF proofs which can be annotated; for this you will need to download Adobe Reader version 9 (or higher) available free from http://get.adobe.com/reader. Instructions on how to annotate PDF files will accompany the proofs (also given online). The exact system requirements are given at the Adobe site: http://www.adobe.com/products/reader/tech-specs.html.

If you do not wish to use the PDF annotations function, you may list the corrections (including replies to the Query Form) and return them to Elsevier in an e-mail. Please list your corrections quoting line number. If, for any reason, this is not possible, then mark the corrections and any other comments (including replies to the Query Form) on a printout of your proof and return by fax, or scan the pages and e-mail, or by post. Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. We will do everything possible to get your article published quickly and accurately. It is important to ensure that all corrections are sent back to us in one communication: please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proofreading is solely your responsibility.

Offprints

For a fee, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier's WebShop (http://webshop.elsevier.com/myarticleservices/offprints). Authors requiring printed copies of multiple articles may use Elsevier WebShop's 'Create Your Own Book' service to collate multiple articles within a single cover (http://webshop.elsevier.com/myarticleservices/offprints/myarticlesservices/booklets).

The corresponding author, at no cost, will be provided with a personalized link providing 50 days free access to the final published version of the article on ScienceDirect. This link can also be used for sharing via email and social networks. For an extra charge, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier's WebShop (http://webshop.elsevier.com/myarticleservices/offprints). Authors requiring printed copies of multiple articles may use Elsevier WebShop's 'Create Your Own Book' service to collate multiple articles within a single cover (http://webshop.elsevier.com/myarticleservices/booklets).

Author Inquiries

You can track your submitted article at http://help.elsevier.com/app/answers/detail/a_id/89/p/8045/. You can track your accepted article at http://www.elsevier.com/trackarticle. You are also welcome to contact Customer Support via http://support.elsevier.com.