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AVALIAÇÃO DA RESISTÊNCIA DA UNIÃO ADESIVA ENTRE DENTES ARTIFICIAIS E UMA RESINA ACRÍLICA PRÉ-POLIMERIZADAS PARA O SISTEMA CAD/CAM

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RESUMO

O objetivo da presente dissertação foi avaliar a resistência da união de dentes de resina acrílica à base da prótese total removível confeccionada pela técnica convencional e CAD/CAM.

No presente estudo, um teste de microtração foi realizado com uma máquina de teste universal, onde os materiais usados na construção de próteses totais removíveis foram testados. Foi avaliada a resistência à microtração de adesão de duas resinas acrílicas usadas para base de prótese, uma pré-polimerizada usada em sistemas CAD/CAM e outra por termopolimerização convencional juntamente com os dentes de resina acrílica pré-fabricados. Um total de 24 dentes molares artificiais foram preparados e divididos em 4 grupos (n = 6), de acordo com a resina utilizada e o tempo de armazenamento previo ao ensaio. A análise estatística foi realizada por meio de análise de variância de duas vias (ANOVA) com um nível de significância de 5% e um teste post hoc de Tukey. A resistência de união do acrílico com a polimerização ativada por calor aos dentes foi superior ao sistema CAD/CAM. A análise mostrou uma diferença estatisticamente significativa entre os grupos em relação ao tipo de material utilizado (resinas acrílicas convencionais polimerizadas em relação ao disco de resina acrílica CAD/CAM ($p = 0.001$).

Palavras-chave: CAD/CAM; prótese removível total; resina acrílica de prótese; resistência da união; termopolimerização

ABSTRACT

The aim of this thesis was to evaluate the bond strength between artificial resin teeth and the acrylic denture base made by the conventional technique and CAD/CAM.
In the present study, a microtensile bond strength test was performed with a universal test machine, where the materials used in the construction of removable complete dentures were tested. The microtensile bond strength of two PMMA acrylic resins used for the complete denture base was evaluated, one pre-polymerized used in CAD/CAM systems and another by conventional heat cure together with commercial available acrylic resin teeth. 24 artificial teeth were prepared and divided into 4 groups (n = 6). Two different acrylic resin and two storage time. Both species were evaluated immediately for their preparation and 2 groups aged and tested at 6 months. Statistical analysis was performed by a two-way ANOVA at 0.05 significance level with a post hoc Tukey test.

The bond strength of heat-polymerized acrylic was higher than CAD/CAM system. The analysis showed a significant statistical difference among the groups related to the type of material used (conventional heat-polymerized acrylic resins vs CAD/CAM acrylic resins disc ($p = 0.001$).

Key-words: CAD/CAM; complete denture; acrylic denture base; bonding strength; heat polymerization

SUMARIO

INTRODUÇÃO

A integração de um dos tratamentos mais antigos, como reabilitações com próteses totais removíveis, às técnicas de produção de computadores, é prova de que a odontologia tem abraçado a era digital. O Desenho Assistido por Computador / Manufatura Assistida por Computador (CAD/CAM) de próteses totais foi introduzido após o sucesso do CAD/CAM em outras áreas, como implantes e próteses fixas (BABA et al., 2016).

Em comparação com próteses processadas convencionalmente, as próteses produzidas por CAD/CAM oferecem alguns benefícios importantes: redução de monômero residual, melhoria das propriedades físicas da base de resina acrílica, redução do encolhimento da polimerização, redução no número de visitas de pacientes e adesão de Candida albicans à base da prótese. (CHEN et al., 2015; YAMAMOTO et al., 2014; YAMAMOTO et al 2016; BIDRA et al., 2013; STEINMASSL et al. 2017; KANAZAWA et al. 2011).

Em 2011, Kanazawa et al avaliaram o conceito de fabricação de uma prótese completa usando um sistema CAD/CAM (KANAZAWA et al. 2011). Goodacre et al publicaram o primeiro relato de tratamento clínico de paciente com prótese de CAD/CAM. (GOODACRE et al., 2012). Após terem sido desenhadas digitalmente, as próteses foram processadas a partir de um bloco de resina pré-polimerizada ao qual os dentes artificiais foram fixados com um agente adesivo nos orifícios criados na base protética. Desde então, eles foram transformados em um processo inovador totalmente digital.

A literatura atual também tem demonstrado os benefícios oferecidos pelas próteses CAD/CAM, como menor número de visitas dos pacientes, armazenamento de

arquivos digitais que permitem repetições fiéis de tratamentos, melhor adaptação da base da prótese e melhor retenção, citando apenas alguns fatores (GOODACRE et al.,2012; BABA et al., 2016; BIDRA et al., 2013; BIDRA et al., 2016).

Um estudo retrospectivo que avaliou as experiências de estudantes de graduação e pós-graduação em manufatura concluiu que ambos precisavam de uma média de 2,39 visitas para fabricar próteses digitais (SAPONARO et al., 2016). Os autores também relataram três tipos de complicações comuns: falta de retenção da prótese, dimensão vertical da oclusão inadequada e relação cêntrica incorreta. Na discussão do artigo, os autores indicaram que essas complicações poderiam estar relacionadas à técnica de fabricação de CAD/CAM.

Poucos estudos de laboratório compararam a distorção de processamento das técnicas tradicionais e a técnica de fabricação CAD/CAM (GOODACRE et al., 2016; SRINIVASAN et al., 2017; STEINMASSL et al., 2018).

Os resultados do estudo de laboratório da Goodacre indicam que a técnica de processamento CAD/CAM oferece um grau mínimo de distorção durante a fabricação e melhor adaptação. Eles encontraram que o processo CAD/CAM é a técnica de fabricação de próteses mais precisa e reprodutível em comparação com as técnicas tradicionais (GOODACRE et al., 2016).

Srinivasan em seu estudo comparativo concluiu que a precisão da superfície interna das três técnicas investigadas parece permanecer dentro de uma faixa clinicamente aceitável, eles relataram que o grupo CAD/CAM mostrou a compressão mais forte (com exceção das tuberosidades), principalmente na área da flange vestibular (SRINIVASAN et al., 2017).

Tendo detectado a ausência de publicações ligadas à fixação dos dentes nas bases das próteses de CAD/CAM e levando em conta que este problema é frequente nas técnicas convencionais (COLEBECK et al., 2015) é que propusemos o desenvolvimento do seguinte estudo.

OBJETIVO

Com base no exposto, o objetivo da presente dissertação foi comparar a resistência da união de dentes de resina acrílica à base da prótese total removível confeccionada pela técnica convencional e CAD/CAM.

MANUSCRITO

A presente dissertação é composta por um manuscrito fomatado para a submissão para *Journal of Prosthodontic Reseacrh.*

MANUSCRITO

Evaluation the microtensile Bond strength between artificial teeth to PMMA acrylics dentures bases used in different systems

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Abstract

Purpose: To evaluate the microtensile bond strength of two PMMA acrylic resins used in removable denture base to artificial acrylic resin teeth: a pre-polymerized acrylic resin used in CAD/CAM systems and heat-polymerization acrylic resins.

Methods: 24 artificial molar teeth were divided in four groups (n=6) for each one of the two acrylic resins denture bases and two storage times,. Each set of denture bases with its bonded acrylic tooth, was sectioned perpendicular to the bonded interface, using a micro cutting machine to obtain regular specimens, with a transversal area of 1mm^2. The aged groups were kept in distilled water during 6 months at 37°C. The bond strength was made by using a universal test machine with a cruise speed of 1mm/min. The maximum force (N) was registered in the moment of failure of each specimen. The microtensile bond strength was calculated with the equation: R=F/A, R is the microtensile strength (MPa), F is the load required for the sample (N) failure, and A is the bond area (mm^2) of the specimens. The statistical analysis was made by the study of variance of two-way ANOVA to permit to analyze the results at a significant level of 0.05 with a post hoc test of Tukey.

Results: The bond strength of heat-polymerized acrylic was higher than CAD/CAM system. The analysis showed a significant statistical difference among the groups related to the type of material used (conventional heat-polymerized acrylic resins vs CAD/CAM acrylic resins disc (p= 0.001).

Conclusions:

The bond strength was higher in the heat-cured and conventional procedures groups with reference to the CAD/CAM pre-polymerized acrylic resins and bond agent groups.

Keywords: CAD/CAM; complete denture; acrylic denture bases; bonding strength; heat polymerization

Introduction

Technology assisted by a computer is an installed reality in Dentistry since last decade. It represents the most modern method to design, develop and produce all type of restorations and dental prosthesis. The publications that describe the utilization of this technology and the materials for the production of complete dentures have registered an important increase in the last years (1).

The use of CAD/CAM (Computer Aided Design - Computer Aided Manufacturing) technology for the manufacturing of complete dentures appliances allows to improve many aspects compared to the conventional techniques, as for example the possibilities of design, superior esthetic results, a better adjustment of the denture base to the tissues due to the absence of polymerization contraction caused by the use of blocks of acrylic resins pre-polymerized for milling, as well as reduced risk of having microorganisms (2) (3) (4) (5) (6).

There are different procedures and objectives to manufacture complete dentures using CAD/CAM technology. The procedures for obtaining digital images are useful to study, diagnose and design the different prosthodontic solutions. They can be used with the objective of obtaining and simplifying some main stages of the conventional procedures (obtaining models, impression trays, record rims and trial dentures) which allows to reduce the patients visits. A pure digital procedure can be obtained, starting from digital impressions arriving to the final stages through procedures directed exclusively by a computer (7).

The denture base and the artificial occlusion could be designed by the computer. Through different procedures CAD, trial dentures are obtained, which allows the restauration in the patient. Satisfied with what was obtained, the CAM stage begins,

through a milling strategy, pre-polymerized polymethilmethacrylate (PMMA) discs are milled until a denture base in pink acrylic with the cavities where the artificial teeth are placed. After the complete denture base is obtained, the artificial teeth are located to the base through bonding agents.

The PMMA acrylic resins have been used in prosthodontic since their introduction in 1937, and have been widely used due to the fact that they are easy to use, resistant and low cost (8). The conventional PMMA for denture base is generally supplied as liquid and powder. The liquid contains methacrylate monomer, while the powder contains PMMA pre-polymerized particles in the shape of small pearls. Once the liquid and powder are mixed, it is waited until the material reacts acquiring a handling plastic consistency and the material can be introduced inside the muffle with the desired shape for its polymerization (9).

There are different base materials that can be classified according to the activation method. The activation through heat, the most used method, is produced when the muffle is submerged in hot water for a specific time at a determined temperature indicated by the manufacturer. According to the manipulation methods of these materials, the molding by compression is the most used. But this can have errors as acrylic porosities, teeth movement and mismatches of the base to the tissue due to the polymerization contraction (9). This can result in dentures that frequently need to be adjusted after the procedure to guarantee an adequate support and occlusion.

The chemical bond between the artificial teeth and the base materials, especially those cured by heat, have been thoroughly studied (10). However, the manufacturers of teeth provide little or none information about the bond strength with the different acrylic systems that can be used. Debonding of the artificial teeth from the

dentures base has been one of the principle disadvantages of these materials (11) Colebeck (12) mentions the acrylic teeth debonding from the base as a frequent event in the prosthodontic practice, that implies between 22% to 30% of the repairs. Most of the authors belief that the failure of bonding of these materials is related to the contamination of the surfaces of the artificial tooth due to residual wax or means of separation used in an inadequate way (13) (14) (15) (16).

There are different procedures to bond artificial teeth to the acrylic resin denture base, such as the creation of macro retentions or even chemical activation, putting previously pure monomer on the contact surface of the artificial teeth. Although these teeth are industrially processed, the grade of polymerization is so high, and the presence of terminal groups with no reaction is reduced, the monomers that have not reacted to the denture base material that polymerizes in contact with artificial teeth is capable of generating new chemical links with the material already polymerized (17). With the use of CAD/CAM procedures described, the debonding of the teeth from the denture's base can be a clinic challenge to overcome due to two surfaces already polymerized that are in contact.

The aim of this study was evaluate the microtensile bond strength of two PMMA acrylic resins used in removable denture base (CAD/CAM systems and heat-polymerization acrylic resins) to artificial acrylic resin teeth.

Materials and Methods

2.1. Confection of samples

This study evaluated the bond strength of two techniques to produce acrylic dentures. One pre-polymerized acrylic resin (VIPI BLOCK PMMA®) and another one with heat-polymerization (VIPI CRIL PLUS®) were used. The materials used in this study are presented in Table 1.

Table 1. Materials used

Material	Composition
Artificial teeth (BIOLUX OMC®, Pirassununga - Sao Paulo - Brazil)	Polymethyl methacrylate combined with polymerized Ethylene glycol dimethacrylate and OMC (Organically Modified Ceramics)
PMMA discs for Dental CAD/CAM (VIPI BLOCK PMMA MONOCOLOR®, Pirassununga - Sao Paulo - Brazil)	PMMA Acrylic resins, biocompatible pigments and EDMA
Heat-polymerized acrylic for denture bases (VIPI CRIL PLUS®,Pirassununga - Sao Paulo - Brazil)	Powder: Methyl polymethyl methacrylate, Benzoyl peroxide and biocompatible pigments Liquid: Methyl methylmethacrylate, EDMA (Crosslink) and an unspecified inhibitor
Bonding agent (VITACOLL®, Bad Säckingen – Germany).	Methyl methacrylate and butanone

A total of 24 molar artificial teeth were randomly divided in 4 groups (AHP_{im}, AHP_{6m}, $ACAD_{im}$, $ACAD_{6m}$) with n=6 for each one. Each one of the denture´s base materials

were evaluated immediately after the preparation (AHP_{im} and $ACAD_{im}$), and the others after 6 months of their preparation (AHP_{6m} and $ACAD_{6m}$)

- Group AHP_{im}: Acrylic heat-polymerization (VIPI CRIL PLUS®) immediate test;
- Group AHP_{6m}: Acrylic heat-polymerization (VIPI CRIL PLUS®) aged tested after 6 months
- Group $ACAD_{im}$: Acrylic pre-polymerization CAD/CAM (VIPI BLOCK PMMA®) immediate tested;
- Group $ACAD_{6m}$: Acrylic pre-polymerization CAD/CAM (VIPI BLOCK PMMA®) tested after 6 months.

2.2 Teeth preparation

All teeth have their occlusal surface removed and, smoothed with a carbide disc. The bond surfaces were manually sandblasted by the same operator with a sequence of silicium carbide paper of 400, 600 and 800 for 10 seconds, before their bonding.

Teeth of all the groups were put in an ultrasonic unit during 10 minutes with distilled water, and afterwards dried at room temperature.

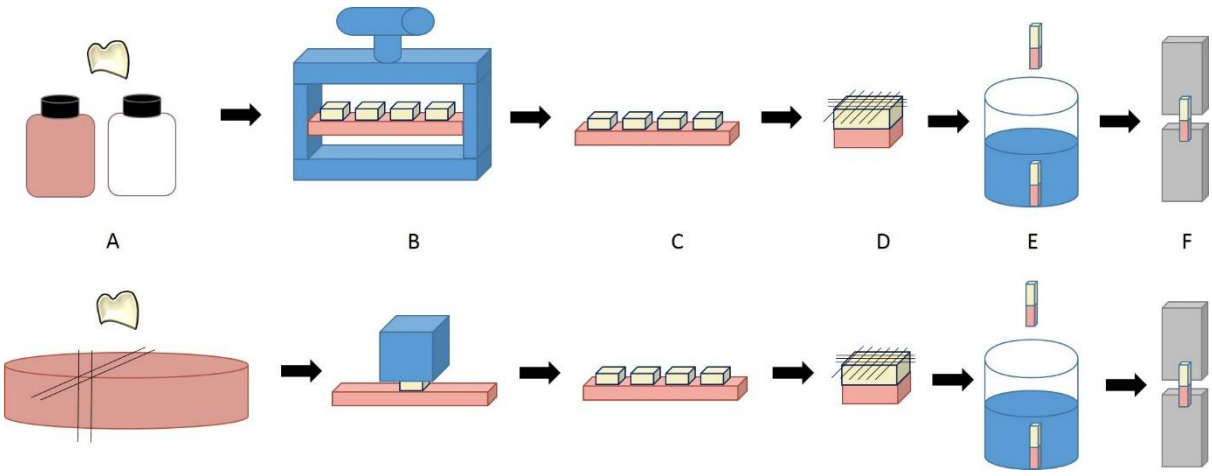

Fig. 1- Preparation of samples for the microtensile bond strength test. A. Artificial molar teeth, conventional heat cured acrylic and PMMA acrylic CAD/CAM disc preparation; B. Conventional muffle procedures and bonding teeth to acrylic CAD/CAM model; C and D Preparation of samples for the microtensile bond strength test; E Acrylic heat-polymerization immediately, aged Acrylic heat-polymerization, acrylic pre-polymerization CAD/CAM treated immediately and aged Acrylic pre-polymerizationCAD/ CAM; F Microtensile Bond Strength Test.

2.3 Preparation of acrylic denture base

The procedure method recommended by the manufacturer was used for the heat-polymerization denture base material (VIPI CRIL PLUS®). A polyvinylsiloxane matrix was filled with meltedwax to obtain a standardized block with the same dimensions. This model allowed the placement of the teeth and the processing of the acrylic in the muffle.

The muffles were heated up to 100°C during 5 minutes to eliminate the wax. The teeth were cleaned with REMOX®. The acrylic resin (VIPI CRIL PLUS®) was mixed according with the manufacturer's instructions (6.5 ml of monomer and 14 g of powder) and was left resting during 120 minutes. The monomer used in the acrylic preparation was applied on the contact surface teeth and later the acrylic resin was placed with the traditional method. This acrylic was cured during 30 minutes in water at 70°C, followed by 90 minutes at 100°C. The muffle was left at room temperature before proceeding to open it.

The PMMA acrylic CAD/CAM discs used (VIPI BLOCK MONOCOLOR) were cut with a diamond disc with irrigation to obtain acrylic models of 3 mm of height. The BIOLUX OMC teeth and the acrylic models (VIPI BLOCK MONOCOLOR) after being

cleaned and dried, were moistened with VITACOLL®, and placed one on top of the other, under the pressure of a body of 100 grams for 10 minutes for each tooth.

2.4 Preparation of samples for the microtensile bond strength test

Each set of acrylic denture base with its bonded acrylic teeth was cut perpendicular to the bonded surface, with a micro cutting machine (Gellings-hanco Hamco machines INC, Rochester New York, USA), refrigerated with water, and regular samples with a transversal media area of 1mm^2. The AHP6m and ACAD6m groups were kept in distilled water during 6 months at a constant temperature of 37°C.

2.5 Microtensile Bond Strength Test

Each test was realized individually using a microtensile device (JIG 1 Plus, Odeme Dental Research). The samples were fixed with cyanoacrylate bond and a universal material testing machine (SANS CMT 2000, Shen Zhen - China). Before the alignment in the holder, a digital caliper was used to measure the bond area (mm^2) of each sample. The maximum force of failure was registered (N).

The bonding strength was calculated using the following equation:

$$R = \frac{F}{A}$$

R is the microtensile strength (MPa),

F is the required load for the sample failure (N)

A is the interphase area (mm^2) of the samples.

Statistical Analysis

The statistical analysis was performed by two way - ANOVA at a significant level of 0.05 with a post hoc test of Tukey in the Sigma Stat 3.5® software.

Results

The bond strength values (MPa) of each group are shown in Table 2. The analysis showed a statistically significant difference between the groups according to denture base material used (conventional heat-polymerized acrylic resins vs CAD/CAM acrylic resins disc (p = 0.001). No statistical significant interaction was found between material and time. (p=0.397)

Table 2. Mean (standard deviation) of bond strength, in MPa, of different groups

Table 2. Microtensile strength (MPa)		
	Immediately	6 months
Heat cured	27.1 (6.9)^{Aa}	25.3 (4.4)^{Aa}
CAD/CAM	15.3 (4.4)^{Ba}	10.0 (2.5)^{Ba}

Different capital letter indicates significant difference in the same column ($p<0.05$). Different small letter indicates significant difference in the same line ($p<0.05$).

Discussion

Different techniques and materials are available to produce acrylic removable dentures. The majority of the artificial teeth of acrylic resin are based on PMMA, which are very similar to the ones used in the construction of denture base. The reticulation grade of the acrylic resins, that compose both prosthodontic materials are very important to obtain a correct bond between both of them (17).

Most of the studies that test the bond strength between the teeth and the acrylic resin have used shear or tensile tests (13). The bond strength test is designed in the ISO 22112 standard (18). The microtensile test traditionally used in studies that evaluate the bond strength between composite-adhesive-dentine can be applied in the same way to study the bond strength of the acrylic teeth with the denture acrylic base (19) (20). An advantage of this method is the capacity of controlling the bonding surface, allowing each sample to have standardized stress distribution. The development of a miniature tensile test method is associated with higher tensile strengths, while the larger surface areas show lower tensile strengths. According to Griffith's theory of defects, the tensile strength of a material decreases with increasing sample size. (21)

The use of heat cured acrylic resin involves manually mixing of the acrylic powder and liquid. On the other hand, the CAD/CAM acrylic discs for denture base are industrially manufactured (22) (23) and are cured with high temperature and pressure (24) (6). It is supposed that the resins for denture base are highly condensed and have less micro-porosities (24). This can mean that the CAD/CAM resin denture base could have superior mechanic and biological properties (25) (26).

Steinmassl (26) showed that the denture bases produced by CAD/CAM did not presented higher resistance to the fracture than the conventional technique. The denture base materials activated by heat are most used material for denture base production. (27)The heat can be provided by hot water or microwave, although there are other methods like chemical activation or physical curing (9).

In the case of the used resins in the CAD/CAM system, this difficulty seems not to exist as material that can contaminate the dental surface are not used (28). These systems have the challenge to bond two polymerized surfaces. There is no scientific literature published up to the present date that covers this issue, probably due to the recent introduction of the denture acrylic CAD/CAM.

The inconvenience of the teeth debonding has been studied for the traditional systems, and it has been proposed to use different substances conditioning the artificial teeth contact surface. (15) The studies that used the mechanic and chemical preparation of the dental surface that contact the denture base material have obtained different results. Some studies had contradictory results of strength when the teeth were treated with methyl methacrylate and or mechanically modified on their bond surface (29) (30) (31) Bond agents are commercially available to teeth attach to denture base, as Vitacoll®. Chittaranjan (32) and Saavedra (33) obtained more number of failures occurred in the control group as compared to the experimental group of thermopolymerization acrylic resin subjected to surface conditioning with Vitacoll.In March, 2017 Vita launched to the market the open system VITA VIONIC® (34) which contains all the materials for the production of CAD/CAM complete acrylic resin dentures, in which a specific adhesive is included, also based in methyl methacrylate for the bond of artificial teeth to acrylic bases to be used in this systems. There are no reports of investigations the *in vitro* or clinical behavior of this material. The higher bond

strength conventional procedures than to the CAD/CAM prepolymerized acrylic and bonding agent Vitacoll could anticipate a possible problem with the debonding teeth as a challenge to be resolved. The aging of both type of materials in distilled water at 37°C, during 6 months, didn't show a decrease in the bond strength as could have been expected. The time could have been insufficient to observe a significant statistical effect, considering that the samples stored in distilled water at 37º during 6 months have a more accelerated degradation. (35) (36)

In the present study, we found that the PMMA heat cured acrylic denture base showed significantly higher bond strength compared with acrylic CAD/CAM denture base.

Conclusions

The bond strength was higher in the heat-cured and conventional procedures groups than CAD/CAM prepolymerized acrylic resins and bond agent groups.

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CONSIDERAÇÕES FINAIS

No presente estudo foi avaliada a resistência de união produzida entre os dentes artificiais e as bases de PMMA com a técnica convencional e resina acrílica termopolimerizável e a base de PMMA para CAD/CAM. O desenvolvimento de materiais para uso em fluxos digitais, como resina de PMMA para CAD/CAM, vem ganhando interesse. Para que se promova novos tratamentos baseados em evidências científicas é necessário que se avalie esses novos materiais. A união dos dentes artificiais às bases de PMMA pré-polimerizadas e de suma importância para o desempenho clínicos das próteses odontológicas. Foi interesse nesse estudo conhecer e aprofundar o conhecimento sobre materiais e seu desempenho em sistemas CAD/CAM, depois de identificar possíveis dificuldades que possam surgir na aplicação desta modalidade de tratamento em Clínica de Reabilitação, Prótese Removível 1 e Gerodontologia da Faculdade de Odontologia da UdelaR.

Para o tratamento de desdentados totais, existem várias modalidades. Com o uso de implantes osseointegrados foram abertas novas possibilidades que melhoram substancialmente a função, conforto e, consequentemente, a qualidade de vida desses pacientes. Da mesma forma acontece com a odontologia digital. O estabelecimento de tecnologia assistida por computador representa um método moderno para o design, desenvolvimento e produção de todos os tipos de restaurações e próteses dentárias. As publicações que descrevem o uso desta tecnologia e os materiais utilizados registraram um aumento significativo nos últimos anos. Com base na evidência, esta modalidade de tratamento melhora as possibilidades de design, promete resultados estéticos superiores e um melhor ajuste da base da prótese para em os tecidos, devido à ausência de contração de

polimerização por meio da utilização de blocos de resina acrílica pré-polimerizados para fresagem, bem como um menor potencial para abrigar microorganismos.

Nesse sentido, essas características mencionadas anteriormente poderiam ser consideradas vantagens importantes sobre as terapias convencionais. No entanto, algumas desvantagens também podem ser mencionadas. A principal delas é a diferença econômica em termos de realização desses tratamentos. Enquanto não há nenhuma diminuição no custo de materiais e maior oferta generalização por laboratórios podem considerar-se inacessível a partir do ponto de vista econômico para a maioria dos pacientes. Bem como o descolamento de dentes artificiais de suas respectivas bases protéticas, de acordo com os resultados obtidos neste estudo, pode representar outra desvantagem que deve ser superada.

Em qualquer caso, mais pesquisas devem ser realizadas para elucidar se os menores valores de resistência a microtração desses sistemas têm significado clínico.

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