UNIVERSIDADE DE SÃO PAULO

FACULDADE DE ODONTOLOGIA DE BAURU

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Mechanical properties of CAD-CAM blocks for base denture prosthesis after chemical disinfection protocols

Propriedades mecânicas dos blocos CAD-CAM para base de dentadura após ciclos de desinfecção química

BAURU

2020

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Tese constituída por artigos apresentada a Faculdade de Odontologia de Bauru da Universidade de São Paulo para obtenção do título de Doutor em Ciências no Programa de Ciências Odontológicas Aplicadas, na área de concentração Reabilitação Oral
Orientador: Prof. Dr. Vinicius Carvalho Porto

BAURU
2020

Marcillo-Toala, Oscar Oswaldo

Mechanical properties of CAD-CAM blocks for base dentures prosthesis after chemical disinfection protocols.— Bauru, 2020

102 p. : il.; 31cm.

Tese Doutorado – Faculdade de Odontologia de Bauru. Universidade de São Paulo

Orientador: Prof. Dr. Vinicius Carvalho Porto

ERRATA

FOLHA DE APROVAÇÃO

DEDICATÓRIA

Este trabalho foi produto de muitos anos de esforço e dedicação, formado em 2009, quando formei da faculdade e comecei a busca de uma Odontologia diferente, baseada na ciência e direcionada pela aplicabilidade clínica.

Em primeiro lugar, dedico este trabalho a Deus, só com ele foi possível resolver muitos desafios e problemas, assim como alegrias e emoções. Só Ele sabe que acredito que tudo tem um significado na vida e nada acontece por acaso.

Meus pais, Mario Oswaldo Marcillo Baque e Guadalupe Annabell Toala Salazar. Meus grandes heróis e exemplos de vida. Foi uma longa caminhada e não foi fácil, no entanto, vamos aproveitar esses novos anos em família mais uma vez. Cada desespero, cada alegria, cada sorriso e cada conversa mantida pela internet ou pelas ligações no telefone, lá por volta do 2010. Muito obrigado pelo apoio, sabedoria e paciência, sem vocês não seria possível realizar este sonho acadêmico, profissional e pessoal.

À Mery Laura de la Rosa Batista, minha vida, parceria e amor. Com certeza você é um fator chave e fundamental na realização desde projeto. Obrigado pelas palavras, tempo, paciência, escuta e trabalho em equipe. Você vem caminhando do meu lado desde 2011, e desde aqueles tempos lembro que nossa primeira conversa foi meu sonho de me tornar professor. Chegou o dia e este trabalho é dedicado para você.

Meus filhos... quem acompanhou minha trajetória em Bauru sabe a importância e espaço deles na minha vida. Oscar Andrés Marcillo de la Rosa, meu filho mais velho, e Laura Marie Marcillo de la Rosa, a minha princesa, vocês são e serão minha maior fonte de energia e inspiração. Por vocês e para vocês, esta tese é dedicada com muito amor, Oscarito y Laurita.

AGRADECIMENTOS

Um agradecimento especial aos meus amigos desde a turma do mestrado (2013): Vinicius (Sarnette ou Big Boss), Fernanda (Teacher Fer), Patrick (Grande Patrick), Guilherme (Gui), Ilana (Teacher Ilaninha), Thereza (Teacher The), Andreia (Teacher Dita), Gustavo (Po) e Verena (Teacher Verena). Foram tantas risadas e momentos de estrese dentro e fora da faculdade, o mais importante, conseguimos realizar nossos sonhos.

Impossível não lembrar dos meus amigos de conversas, espetinhos, pizzas e lazer, Rodrigo (Rod) e Henrique (Sulito). Foram momentos de trabalho virando muitas noites no laboratório e no CIP, assim como discutindo de casos, sequencias e fotografia. É bom sempre lembrarmos daquelas risadas e esperando a bolsa cair no dia certo. Vamos manter o contato e continuarmos dando risadas ou falando dos nossos problemas e/ou situações estressantes.

Um agradecimento especial ao nosso grupo de pesquisa: Ana Paula (Ana P), Helena, Rod e Mariana. Mesmo com linhas de pesquisa diferentes, a gente conseguiu estabelecer uma ordem e trabalho em equipe na hora de submeter e desenvolver os artigos, assim como ajudarmos durante as atividades na faculdade.

Um agradecimento especial pra Denise, sendo meu primeiro contato com pesquisa e dividirmos o tempo entre resina acrílica e Cândida albicans no CIP. Lembro daqueles dias onde não sabia como padronizar ou ate mesmo usar o fluxo contaminado tentando não estragar ou colocar errada a pipeta. Obrigado Dê.

Meus amigos na pós-graduação: Bruna, Samira, Lucas, Carolzinha, Dyanne, Guilherme, Isadora, Jefferson, Karina, Lucas, Maria Isabel, Pedro, Janaina, Michelly, Naida, Abbas, Adolfo, Bárbara, Dyna Mara, Ernestito, Everardo, Giancarlo, Jorge, Clara, Milena, Nicole, Luisa, Ana Clara, Rodrigo, Cindy, Fábio, Leticia, Laila.

Meus amigos de CIP: sempre com um sorriso prestes a ajudar e direcionar os trabalhos assim como resolver as duvidas e perguntas em qualquer momento: Rafa, Marcelo e Marcia. Amigos do CIP, também são os pós-graduandos que, lutando

dia a dia, conseguíamos dar risadas dos nossos experimentos bem sucedidos assim como daqueles erros que nos obrigavam a refazer, com muito azar, todo o experimento: Nara (Nara Ligia a artista), Nati, Karen, Cinthia, Maricel, Dani. A nossa frase era: tranquilo, no final das contas vai dar tudo certo. E deu mesmo!!!

Pós-graduação não é apenas estudo, mas também diversão assim como esporte. Obrigado aos meus amigos do Fut dos Broders: Naoki, Bruno, Chalo, Nassif, Gaucho, Julinho, Julião, Bixo, Jussaro, Thiago, Caio, Gustavo, Ricardo, Renato, Marcão, Espeto, Vinicius e Rayovac. É bom jogar bola mas a discussão pelo top 5 sempre será boa. Obrigado galera!!

Agradecimento especial ao meu orientador, Prof. Vinicius Carvalho Porto. Obrigado professor pelo tempo, dedicação, ajuda e conselhos durante os momentos bons e ruins. Lembrando sempre que existe um Deus no nosso caminho e tudo que acontecer sempre foi, é e será controlado por Ele. Obrigado professor pelo suporte e ajuda quando mais o precisava. Como não lembrar daquelas conversas com a maior calma do mundo e sempre procurando uma solução para todos os problemas. Hoje em dia, sei que na vida não adianta ficar nos problemas (e sempre falo pra minha esposa isso), o mais importante é conversarmos das possíveis soluções para esses problemas.

Um agradecimento especial aos professores durante minha formação na clínica da Pós-graduação: Prof. Luis Fernando Pegoraro (o Senhor sempre será um exemplo de integridade profissional e pessoal, além disso posso dizer que tive o privilegio de ser seu aluno durante estes anos na FOB), Prof. Accácio Lins do Valle (meu querido prof. Accácio, lembro daqueles pasteis na feira ou nos rolé de açaí, sempre disponível pra uma boa conversa, um grande amigo), Profa Ana Lucia Fraga de Almeida (Prof.ª obrigado por tudo, pela valorização de uma prótese ligada diretamente com os princípios periodontais, hoje em dia, minha bandeira na divulgação de uma prótese consciente e ideal), Prof. José Henrique Rubo (Prof.

Obrigado pela paciência e atitude favorável em todo momento, durante os atendimentos clínicos assim como nas atividades do departamento).

Gostaria agradecer aos professores do departamento: Prof.ª Karin Neppelenbroek, Prof.ª Simone Soares, Prof.ª Lucimar Falavinha Vieira, Prof. Gerson Bonfante, Prof. Renato de Freitas, Prof. Pedro Garcia de Oliveira, Prof. Paulo Conti, Prof. Estevam Bonfante, Prof. Carlos Araujo, Prof. Wellington Bonachela. Obrigado pelo tempo e dedicação durante os seminários e PAEs nestes gratos anos na faculdade.

Também gostaria agradecer aos funcionários e técnicos no departamento, além de excelentes pessoas, grandes amigos: Reivanildo, Macelo, Déborah, Cleide, Valquiria, Ziley.

À empressa VIPI Produtos Odontológicos pela concessão dos materiais para o desenvolvimento deste estudo.

Gostaria agradecer a Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Código de financiamento 001, pela concessão da bolsa de doutorado, fundamental para o aperfeiçoamento durante a pós-graduação.

“A educação é o passaporte para o futuro,

amanhã pertence a quem se prepara hoje”.

Malcom X

RESUMO

A inovação dos procedimentos computadorizados levou a confecção de blocos de poli-metilmetacrilato (CAD/CAM PMMA blocos) para base dentadura, monstrando ótimas propriedades mecânicas e biológicas, uma melhor adaptação, e procedimentos com reduzido numero de atendimentos. No entanto, os protocolos de desinfecção são necessários com o intuito de remover o biofilme na superfície protética. O efeito destes desinfetantes é muito discutido na literatura mostrando diversos efeitos sobre as propriedades mecânicas e superficiais das resinas em função da concentração, tempo de imersão, e tipo de solução. O objetivo deste trabalho foi avaliar o efeito a curto e longo prazo de soluções desinfetantes nas propriedades mecânicas e superficiais da resina CAD/CAM PMMA para base de dentadura. As resinas testadas foram VIPI Gum Block (CAD/CAM PMMA) (VIPI) e VIPI Cril Plus (Convencional PMMA)(VIPI) e as soluções desinfetantes foram: Grupo controle: Água deionizada; H1= Hipoclorito de sódio 1%; H05= Hipoclorito de sódio 0,5%; e C2= Gluconato de clorexidina 2%. Foram confeccionados 140 corpos de prova (12x12x3mm) direcionada para microdureza (KHN) e rugosidade (Ra) (n=10); e 280 corpos de prova (65x10x3 mm), direcionados para resistência Flexural (RF) e módulo de elasticidade (ME) (n=10). Cada ciclo de desinfecção representava 10 minutos em cada solução e os tempos avaliados foram: 0 (inicial), 14, 30, 130 e 260 ciclos. Os testes estatísticos para KHN e Ra foi ANOVA medidas repetidas e, posteriormente ,o teste de Tukey HSD com nível de significância 5%. Para a RF e ME, a estatística empregada foi ANOVA 3 criterios e teste de Tukey para comparações entre grupos, adotando um nível de significância de 5%. O primeiro trabalho avaliou o efeito a curto prazo das soluções desinfetantes sobre as propriedades superficiais da resina. Os valores Ra não mostraram diferença significante das resinas quando expostas nas soluções durante o período avaliado ($p>0,05$). No entanto, na KHN a CAD/CAM PMMA mostrou-se superior à convencional quando imersa em todas as soluções ($p<0,05$) em todos os tempos ($p<0,05$). O segundo artigo avaliou o efeito ao longo prazo das imersões em soluções desinfetantes da resina CAD/CAM. Nas propriedades superficiais, a KHN mostrou diferença significante no tipo de resina ($p<0,000$), tempo ($p=0,002$) e a interação solução*resina ($p<0,000$). A Ra mostrou uma diferença significante no tipo de solução ($p=0,007$). Na RF, a resina foi determinante no resultado em Mpa ($p=0,001$), o tempo foi outro fator relevante

(p=0,032), e a interação solução*resina (p=0,008). No ME, os fatores relevantes foram: resina (p=0,001), tempo (p=0,032), e solução*resina (p=0,008). A resina CAD/CAM PMMA mostrou valores iniciais superiores na KHN e RF, a Ra e ME semelhante à resina Convencional PMMA. No entanto, quanto maior a exposição (ciclos) da resina às soluções desinfetantes, os testes de KHN, RF e ME mostraram valores superiores da resina Convencional PMMA com diferença significante. Dentro das limitações deste estudo, a resina CAD/CAM PMMA mostrou propriedades favoráveis de acordo com cada experimento realizado e as soluções desinfetantes (H1, H05 e C2) não afetaram negativamente a resina ao longo do tempo.
Palavras-chave: Desenho assistido por computador (CAD). Manufatura assistida por computador (CAM). Poli metil metacrilato (PMMA). Base de dentadura

ABSTRACT

Mechanical properties of CAD/CAM blocks for base denture prosthesis after chemical disinfection protocols

The innovation of computerized procedures led to the manufacture of polymethylmethacrylate blocks (CAD/CAM PMMA blocks) for denture base, showing excellent mechanical and biological properties, better adaptation, and reduced number of attendances. However, disinfection protocols are necessary in order to remove the biofilm on the prosthetic surface. The effect of these disinfectants is widely discussed in the literature, showing several effects on the mechanical and surface properties of resins depending on the concentration, immersion time, and type of solution. The objective of this work was to evaluate the short and long term effect of disinfectant solutions on the mechanical and surface properties of CAD/CAM PMMA resin for denture base. The tested resins were VIPI Gum Block (CAD/CAM PMMA) (VIPI) and VIPI Cril Plus (Conventional PMMA) (VIPI) and the disinfectant solutions were: Control group: Deionized water; H1 = 1% sodium hypochlorite; H05 = 0.5% sodium hypochlorite; and C2 = 2% chlorhexidine gluconate. One hundred and forty specimens were made (12x12x3mm) for microhardness (KHN) and roughness (Ra) tests (n = 10); and 280 specimens (65x10x3 mm), for Flexural Strength (FS) and Flexural Modulus (FM) (n = 10). Each disinfection cycle represented a 10 minutes immersion in each solution and the evaluated times were: 0 (initial), 14, 30, 130 and 260 cycles. The statistical tests for KHN and Ra were repeated-measures ANOVA and, subsequently, the Tukey HSD test with a significance level of 5%. For FS and FM, the statistics used was 3-Way ANOVA and Tukey's test for multiple comparisons, adopting a significance level of 5%. The first work evaluated the short-term effect of disinfectant solutions on the surface properties of the resin. The Ra test showed no significant difference in resins when exposed to the solutions during the evaluated period ($p > 0.05$). However, the KHN test showed that CAD/CAM PMMA was superior to conventional when immersed in all solutions ($p < 0.05$) at all times ($p < 0.05$). The second article evaluated a long-term effect of CAD/CAM PMMA resin immersed in the solutions. In surface properties, KHN showed a significant difference in the type of resin ($p < 0.000$), time ($p = 0.002$) and the solution * resin interaction ($p < 0.000$). The Ra showed a significant difference in the type of solution ($p = 0.007$). In RF, the resin was decisive in the result in Mpa ($p = 0.001$), the time was another relevant factor ($p = 0.032$), and the

solution*resin interaction (p = 0.008). In the ME, the relevant factors were: resin (p = 0.001), time (p = 0.032), and solution * resin (p = 0.008). The CAD/CAM PMMA resin showed higher initial values in KHN and FS, Ra and FM similar to the conventional PMMA resin. However, the greater the exposure (cycles) of the resin to disinfectant solutions, the KHN, FS and FM tests showed higher values of the conventional PMMA resin with a significant difference. Within the limitations of this study, the CAD/CAM PMMA resin showed favorable properties according to each experiment performed and the disinfectant solutions (H1, H05 and C2) did not negatively affect the resin over time.
Keywords: Computer-aided design (CAD). Computer-aided manufacturing (CAM). Poly methyl-methacrylate (PMMA). Base denture.

LISTA DE ABREVIATURA E SIGLAS

PMMA	Poli Metil Metacrilato
CAD	Desenho assistido por computador
CAM	Manufatura assistida por computador
KHN	Microdureza Knoop
Ra	Rugosidade
µm	Micrometro
Mpa	Megapascal
CD	Complete denture (dentadura)
DS	Denture Stomatitis (Estomatitis)
C. albicans	*Cândida albicans*
SDJ	Saudi Dental Journal
JPD	Journal of Prosthetic Dentistry
ANOVA	Analysis of Variance
HSD	Honestly Significance Difference

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1 Introduction

1 INTRODUCTION

The introduction of computer-aided design (CAD) and computer-aided manufacturing (CAM) in dentistry has helped the clinicians indicate a new presentation of dental materials with better mechanical, physical and biological properties, as well as reduced appointments.[1,2,3] Even though the implant therapy has been recognized as an excellent alternative for complete, partial, or single replacement of tooth and related-structures, complete dentures (CD) are still a treatment option for edentulism when the patient is not suitable for implant therapy due to a compromised health condition, financial limitations or phycological factors. [1] Since 1937, the poly-methyl methacrylate (PMMA) have been used for the fabrication of CD in the majority of cases except patients with allergy or hospitalized condition. [1,4,5] The PMMA is a synthetic thermoplastic polymer composed by the reaction of methyl-methacrylate monomers: [1] the interaction of powder (microspheres of pre-polymerized PMMA, benzoyl peroxide and pigments) and liquid (monomer, cross-link agents, plasticizers and stabilizers compounds). [6,7,8] The PMMA can be classified according to the polymerization process: Chemical polymerization, which is initiated by the reaction of a tertiary amine; and Heat polymerization, which includes a thermal bath with or without pressure, and microwave polymerization. [7] In the last decades, pre-polymerized blocks have been introduced that could be milled based on a CAD/CAM project. [1,2,3] The PMMA is widely accepted in many fields of dentistry, it could be indicated for temporary crowns, surgical guides, occlusal appliances, and CD. [1,7]

One of the critical tasks for CD wearers is the adequate cleansing of the prosthesis, mainly the inner surface that directly contacts the patient´s mucosa. [1,9,10] A poor hygiene would lead to microbial adherence and superficial colonization of the

prosthetic device, and facilitate a mucosa alteration known as Denture Stomatitis (DS). [1] DS is a multifactorial condition, frequently associated to *Candida albicans* development within the PMMA, and could migrate to the oral mucosa. [9,10] Researches have appointed that mechanical removal of microorganisms (brushing) is the best hygiene method removing the adhered plaque on the acrylic resin. [3] However, some patients might experience limited motor skills and would need an additional mechanism for cleansing, such as chemical solutions or physical disinfection. [9,10] Additionally, literature detailed one problem related to this pathogen (*Candida albicans*), which could be allocated in the resin a depth of 631μm [11]; making imperative the use of an associated mechanism for the correct cleansing and disinfection of the CD. [10]

Chemical disinfection have been categorized as a fast, low cost, and secure protocol of decontaminating the base denture. [10] But, there is no consensus about the best solution in terms of composition, concentration, time of immersion, and the deleterious effect of the mechanical and surface properties generated after continuous disinfection. [10] The most common solutions used in dentistry are sodium hypochlorite (varying from 0,5 to 2,5%), chlorhexidine gluconate (2 or 4%), peracetic acid and vinegar; and the immersion time would vary from 10 minutes to 8 hours disinfection cycle. [9,10,12] Other approaches included the microwave disinfection (physical disinfection), application of coating (cyanoacrylates or related-coatings) and photodynamic therapy, all of them, trying to reduce the microbial colonization and harmless disinfection on mechanical properties of the PMMA. [1,13,14] Current literature referred that the chemical solution would disinfect the irregularities on the resin microtopography (peaks and valleys) whereas the brushing might not have access, and the ability to penetrate in the PMMA matrix. [9,12] The previous statement confirmed

the need for studying the effect of continuous exposure of PMMA to chemical disinfection solutions on the superficial characteristics and mechanicals aspects.

The CAD/CAM technology facilitate a new possibility to deliver a CD, which could mill the base denture from CAD/CAM PMMA block and, subsequently, fix pre-fabricated teeth, or produce a complete denture (teeth and base) from monoblock pucks. [6] Maeda et al. (1994) published the first paper of a CD fabricated by CAD/CAM technology using a 3D lithography machine through an additive process. [6] Therefore, a new wave of researches have been carried on to identify the benefits, limitations, and advantages of this material (CAD/CAM PMMA) under certain conditions: thermal cycling, coffee staining, water storage, and mechanical, biological, optical and surface properties. [8,15] According to literature, one of the main advantages of CAD/CAM PMMA blocks is the manufacturing condition under high temperature and controlled pressures, producing a dense polymer with a low monomer release rate and porosity. [6] This condition might produce a resin with higher mechanical and superficial characteristics, even higher than conventional PMMA. [16] Many papers have demonstrated that CAD/CAM PMMA did have higher microhardness values and a smoother surface than conventional ones, as well as higher initial flexural properties and after an accelerated thermal aging protocol. [2,3,16] However, the effect of chemical disinfection on these characteristics of CAD/CAM PMMA has not yet been studied.

Based on these statements, the objectives of the present study were to evaluate the flexural and surface properties of CAD/CAM PMMA blocks after chemical disinfection during a short and long-term analysis. The first null hypothesis was that the flexural properties and superficial characteristic of CAD/CAM PMMA resin have no

difference to Conventional PMMA. The second null hypothesis was that CAD/CAM PMMA resin is not affected by chemical solutions through time.

4 Conclussions and final considerations

4 CONCLUSIONS OR FINAL CONSIDERATIONS

CAD/CAM PMMA resin showed higher mechanical values in terms of microhardness and flexural properties at baseline when compared to conventional PMMA. However, CAD/CAM PMMA resins could be safety disinfected with the tested chemical solutions and would be above the minimal recommendations for clinical acceptance.

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Annexes

Annex 1

Manuscript Details

Manuscript number	SDENTJ_2020_418
Title	Does chemical disinfection affect the superficial properties of CAD CAM resin blocks?
Short title	Disinfection on CAD CAM base denture
Article type	Full Length Article

Abstract

Complete dentures are being fabricated by computer-aided design and computer-aided manufacturing (CAD CAM) showing high mechanical and superficial properties. The purpose of this study was to evaluate the effect of chemical disinfection on the superficial roughness (Ra) and Knoop hardness (KHN) of a CAD CAM resin block after 14 and 30 immersion cycles. Quadrangular specimens (12x3mm) were divided into 2 groups: Control Group (n=10)(heat and pressure-controlled polymerization, Vipi Cril Plus, VIPI®) and a CAD CAM group (n=10)(pre-polymerized resin pucks, Vipi GUM, VIPI®). The immersion solutions were Control Group (deionized water), H1 (Sodium hypochlorite 1%) and C2 (chlorhexidine gluconate 2%). The immersion cycles were evaluated according to Baseline (0 cycles), T1 (14 cycles) and T2 (30 cycles). Measurements were applied on a contact profilometer (Roughness, Ra) and a hardness tester (Knoop microhardness, KHN). The results were analyzed using a 3-way ANOVA and a Tukey HSD pos hoc test (p=0.05). Roughness: At Baseline, the CAD CAM (0,17±0,02µm) showed no difference to conventional (0,18±0,01µm) resin. At T2, CAD CAM resins exposed to CG and H1 showed a reduction in Ra values, with significant difference among the solutions (p<0,00), groups (p<0,00), and their interaction with time (p<0,01). Microhardness: CAD CAM resin showed a higher value (20,3±0,5 KHN) than the conventional resin (18,6±0,5 KHN). CG and H1 did not affect KHN values (p>0,05) for both resins, but there was a significant difference between groups (p<0,00), time (p<0,00) and time*solution (p<0,00). However, the C2 reduced the KHN values for both resins at T1, and it was restored at T2. Disinfection solutions (H1 or C2) did not affect adversely roughness or hardness of the CAD CAM resin. Both tested materials demonstrated values above minimal clinical requirements.

Keywords	Computer-aided design; Computer-aided manufacturing; base denture; disinfection; microhardness; roughness
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Annex 2

The Journal of Prosthetic Dentistry

Does continuous chemical disinfection affect mechanical properties of CAD/CAM PMMA

--Manuscript Draft--

Manuscript Number:	
Article Type:	Research and Education
Keywords:	Computer aided design; Computer aided manufacturin; Complete denture; flexural properties; superficial properties
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Abstract:	State of the problem : Complete dentures fabricated by computer-aided design and computer-aided manufacturing (CAD/CAM) have shown higher mechanical properties when compared to conventional base denture resins, but there is no evidence of its performance after repeated disinfection immersions. Purpose : The purpose of this paper was to analyze the effect of consecutive disinfection immersions on physical properties of CAD/CAM base denture blocks. Materials and Methods : Two groups of base denture resins were tested: Heat-polymerized (VipiCryl, VIPI®) and milled blocks (VipiGum, VIPI®). The specimens were designed into quadrangular (12x3mm) (n=40) and rectangular (64x10x3,3mm) (n=240) specimens. Specimens were stored in water for 48 hours. Therefore, they were immersed in the disinfection chemical solutions: CG (control group, deionized water), H1 (sodium hypochlorite 1%), H05 (sodium hypochlorite 0,5%) and C2 (Chlorhexidine 2%). Each disinfection cycle represented a weekly disinfection process (10 min immersion). The immersion periods represented: baseline (0 cycles), 2.5 years (130 cycles) and 5 years (260 cycles). The analysis was based on the Roughness (Ra), Microhardness alterations (KHN), Flexural strength (FS) and Flexural Modulus (FM). The applied statistical tests were a 3-way ANOVA and Tukey HSD Pos Hoc Test were applied for all experiments, significance level of 5%. Results: CAD/CAM PMMA showed higher flexural properties: flexural strength ($p=0,001$) and flexural modulus ($p<0,000$), than conventional PMMA. Microhardness KHN ($p<0,000$) was superior than conventional PMMA, but the chemical solution affected all resin in the surface roughness ($p=0,007$), values were under the 0,20 µm threshold for microbial adherence. Conclusions : Within the limitations of this study, the CAD/CAM PMMA blocks can be safely disinfected without a negative effect on flexural and superficial properties.