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Análise da energia de superfície de fios ortodônticos de diferentes ligas submetidas a exposição de ácidos

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Análise da energia de superfície de fios ortodônticos de diferentes ligas submetidas a exposição de ácidos

Dissertação apresentada à Faculdade de Odontologia de Araçatuba da Universidade Estadual Paulista "Júlio de Mesquita Filho" – UNESP, como parte dos requisitos para a obtenção do título de Mestre em Odontologia – Área de Ortodontia.

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Dedicatória

Dedico este trabalho

À minha mãe, Rosario

Pelo amor, paciência e torcida de sempre, nos momentos mais difíceis a família é o mais importante deste mundo.

Ao meu Pai, Manuel

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Epígrafe

“A verdadeira motivação vem de realização, desenvolvimento pessoal, satisfação no trabalho e reconhecimento.”

(Frederick Herzberg)

Resumo

ADRIAZOLA IQUE, M. **Análise de energia de superfície de fios ortodônticos de diferentes ligas submetidas a exposição de ácidos.** 2019. Dissertação (Mestrado em Odontologia, área de Ortodontia) - Faculdade de Odontologia de Araçatuba, Universidade Estadual Paulista, Araçatuba, 2019.

Resumo

O objetivo deste estudo foi avaliar *in vitro* a energia de superfície livre e rugosidade de superficie de ligas metálicas sob desafios de soluções ácidas. Para o estudo foram utilizados 270 corpos de prova representados por segmentos de fios retangulares de 0,019" x 0,025" - 3 marcas comerciais (GAC, American Orthodontics e Orthoclassic) foram divididas em 3 grupos de diferentes soluções sendo 90 para água deionizada, 90 para ácido cítrico e 90 para ácido fosfórico, dentro dos grupos de solução dividiu-se em 30 de aço inoxidável, 30 de níquel titânio e 30 titânio molibdênio. Cada grupo de análise (n=10) foi imerso em meio a cada solução por 72 horas a 37º C e agitação de 130 rpm. A análise de ESL foi avaliada através do dispositivo goniômetro para interpretação do ângulo de contato avaliando a variável. As médias foram submetidas ao teste ANOVA e as comparações ao Tukey a 5% de significância. A superfície da liga de TMA apresentou maior valor de energia de superfície ($p<0,001$). Concluiu-se que a liga de TMA apresentou maior energia de superfície e o desafio de ácido cítrico provocou as maiores alterações.

Palavras Chave: Fios, ácidos, adsorção, energia livre de superfície.

Abstract

ADRIAZOLA, M. **Surface energy analysis of orthodontic wires from different alloys subjected to acid exposure.** 2019. Dissertação (Mestrado em Odontologia, área de Ortodontia) - Faculdade de Odontologia de Araçatuba, Universidade Estadual Paulista, Araçatuba, 2019.

Abstract

The objective of this study was to evaluate in vitro the free surface energy and surface roughness of metallic alloys under challenges of acid solutions. For the study, 270 pieces represented by 0.019 "x 0.025" rectangular strands were used - 3 commercial brands (GAC, American Orthodontics and Orthoclassic) were divided into 3 groups of different solutions, 90 for deionized water, 90 for acid citric acid and 90 to phosphoric acid, within the solution groups was divided into 30 stainless steel, 30 nickel titanium and 30 titanium molybdenum. Each assay group (n = 10) was immersed in each solution medium for 72 hours at 37 ° C and shaking at 130 rpm. The ESL analysis was evaluated through the goniometer device for the interpretation of the contact angle evaluating the variable. The means were submitted to the ANOVA test and the Tukey comparisons at 5% significance. The surface of the TMA alloy had a higher surface energy value ($p < 0.001$). It was concluded that the TMA alloy presented higher surface energy and the citric acid challenge caused the greatest changes.

Keywords: Wires, acid, adsorption, surface free energy.

Lista de Tabelas

LISTA DE TABELAS

Lista de Abreviaturas

Lista de Abreviaturas

ANOVA	Analise de variância
LWAB	Equação Ácido-base Lifhitz vander-Walls
µL	Microlitros
γ^+	Componente receptor
γ^-	Componente doador
γ^{LW}	Componente van der Walls
γ^{AB}	Componente Ácido-Base de Lewis
γ^L	Energia livre de Superfície Total
γ^S	Energia de Superfície

Sumário

SUMÁRIO

Análise da energia de superfície de fios ortodônticos de diferentes ligas submetidas a exposição de ácidos

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*De acordo com as instruções aos autores do periódico Dental Materials

1 –INTRODUÇÃO

A movimentação dentaria induzida por forças ortodônticas é o resultado de uma cascata de eventos biológicos em resposta ao estímulo gerado por vários componentes do aparelho ortodôntico, entre eles: elásticos, molas e fios. [22][23]

Por meio dos fios ortodônticos, o ortodontista é capaz de realizar movimentos de alinhamento e nivelamento, para os quais a flexibilidade e o módulo de elasticidade são características fundamentais; também e capaz de realizar retrações dentárias e fechamento de espaços para os quais a rigidez e o polimento da superfície dos fios tornam-se as propriedades mais importantes. [26]

Para a escolha do fio mais adequado para cada fase do tratamento ortodôntico, o ortodontista elabora um raciocínio considerando os seguintes fatores: objetivos do tratamento, flexibilidade ou rigidez do fio, formabilidade ou soldabilidade do fio, entre outras propriedades bem documentadas na literatura especializada. [8][29]

Especificamente para a fase de final de nivelamento e retração anterior, os fios retangulares são recomendados devido, entre outras propriedades, ao encaixe quase que completo na canaleta dos braquetes. Para a retração anterior, o contato entre o fio e a canaleta geram um elemento denominado de atrito.[5][30]

O atrito é um fator intrínseco da mecânica ortodôntica em quanto maior a sua expressão, maior será a necessidade de forças com magnitude superior à sua resistência, o que por sua vez provoca efeitos colaterais na mecânica ortodôntica e nas respostas biológicas relacionadas com estas forças. [1][30]

Um dos meios de reduzir o efeito do atrito é um alinhamento perfeito entre todas as canaletas dos braquetes, associado a utilização de fios com alta qualidade de polimento. Os fabricantes de fios percebem que este polimento é um desafio constante e muitos avanços nesta área foram alcançados.[3][35]

Um dos métodos utilizados para análise da superfície de corpos sólidos submetidos a desafios provocados por soluções ácidas é a análise da energia de superfície livre (ESL). A ESL indica a interação entre as forças de coesão e adesão e determina a capacidade de molhamento de um sólido, sendo mensurada pelo ângulo de contato formado entre o sistema sólido/líquido, esta referência é relacionada com a tensão superficial já que é difícil diferenciar o trabalho necessário para aumentar o tamanho da superfície do trabalho de deformação por medição.[7] Podemos definir que a ESL é o trabalho que tem que ser gasto para aumentar o tamanho da superfície de uma fase é referido como a energia livre da superfície. [10][36]

Em situações cotidianas de pacientes que ingerem bebidas ácidas e estão em tratamento ortodôntico, com uso de fios retangulares, o efeito que estas bebidas provocam sobre a superfície dos fios, e consequentemente sobre uma possível redução do polimento superficial permanece uma dúvida pouca explorada em estudos científicos.[4][6]

Portanto, o objetivo deste trabalho é avaliar a característica da superfície dos fios ortodônticos submetidos a bebidas ácidas, tendo como meio de estudo as alterações da energia de superfície.

Material e Métodos

2 - MATERIAL E MÉTODOS

2.1 - Material

2.1.1 – Fios

Para a realização deste trabalho foram utilizados fios ortodônticos metálicos todos com formato retangular e secção transversal de 0,019” x 0,025”. As ligas utilizadas foram o aço inoxidável, níquel titânio e titânio molibdênio. Os fios utilizados de acordo com as ligas e marcasforam: 1)fio de aço inoxidável American Orthodontics (Sheboygan, WI, EUA, Stainless Steel StraightWire, código 856-011), 2) fio de aço inoxidável Dentsply (Bohemia, NY, EUA, Stainless Steel, código 03-925-68), 3) fio de aço inoxidável Orthoclassic (Mc Minnville, OR, EUA, Stainless Steel StraightWire, código 40.40.880.01925), 4) fio de níquel titânio American Orthodontics (Sheboygan, WI, EUA, NiTi Memory Wire, código 858-546), 5) fio de níquel titânio Denstply(Bohemia, NY, EUA, Bio Force Nickel Titanium, código 02-528-061), 6) fio de níquel titânio Orthoclassic (McMinnville, OR, USA, Nickel Titanium Archwire, código 61.40.720.19250), 7) fio de titânio molibdênio American Orthodontics (Sheboygan, WI, EUA, Beta TitaniumStraightWire, 857-699SP), 8) fio de titânio molibdênio Dentsply (Bohemia, NY, EUA, Resolve Beta Titanium, código 03-925-99), 9) fio de titânio molibdênio Orthoclassic (McMinnville, OR, EUA, Beta Titanium StraightWire, código 40.40.870.01925).

2.1.2 – Soluções

Para a análise da ESL foram utilizadas as seguintes soluções: 1) solução de ácido cítrico pH 3,2; 2) solução de ácido fosfórico pH 2.5. Todas as soluções foram preparadas de acordo com os protocolos estabelecidos para preparação,

no laboratório experimental da Disciplina de Odontopediatria da Faculdade de Odontologia de Araçatuba-UNESP.

2.2 – MÉTODOS

2.2.1 – Tratamento experimental dos fios

Para o tratamento experimental foi utilizado um segmento de fio com 10mm de comprimento. Para obter uma superfície isenta de detritos os segmentos de fio foram submetidos a limpeza inicial por meio de um aparelho de ultrassom (Unique USC 1400, Indaiatuba, SP, Brasil) calibrado com frequência de 40Hz em água deionizada, durante 20 minutos, e após a limpeza cada segmento de fio foi acomodado num microtubo de PCR (Axygen, MCT-200-C, Union City, CA, USA).

2.2.2 – Formação dos grupos

Para a execução do procedimento experimental os segmentos de fio foram organizados em grupos com a seguinte descrição:

Grupo 1(Controle) composto por 9 segmentos de fio sendo 3 de cada tipo de liga, e para cada liga um segmento de cada marca, que foram imersos num recipiente (microtubo de PCR – Axygen) com 1,5mL de água deionizada e permaneceram submersos por um tempo de 72 horas. Estes recipientes foram colocados no interior de uma incubadora com agitação orbital (Tecnal, TE-420, Piracicaba, SP, Brasil) regulada em 130 rpm e a 37ºC e seguir as amostras foram lavadas com água deionizada por 15 segundos e secas com papel toalha.

Grupo 2(Controle) composto por 9 segmentos de fio sendo 3 de cada tipo de liga, e para cada liga um segmento de cada marca, que foram imersos num recipiente (microtubo de PCR – Axygen) com 1,5mL de ácido cítrico e permaneceram submersos por um tempo de 72 horas. Estes recipientes foram

colocados no interior de uma incubadora com agitação orbital (Tecnal, TE-420, Piracicaba, SP, Brasil) regulado em 130 rpm e a 37º C e seguir as amostras foram lavadas com água deionizada por 15 segundos e secas com papel toalha.

Grupo 3(Controle)composto por 9 segmentos de fio sendo 3 de cada tipo de liga, e para cada liga um segmento de cada marca, que foram imersos num recipiente (microtubo de PCR – Axygen) com 1,5mL de ácido fosfórico e permaneceram submersos por um tempo de 72 horas. Estes recipientes foram colocados no interior de uma incubadora com agitação orbital (Tecnal, TE-420, Piracicaba, SP, Brasil) regulado em 130 rpm e a 37º C e seguir as amostras foram lavadas com água deionizada por 15 segundos e secas com papel toalha.

Grupo 4(Água deionizada) composto por 90 segmentos de fio sendo 30 de cada tipo de liga, e 10 segmentos de cada marca analisada por liga. Estes segmentos foram imersos num recipiente (microtubo de PCR – Axygen) com 1,5mL de água deionizada e permaneceram submersos por um tempo de 72 horas. Estes recipientes foram colocados no interior de uma incubadora com agitação orbital (Tecnal, TE-420, Piracicaba, SP, Brasil) regulado em 130 rpm e a 37º C e seguir as amostras foram lavadas com água deionizada por 15 segundos e secas com papel toalha.

Grupo 5(Ácido cítrico) composto por 90 segmentos de fio sendo 30 de cada tipo de liga, e 10 segmentos de cada marca que foram imersos num recipiente (microtubo de PCR – Axygen) com 1,5mL de ácido cítrico e permaneceram submersos por um tempo de 72 horas. Estes recipientes foram colocados no interior de uma incubadora com agitação orbital (Tecnal, TE-420, Piracicaba, SP, Brasil) regulado em 130 rpm e a 37º C e seguir as amostras foram lavadas com água deionizada por 15 segundos e secas com papel toalha.

Grupo 6(Ácido fosfórico) composto por 90 segmentos de fio sendo 30 de cada tipo de liga, e 10 segmentos de cada marca que serão imersos num recipiente (microtubo de PCR – Axygen) com 1,5mL de ácido fosfórico e permaneceram submersos por um tempo de 72 horas. Estes recipientes foram colocados no interior de uma incubadora com agitação orbital (Tecnal, TE-420, Piracicaba, SP, Brasil) regulado em 130 rpm e a 37º C e seguir as amostras foram lavadas com água deionizada por 15 segundos e secas com papel toalha.

2.2.3 – Análise da ESL

Após a secagem, cada segmento de fio foi posicionado numa plataforma da área de trabalho de um aparelho denominado de goniômetro (DSA100S, KRÜSS GMBH, Borsteler Chaussee 85-99a, 22453 Hamburgo, Alemanha). Este goniômetro possui 3 sondas e no interior de cada uma delas existe um líquido: sonda 1 água deionizada(apolar), sonda 2 etilenoglicol (polar) e na sonda 3 diiodometano (polar com componente ácido e base) que foram dispensados sobre o segmento do fio em forma de gota.[33]

A análise da ESL (γ_s) foi realizada pela interpretação do ângulo de contato (AC), que é o ângulo formado entre as superfícies laterais da gota originada das sondas e a superfície do segmento de fio. O goniômetro obtém uma imagem que pode ser capturada e mensurada com precisão. O resultado final da ESL foi a soma dos ângulos obtidos com os três líquidos gotejados.[34][24]

Para a determinação do ângulo de contato um volume de 0,3µL de cada líquido foi dispensado sobre cada segmento de fio(amostra). O ângulo de contato foi mensurado 5 vezes a partir de imagens capturadas pela câmera CCD do goniômetro, quando o movimento observável estiver cessado, a uma temperatura de 23º C.

Os parâmetros de γ^{LW} e γ^{Ab} e os componentes ácido (γ^{+}, componente receptor) e base (γ^{-} componente doador) da energia livre de superfície (mN/m), foram calculados de acordo com o modelo de van Oss, Chaudhery e Good para determinação da energia livre de interação dos substratos. [17][33][34]

2.2.4 –Análise Estatística

Os resultados foram analisados estatisticamente considerando como fatores de variação o tipo de liga e os meios de exposição. As variáveis analisadas foram a energia livre de superfície e energia de superfície. Os dados foram submetidos aos testes de normalidade para aplicar a análise estatística mais adequada à distribuição dos dados. Todas as análises foram realizadas com o programa SigmaPlot versão 12.0 com limite de significância de 5%.

Resultados

3–RESULTADOS

As médias, desvios padrão e as comparações estão apresentadas na tabela 1. Letras minúsculas distintas indicam diferença entre as médias considerando a interação tipo de liga e meio de imersão para cada marca comercial e variável (Two Way Analysis of Variance, Student-Newman-Keuls Method, $p<0.001$). Letras maiúsculas distintas indicam diferença entre a mesma variável comparando as marcas comerciais (Two Way Analysis of Variance, Student - Newman-Keuls Method, $p<0.001$).

3.1 Marca Comercial versus soluções

3.1.1 Marca comercial versus água deionizada

Considerando a marca comercial imersa em água, as comparações entre as médias obtidas, apresentaram os seguintes resultados: (1) as marcas apresentaram diferentes valores de γ_s ($p<0,001$); (2) GAC e OC não diferem para γ_s^{LW} ($P=0,756$) que diferiram da marca AO ($p<0,001$); (3) as marcas OC e AO não apresentaram diferença para os valores de γ_s^{AB} ($p=0,616$), γ_s^- ($p=0,119$) e ΔG_{sws} ($p=0,326$), diferindo da marca GAC ($p<0,001$); e (4) não houve diferença entre as marcas comerciais para γ_s^+ ($p=0,303$). As médias, desvios padrão e as comparações estão apresentadas na tabela 1.

3.1.2 Marca comercial versus ácido fosfórico

Em ácido fosfórico: (1) marcas OC e AO não diferiram entre si para os valores de γ_s ($p=0,295$) e γ_s^{AB} ($p=0,113$), porém foram diferentes da marca GAC ($p<0,001$) e (2) as marcas apresentaram diferença para os valores de γ_s^{LW}, γ_s^+, γ_s^- e ΔG_{sws} ($p<0,001$). As médias, desvios padrão e as comparações estão apresentadas na tabela 1.

3.1.3 Marca comercial versus ácido cítrico

A imersão em ácido cítrico: (1) marcas OC e AO não diferiram entre si para os valores de γ_s^{AB} (p=0,915) e γ_s^+ (p=0,174), porém foram diferentes da marca GAC (p<0,001); (2) as marcas apresentaram diferença entre si para os valores de γ_s, γ_s^- e ΔG_{sws} (p<0,001); e (3) GAC e AO não diferiram para os valores de γ_s^{LW} (p=0,996) e apresentaram-se diferentes da marca OC (p=0,002). As médias, desvios padrão e as comparações estão apresentadas na tabela 1.

3.2 Ligas Metálicas versus soluções

3.2.1 Ligas metálicas versus água deionizada

Considerando a marca comercial imerso em água: (1) as marcas apresentaram diferentes valores de γ_s (p<0,001); (2) GAC e OC não diferem para γ_s^{LW} (P=0,756) que diferiram da marca AO (p<0,001); (3) as marcas OC e AO não apresentaram diferença para os valores de γ_s^{AB} (p=0,616), γ_s^- (p=0,119) e ΔG_{sws} (p=0,326), diferindo da marca GAC (p<0,001); e (4) não houve diferença entre as marcas comerciais para γ_s^+ (p=0,303).

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valores de γ_s, γ_s^- e ΔG_{sws} (p<0,001); e (3) GAC e AO não diferiram para os valores de γ_s^{LW} (p=0,996) e apresentaram-se diferentes da marca OC (p=0,002).

Tabela 1. Valores médios (SD) da energia livre de superfície (γ_s), energia apolar (γ_s^{LW}) e energia polar (γ_s^{AB}) de fios retangulares de acordo com marca comercial, tipo de liga metálica e desafio (n=10)

Desafio	Liga	GAC (mN/m)			OC (mN/m)			AO (mN/m)		
		γ_s	γ_s^{LW}	γ_s^{AB}	γ_s	γ_s^{LW}	γ_s^{AB}	γ_s	γ_s^{LW}	γ_s^{AB}
Água	Aço	26,5^{a,A} (1,4)	28,9^{a,A} (1,2)	-2,4^{a,A} (0,6)	25,7^{a,A,B} (1,3)	27,4^{a,B} (0,8)	-1,7^{a,A} (1,1)	25,0^{a,B} (1,8)	28,7^{a,A} (1,9)	-3,7^{a,B} (1,7)
	NiTi	29,3^{b,A} (1,1)	27,8^{a,A} (0,8)	1,5^{b,A} (0,5)	27,0^{b,B} (0,7)	27,7^{a,A} (0,8)	-0,7^{b,B} (0,4)	30,1^{b,A} (0,9)	29,0^{a,A} (0,7)	1,2^{b,A} (0,7)
	TMA	31,8^{c,A} (1,4)	30,4^{b,A} (1,4)	1,4^{b,A} (0,6)	32,2^{c,A} (1,6)	31,7^{b,B} (1,5)	0,5^{c,B} (0,1)	34,5^{c,B} (1,2)	33,7^{b,C} (1,5)	0,9^{b,A,B} (0,1)
Fosfórico	Aço	28,9^{b,A} (1,6)	32,6^{c,A} (1,2)	-3,7^{a,A} (1,3)	28,8^{d,A} (0,8)	27,8^{a,B} (1,1)	1,0^{c,B} (0,3)	27,8^{d,A} (2,0)	26,3^{c,C} (2,0)	1,5^{b,B} (0,6)
	NiTi	32,0^{c,A} (2,0)	31,2^{d,A} (1,1)	1,4^{b,A} (0,8)	29,1^{d,B} (1,8)	26,8^{a,B} (1,0)	2,5^{d,B} (0,9)	30,8^{b,A} (1,3)	32,1^{d,A} (0,8)	-1,3^{c,C} (0,8)
	TMA	26,6^{a,A} (1,7)	37,3^{e,A} (1,6)	-11,2^{c,A} (3,2)	38,0^{e,B} (1,3)	35,7^{c,B} (1,8)	2,3^{d,B} (0,6)	38,7^{e,B} (2,2)	34,7^{b,B} (1,7)	4,0^{d,C} (0,6)
Cítrico	Aço	8.8^{d,A} (2.3)	28.5^{a,A} (1.8)	-19.7^{d,A} (2.6)	29,9^{d,B} (0,9)	29,4^{d,A} (1,1)	0,6^{c,B} (0,4)	29,9^{b,B} (0,5)	28,8^{a,A} (0,7)	1,1^{b,B} (0,5)
	NiTi	30.4^{b,A} (1.6)	29.0^{a,A} (1.6)	1.4^{b,A} (0.7)	30,4^{f,A} (0,7)	29,0^{d,A} (0,6)	1,4^{e,A} (0,5)	26,7^{a,B} (0,6)	28,6^{a,A} (0,8)	-1,8^{c,B} (0,6)
	TMA	17.0^{e,A} (1.2)	29.6^{a,b,A} (1.1)	-12.6^{c,A} (1.9)	34,0^{g,B} (1,9)	31,8^{b,B} (1,9)	2,1^{d,B} (0,9)	34,5^{c,B} (1,6)	29,7^{a,A} (1,1)	4,8^{e,C} (1,1)

Considerando as ligas metálicas imersas em água: (1) a liga TMA apresentou maior valor de γ_s e γ_s^{LW} seguido pelo NiTi e Aço (p<0,001); NiTi e TMA que não diferiram (p=0,223) e apresentaram maiores valores de γ_s^{AB} comparado ao Aço (p<0,001); Aço e TMA não diferiram (p=0,222) e apresentaram maiores valores comparados ao NiTi (p<0,001) para γ_s^+; a γ_s^- não diferiu entre as ligas (p<0,050); ΔG_{sws}<0 para todas as ligas. Quando imersas em ácido fosfórico: (2) o NiTi>Aço>TMA (marca GAC) e TMA>NiTI>Aço (marcas OC

e AO) para valores de γ_s e γ_s^{AB} ($p<0,001$); TMA apresentou maior γ_s^{LW} e γ_s^+seguido do Aço e NiTi ($p<0,001$); para γ_s^- TMA>Aço>NiTi (GAC) e NiTi>TMA>Aço (OC e AO) ($p<0,001$); $\Delta G_{sws}<0$ para todas as ligas sendo NiTi<Aço<TMA da marca GAC e Aço<TMA<NiTi das marcas OC e AO ($p<0,001$). Em ácido cítrico: a γ_s foi maior para o fio NiTi da marca GAC e o TMA para as marcas OC e AO, seguidos dos demais fios ($p<0,001$); NiTi da marca GAC apresentou maior valor de γ_s^{AB} e o TMA para as marcas OC e AO ($p<0,001$); a γ_s^{LW} não diferiu entre as ligas ($p<0,050$); a γ_s^+ e γ_s^- para marca GAC foi Aço>TMA>NiTi e para as marcas OC e AO TMA>NiTi>Aço ($p<0,001$); $\Delta G_{sws}>0$ para Aço e TMA da marca GAC ($p=0,457$) e TMA da marca AO, e $\Delta G_{sws}<0$ para marca OC Aço<NiTi<TMA e para a marca AO Aço<NiTi ($p<0,001$). Demais comparações estão descritas nas Tabelas 1 e 2.

Tabela 2. Valores médios (SD) dos sítios receptores de elétrons (γ_s^+) e doadores de elétrons (γ_s^-) da energia polar (γ_s^{AB}) e energia livre de interação (ΔG_{sws}) de fios retangulares de acordo com marca comercial, tipo de liga metálica e desafio (n=10)

Desafio	Liga	GAC (mN/m)			OC (mN/m)			AO (mN/m)		
		γ_s^+	γ_s^-	ΔG_{sws}	γ_s^+	γ_s^-	ΔG_{sws}	γ_s^+	γ_s^-	ΔG_{sws}
Água	Aço	$0,5^{a,A}$ (0,2)	$4,1^{a,A}$ (0,7)	$-54,2^{a,A}$ (4,7)	$0,2^{a,A}$ (0,2)	$3,3^{a,B}$ (1,2)	$-61,3^{a,B}$ (9,0)	$0,8^{a,B}$ (0,8)	$2,9^{a,B,A}$ (0,9)	$-59,2^{a,B,A}$ (9,0)
	NiTi	$0,2^{a,b,A}$ (0,3)	$3,9^{a,A}$ (1,0)	$-57,7^{a,b,A}$ (4,1)	$0,1^{b,A}$ (0,1)	$4,8^{b,B}$ (1,2)	$-57,1^{a,A}$ (5,2)	$0,1^{b,A}$ (0,1)	$5,9^{b,C}$ (1,5)	$-52,7^{b,A}$ (5,9)
	TMA	$0,1^{b,A}$ (0,1)	$4,2^{a,A}$ (0,9)	$-59,4^{b,A}$ (4,5)	$0,8^{c,B}$ (0,2)	$0,3^{c,B}$ (0,2)	$-77,3^{b,B}$ (3,2)	$0,3^{b,A}$ (0,1)	$1,4^{c,B}$ (0,8)	$-79,0^{c,B}$ (8,6)
Fosfórico	Aço	$0,3^{a,b,A}$ (0,3)	$15,6^{b,A}$ (1,8)	$-22,5^{c,A}$ (4,3)	$0,2^{a,A}$ (0,2)	$1,5^{d,B}$ (0,7)	$-72,2^{c,B}$ (4,5)	$0,3^{b,A}$ (0,3)	$2,9^{a,C}$ (1,1)	$-63,1^{a,C}$ (4,1)
	NiTi	$0,2^{b,A}$ (0,2)	$4,2^{a,A}$ (1,3)	$-58,5^{b,A}$ (4,4)	$0,1^{b,A}$ (0,1)	$19,4^{e,B}$ (1,7)	$-12,9^{d,B}$ (3,8)	$0,1^{b,A}$ (0,1)	$11,9^{d,C}$ (2,2)	$-33,2^{d,C}$ (6,7)
	TMA	$1,3^{c,A}$ (0,7)	$23,9^{c,A}$ (1,8)	$-6,8^{d,A}$ (2,6)	$0,3^{a,B}$ (0,3)	$4,0^{b,B}$ (0,8)	$-59,6^{a,B}$ (3,5)	$0,9^{a,C}$ (0,3)	$4,8^{e,B}$ (1,1)	$-49,8^{b,C}$ (3,0)
Cítrico	Aço	$2.1^{d,A}$ (0.5)	$45.6^{d,A}$ (4.3)	$23.5^{e,A}$ (4.8)	$0,1^{b,B}$ (0,1)	$1,7^{d,B}$ (0,3)	$-73,8^{c,B}$ (3,3)	$0,1^{b,B}$ (0,1)	$3,6^{a,C}$ (0,8)	$-61,6^{a,C}$ (3,8)
	NiTi	$0.1^{b,A}$ (0.1)	$10.8^{e,A}$ (2.9)	$-36.2^{f,A}$ (8.4)	$0,1^{b,A}$ (0,1)	$5,8^{b,B}$ (1,4)	$-51,8^{e,B}$ (4,8)	$0,1^{b,A}$ (0,0)	$13,3^{f,C}$ (1,0)	$-27,8^{e,C}$ (2,8)
	TMA	$1.1^{c,A}$ (0.2)	$42.2^{f,A}$ (1.8)	$21.9^{e,A}$ (1.9)	$0,1^{b,B}$ (0,1)	$18,9^{e,B}$ (1,8)	$-15,4^{d,B}$ (4,0)	$0,3^{b,C}$ (0,1)	$29,9^{g,C}$ (1,3)	$2,7^{f,C}$ (4,9)

Letras minúsculas distintas indicam diferença entre as médias considerando a interação tipo de liga e meio de imersão para cada marca comercial e variável (Two Way Analysis of Variance, Student – Newman - Keuls Method, $p<0.001$). Letras maiúsculas distintas indicam diferença entre a mesma variável comparando as marcas comerciais (Two Way AnalysisofVariance, Student - Newman - Keuls Method, $p<0.001$).

Discussão

4 – DISCUSSÃO

O presente trabalho teve como objetivo analisar o comportamento da energia de superfície de fios ortodônticos, de diferentes ligas submetidos a três desafios sob controle laboratorial: água destilada (controle), ácido fosfórico (simulando coca cola) e ácido cítrico (simulando suco de laranja) [10][8][25].A energia de superfície em metais no estado sólido, tem como valor de referência 30 mN/m [14]. Na avaliação dos resultados considerou-se o seguinte raciocínio: quando a energia de superfície de uma liga for maior do que valor de referência, isto representa uma liga hidrofílica com grandes possibilidades de reações entre a liga e o meio bucal. [31] No presente trabalho pode-se considerar que todas as ligas estudadas apresentaram características hidrofóbicas, o que é uma propriedade considerada favorável. Desta forma consideraremos entre as ligas estudadas, o comportamento hidrofóbico.[9][11]

Após análise da variável γs sob desafio da água destilada, verificou-se que a liga de TMA é superior ao NiTi e este superior ao aço inoxidável. No aspecto clínico, uma liga com γs alto significa maior susceptibilidade para adesão de proteínas e biofilme, mais resíduos sobre o fio, maior resistência ao deslizamento. Como o desafio da água, no presente trabalho foi utilizado como controle, os resultados permitem a inferência de que, apesar de todas as suas qualidades, o fio TMA deve ser usado com muita cautela em pacientes com baixo controle de higiene bucal.[2][49]

Como elementos complementares à análise de energia livre foram analisados também γ^{LW} que indica a energia apolar representando a capacidade de reação da liga com substâncias derivadas do carbono bem como substâncias não iônicas.[12][13][15] Na tabela 1 verifica-se que o fio TMA apresenta os

maiores valores de Y^{LW} destacando a capacidade desta liga em reagir com o meio bucal. Ainda nesta linha de análise a variável Y^{AB} (energia polar) que também indica a predisposição da liga a receber ou doar elétrons e reagir com o meio bucal, o TMA também apresenta maiores valores. Na tabela 2 são apresentados os valores das variáveis γ^{s+} (capacidade da liga em receber elétrons), Ys- (capacidade da liga em doar elétrons) e a variável ΔG_{sws}, cujo valor negativo indica um comportamento hidrofóbico para a liga. Por meio desta avaliação o TMA apresentou um comportamento hidrofóbico em comparação ao NiTi e Aço, porém a sua capacidade de troca iônica com meio bucal analisado pela grandeza Ys- se mantem próxima do aço inoxidável bem como da liga de níquel titânio.[21]

Após análise da variável γ^{s} sob desafio do ácido fosfórico, verificou-se que a liga de TMA é superior ao NiTi e este superior ao aço inoxidável. Como elementos complementares a análise de energia livre, foram analisados também Y^{LW} que indica a energia apolar representando a capacidade de reação da liga com substancias derivadas do carbono bem como substancias não iônicas, na tabela 1 verifica-se que o fio TMA apresenta os maiores valores de γ^{LW} destacando a capacidade desta liga em reagir com o meio bucal. Ainda nesta linha de analise a variável γ^{AB} (energia polar) que também indica a predisposição da liga a receber ou doar elétrons e reagir com o meio bucal, o TMA também apresenta maiores valores.[20]

Na tabela 2 são apresentados os valores das variáveis γs+, γs- e ΔG_{sws}, cujo valor negativo indica um comportamento hidrofóbico para a liga. Por meio desta avaliação o TMA da marca GAC apresentou um comportamento com tendência hidrofílica em comparação ao NiTi e Aço, porém a sua capacidade de

troca iônica com meio bucal analisado pela grandeza γs- se mantem próxima do Aço inoxidável bem como da liga de níquel titânio.

Após análise da variável γ^s sob desafio de ácido cítrico, verificou-se que a liga de TMA das marcas OC e AO são superiores que do GAC. A análise das variáveis γ^{LW}, na tabela 1 verifica-se que o fio TMA apresenta os maiores valores de γ^{LW}. Ainda nesta linha de analise a variável γ^{AB} (energia polar), o TMA também apresenta maiores valores, so depois do fio de Aço da marca GAC.

Na tabela 2 são apresentados os valores das variáveis Ys+ (capacidade da liga em receber elétrons, γ^{s-} (capacidade da liga em doar elétrons) e a variável denominada ΔG_{sws}, cujo valor positivo indica um comportamento com tendência hidrofílica para a liga. Por meio desta avaliação o TMA da marca GAC apresentou um comportamento mais hidrofílico de todas as marcas e em comparação ao NiTi e Aço, porém a sua capacidade de troca iônica com meio bucal analisado pela grandeza γ^{s-} se mantem próxima do Aço inoxidável bem como da liga de Níquel Titánio. [18][19]

Avaliando a energia de superfície das ligas, todas tem uma característica hidrofóbica, no qual está dentro dos padrões ideais de um fio, relacionando também que tem menor rugosidade, para confirmar o grau de hidrofobia, se avalia também os valores doadores de elétrons, sendo o valor menor que 28,5 mN/m. [16][28][32]

Conclusões

5 – CONCLUSÕES

Diante as condições experimentais deste trabalho pode se concluir que: Todas as ligas analisadas apresentaram comportamento hidrofóbico, sendo o TMA a liga que apresentou o menor comportamento hidrofóbico, e sob o desafio com acido cítrico sofreu as maiores alterações.

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Anexos

Anexo A: Preparo dos fios

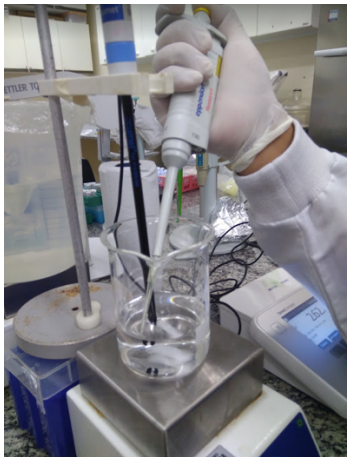
Ativação da maquina ultrassónica

Fios submetidos a limpeza ultrassónica

Secagem das amostras

Anexo B: Formulações das soluções de tratamento

Preparo das soluções

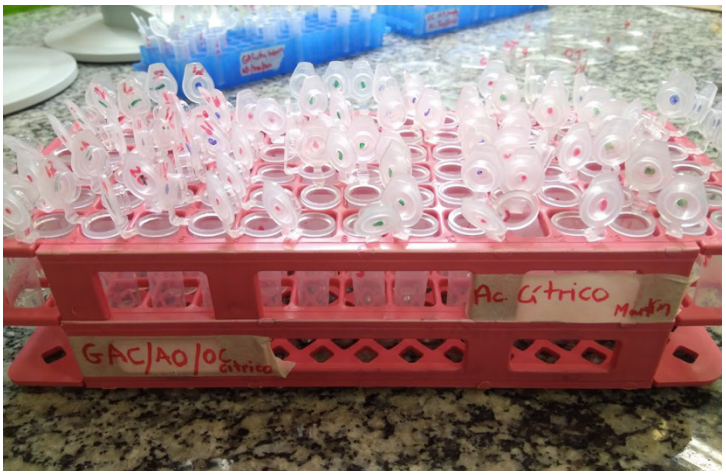


Dosagem para a preparação

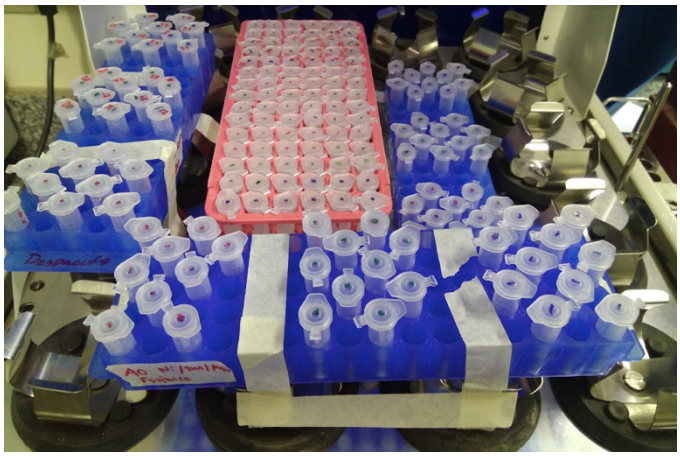
pH do Ácido fosfórico

pH do Ácido Cítrico

Anexo C: Tratamento dos fios com as soluções experimentais



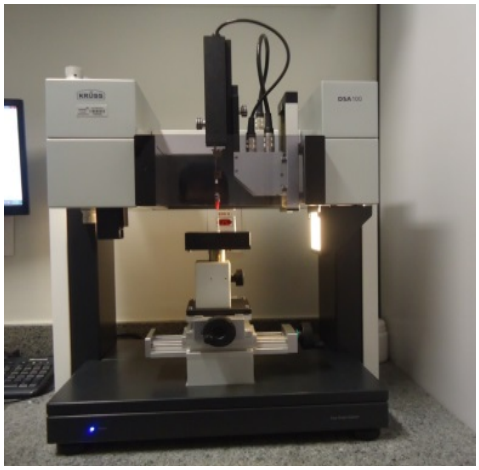
Fios organizados nos microtubos antes da colocar na agitadora



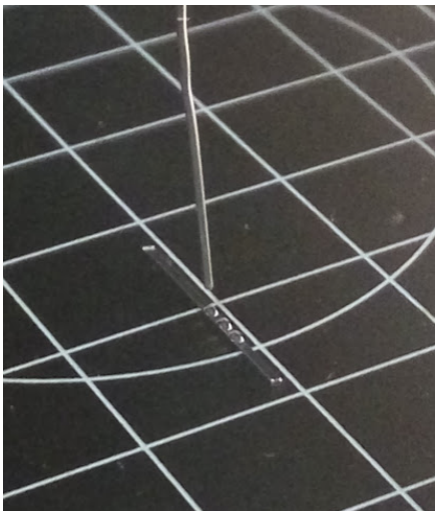
Microtubos colocados na agitadora

Configurações da agitadora: 37°C e 150 RPM

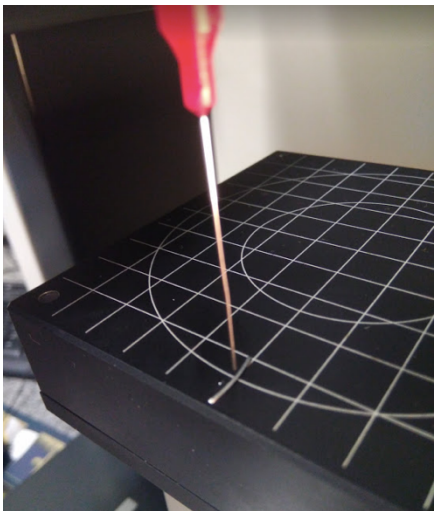
Anexo D: Análise da Energia de Superfície



Goniômetro Kruss DSA 100



Dosagem dos líquidos



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Anexo E: Guias de autor

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[2] Van der Geer J, Hanraads JAJ, Lupton RA. The art of writing a scientific article. Heliyon. 2018;19:e00205. https://doi.org/10.1016/j.heliyon.2018.e00205

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