# RESSALVA

Atendendo solicitação do(a)
autor(a), o texto completo desta tese
será disponibilizado somente a partir
de 14/03/2021.

Universidade Estadual Paulista

"Júlio de Mesquita Filho"

Faculdade de Odontologia de Araraquara

Università Degli Studi di Padova

*Francesco Saverio Ludovichetti*

# CAD/CAM monolithic materials: wear resistance and abrasiveness, and the effect of grinding and polishing on their roughness and fracture resistance.

Araraquara

2019

Universidade Estadual Paulista
"Júlio de Mesquita Filho"
Faculdade de Odontologia de Araraquara

Università Degli Studi di Padova

*Francesco Saverio Ludovichetti*

# CAD/CAM monolithic materials: wear resistance and abrasiveness, and the effect of grinding and polishing on their roughness and fracture resistance.

Tese apresentada ao Programa de Pós-Graduação em Reabilitação Oral – Área de Prótese da Faculdade de Odontologia de Araraquara da Universidade Estadual Paulista, para obtenção do título de Doutor em Reabilitação Oral.

Orientadora: Profa Dra. Renata Garcia Fonseca - UNESP
Orientador: Prof. Gaetano Granozzi - UNIPD

Araraquara
2019

Ludovichetti, Francesco Saverio
CAD/CAM monolithic materials: wear resistance and abrasiveness, and the effect of grinding and polishing on their roughness and fracture resistance / Francesco Saverio Ludovichetti. -- Araraquara: [s.n.], 2019
83 f. ; 30 cm.

Tese (Doutorado em Reabilitação oral) – Universidade Estadual Paulista, Faculdade de Odontologia e Dottorato in Scienze e Ingegneria dei materiali e delle nanostrutture – Università Degli Studi di Padova
Orientadora: Profa Dra. Renata Garcia Fonseca – UNESP
Orientador: Prof. Gaetano Granozzi - UNIPD

1. Projeto auxiliado por computador 2. Cerâmica 3. Resinas compostas 4. Ajuste oclusal 5. Polimento dentário 6. Resistência dos materiais I. Título

Ficha catalográfica elaborada pela Bibliotecária Marley C. Chiusoli Montagnoli, CRB-8/5646
Universidade Estadual Paulista (Unesp), Faculdade de Odontologia, Araraquara
Serviço Técnico de Biblioteca e Documentação

Francesco Saverio Ludovichetti

# CAD/CAM monolithic materials: wear resistance and abrasiveness, and the effect of grinding and polishing on their roughness and fracture resistance.

Comissão julgadora

Tese para obtenção do grau de Doutor

Presidente e Coordenador: Profa. Dra. Renata Garcia Fonseca

2° Examinador: Prof. Dr. Gaetano Granozzi

3° Examinador: Prof. Dr. Gelson Luis Adabo

4° Examinador: Profa. Dra. Lígia Antunes Pereira Pinelli

5° Examindor: Profa. Dr. Paulo Henrique Dos Santos

Araraquara, 14 de Março 2019

# Dados curriculares

## *Francesco Saverio Ludovichetti*

| | |
|---|---|
| NASCIMENTO | 17/08/1988 |
| FILIAÇÃO | Maurizio Ludovichetti |
| | Marialuisa De Tina |
| 2008 – 2013 | Graduação em Odontologia pela Faculdade de Padova (UNIPD), Italia |
| 2015 – 2017 | Especialização em Periodontia pela Faculdade Herrero de Curitiba |
| 2016 | Estágio no Exterior (ACTA – Amsterdam) |
| 2016 | Curso de Extensão em Implantodontia pela FAEPO, Araraquara |
| 2016 | Estágio de Docência em Protése fixa convencional e sobre implantes |
| 2016 | Estágio de Docência em Materiais aplicados a Protése |
| 2017 | Estágio de Docência no exterior em Periodontia |
| 2017 | Curso de Extensão em “Metodologie di Ricerca” pela Universidade de Padova |
| 2017 - 2018 | Adjunct Professor na Universidade de Odontologia de Padova (UNIPD) |
| 2018 - 2019 | Adjunct Professor na Universidade de Odontologia de Padova (UNIPD) |

# DEDICATÓRIA

*Dedico questi miei due Dottorati di Ricerca*

*Alla mia Mamma,*
*che ha dedicato la sua vita a farmi diventare la persona che sono oggi*

*Para minha mãe,*
*que dedicou sua vida a me fazer a pessoa que eu sou hoje*

*Al mio Papà,*
*che mi ha insegnato i valori più importanti*

*Para o meu pai*
*quem me ensinou os valores mais importantes*

*A mio Fratello,*
*che, seppur più piccolo, è stato ed è un esempio da seguire*

*Para o meu irmão*
*que, embora menor, foi e é um exemplo a seguir*

# AGRADECIMENTOS

*La mia Mamma, per avermi dato il coraggio di partire per questa avventura*
*Minha mãe, por me dar a coragem de partir para esta aventura*

*Il mio papà, per aver creduto in me*
*Meu pai, por acreditar em mim*

*Mio fratello, per avermi dato la forza di credere in quello che stavo facendo*
*Meu irmão, por me dar força para acreditar no que eu estava fazendo*

*La mia 95enne Nonna Bruna e anche i miei nonni Duilio, Giulietta e Sergio, che sono sicuro siano orgogliosi di me*
*Minha avó Bruna e também meus avós Duilio, Giulietta e Sergio, que tenho certeza que estão orgulhosos de mim*

*I miei Zii e mia cugina, per avermi sostenuto*
*Meus tios e minha prima, por me apoiar*

*La Professoressa Renata, per avermi guidato sapientemente ogni giorno in questo percorso*
*Professora Renata, por me orientar sabiamente todos os dias nesse caminho*

*Il Professor Granozzi per avermi permesso di realizzare una parte del progetto nella mia città natale*
*Professor Granozzi por me permitir realizar parte do projeto em minha cidade natal*

*Il Professor Carlos Rossa Junior, per avermi permesso di venire in Brasile*
*Professor Carlos Rossa Junior, por ser o primeiro a me permitir vir ao Brasil*

*I Professori Marcelo Ferrarezi e Edson Campos, per la possibilità di lavorare alla FAEPO*

*Professores Marcelo Ferrarezi e Edson Campos, pela oportunidade de trabalhar na FAEPO*

*I Professori Francisco Mollo Junior e Joao Arioli, per i preziosi insegnamenti ricevuti*
*Os professores Francisco Mollo Junior e Joao Arioli, pelas preciosas lições recebidas*

*Le colleghe Flavia e Samira, per tutti i consigli e per le lunghe giornate passate al 4 piano e in laboratorio*
*Os colegas Flávia e Samira, por todos os conselhos e pelos longos dias passados no 4º andar e no laboratório*

*Il Professor Bressan, per avermi spronato a partire*
*Professor Bressan, por me incentivar a sair para o Brasil*

*Michele, per avermi mostrato che c'è ancora voglia di ricerca*
*Michele, por me mostrar que ainda há um desejo de pesquisa*

*Marika, per condividere con allegria le giornate del "Gruppo ricerca Padova"*
*Marika, para compartilhar com alegria os dias do "Grupo de Pesquisa Padova"*

*Aion, per essere stato il primo con cui ho lavorato ad Araraquara*
*Aion, por ter sido o primeiro com quem trabalhei em Araraquara*

*Vinicius, per essere stato il primo a salutarmi al mio arrivo*
*Vinicius, por ter sido o primeiro a me receber na minha chegada*

*Raphael, per essere stato sempre disponibile ad aiutarmi*
*Raphael, por estar sempre disponível para me ajudar*

*Zè Rodolfo, per avermi assistito durante moltissimi interventi*
*Zè Rodolfo, por me ajudar durante muitas cirurgias*

*Guilherme e Mauricio per essere stati i miei primi amici in Brasile*
*Guilherme e Mauricio por ser uns dos meus primeiros amigos no Brasil*

*Camila, per tutti i consigli*
*Camila, por todos os conselhos*

*Leonardo, per tutta la mucogengivale fatta insieme*
*Leonardo, para todas as mucogengivais feitas juntos*

*“las Lauras” per essere state le prime con cui ho condiviso l’avventura del Brasile*
*"Las Lauras" por ser as primeiras com quem compartilhei a aventura do Brasil*

*I miei 2 cani Hasso e Ettore, loro sanno il perché*
*Meus 2 cachorros Hasso e Ettore, eles sabem porque*

*Il Brasile per avermi dato così tanto*
*O Brasil por me dar tanto*

*Tutti i miei maestri e Professori a partire dall’infanzia, per aver contribuito a farmi arrivare qui*
*Todos os meus professores da infância, por ajudar a me trazer aqui*

*Tutte le persone che mi dicevano che un traguardo del genere sarebbe stato raggiungibile*
*Todas as pessoas que me disseram que tal meta seria atingível*

*Tutte le persone che mi dicevano che una cosa del genere non era possibile, per avermi spronato a renderla possibile*
*Todas as pessoas que me disseram que tal coisa não era possível, por ter me estimulado a tornar isso possível*

*Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq, pela bolsa de Doutorado concedida*
*Il CNPq, per l’aiuto finanziario concesso nel mio dottorato*

*Me Stesso, per averci creduto fino in fondo*
*Eu, por ter acreditado até o fim*

ὁ δὲ ἀνεξέταστος βίος
οὐ βιωτὸς ἀνθρώπῳ

Σωκράτης

Ludovichetti FS. Materiais monolíticos CAD/CAM: resistência ao desgaste e abrasividade, e efeito do desgaste e polimento nas suas rugosidade e resistência à fratura [Tese de Doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2019.

**Resumo**

Esta tese consiste em dois estudos, ambos investigando materiais monolíticos fresados por tecnologia CAD-CAM.

**Primeiro estudo. Objetivo.** A resistência ao desgaste e abrasividade do Lava Ultimate, Vita Enamic, Vita Suprinity, IPS e.max CAD e Lava Plus, bem como algumas propriedades que podem estar relacionadas, foram analisadas. **Métodos.** Espécimes desses materiais tiveram sua rugosidade, dureza e coeficiente de atrito avaliados, respectivamente, em microscópio confocal, microdurômetro e tribômetro. O teste de desgaste conhecido como "2-body", no qual os materiais atuaram como abrasivos e, juntamente com o esmalte bovino, também como antagonistas, também foi realizado. A taxa de desgaste foi determinada com perfilômetro de superfície e as superfícies desgastadas foram observadas por microscopia eletrônica de varredura (MEV). **Resultados.** Vita Enamic e Lava Ultimate mostraram a maior rugosidade, enquanto IPS e.max CAD e Vita Suprinity, a menor. O resultado da dureza foi Lava Plus> (Vita Suprinity = IPS e.max CAD)> Vita Enamic> Lava Ultimate. O Lava Ultimate exibiu maior coeficiente de atrito do que o IPS e.max CAD e o Lava Plus. O Lava Plus e o IPS e.max CAD mostraram um potencial significativamente maior para desgastar o Lava Ultimate. Estes dois materiais, juntamente com o Vita Suprinity, foram os que mais desgastaram o esmalte e o Vita Enamic. Vita Suprinity e IPS e.max CAD promoveram o maior desgaste do Lava Plus, e o inverso também ocorreu.

Vita Enamic e Lava Ultimate causaram o menor desgaste do esmalte e de todos os outros materiais avaliados. **Conclusão.** A resina composta nanoparticulada e a cerâmica infiltrada com polímero foram mais amigáveis ao antagonista (seja esmalte ou material) do que as vitrocerâmicas e zircônia. Cuidados devem ser tomados ao selecionar o material que irá entrar em contato principalmente com a vitrocerâmica. A dureza também deve ser considerada ao selecionar um material.

**<u>Segundo estudo</u>. Objetivo.** Avaliar o efeito do desgaste e do polimento na rugosidade e resistência à fratura do Lava Ultimate, Vita Enamic, Vita Suprinity e IPS e.max CAD, submetidos ao envelhecimento mecânico. **Métodos.** Os discos destes materiais foram analisados quanto à rugosidade: 1) após o polimento com lixas de carbeto de silício (Lava Ultimate e Vita Enamic) ou aplicação do glaze (IPS e.max CAD e Vita Suprinity) (controle); 2) após o desgaste com ponta diamantada de 30 µm; 3) e após desgaste e polimento com o kit de polimento Ceramiste Polishers. Para a resistência à fratura, um modelo simplificado de três camadas consistindo de disco restaurador, disco de resina epóxi e um anel de aço, cimentados entre si, foi usado. Os discos tri-camada receberam as mesmos tratamentos de superfície descritos para a análise de rugosidade. Metade dos espécimes foi submetida ao envelhecimento mecânico por $1\times10^6$ ciclos. Todos os espécimes foram ensaiados até sua fratura. O módulo de Weibull foi calculado. **Resultados.** Entre os grupos controle, não foi encontrada diferença significativa entre o IPS e.max CAD e o Vita Suprinity e entre o Lava Ultimate e o Vita Enamic, os quais foram mais rugosos que os materiais vitrocerâmicos. Após o desgaste, esse comportamento foi mantido, com exceção do Vita Enamic, cuja rugosidade foi semelhante à do IPS e.max CAD. Após o polimento, o Vita Enamic mostrou a maior rugosidade, enquanto os outros

materiais não foram estatisticamente diferentes. O IPS e.max CAD e o Vita Suprinity apresentaram a menor rugosidade nos grupos controle. Para Lava Ultimate e Vita Enamic, o polimento promoveu a menor rugosidade. O desgaste, seguido ou não por polimento, e o envelhecimento mecânico não afetaram adversamente a resistência à fratura ou a confiabilidade dos materiais. **Conclusões.** O polimento não recuperou a maior lisura inicial dos materiais vitrocerâmicos. A resistência à fratura não foi afetada pelo desgaste, seguido ou não por polimento, mesmo após o envelhecimento mecânico.

**Palavras-chave:** Projeto auxiliado por computador. Cerâmica. Resinas compostas. Ajuste oclusal. Polimento dentário. Resistência dos materiais.

Ludovichetti FS. CAD/CAM monolithic materials: wear resistance and abrasiveness, and the effect of grinding and polishing on their roughness and fracture resistance [Tese de Doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2019.


**Abstract**

This thesis consists of two studies, both investigating the computer-aided design and computer-aided manufacturing (CAD-CAM) monolithic materials.

**First study.** **Aim.** The wear resistance and abrasiveness of Lava Ultimate, Vita Enamic, Vita Suprinity, IPS e.max CAD, and Lava Plus, as well as some properties that might be related to, were analyzed. **Methods.** Specimens from these materials had their roughness, hardness, and coefficient of friction evaluated, respectively in confocal microscope, microdurometer, and tribometer. The 2-body wear test, wherein the materials acted as abraders and, together with bovine enamel, also as antagonists, was also carried out. The wear rate was determined with surface profilometer and the worn surfaces were observed by scanning electron microscopy (SEM). **Results.** Vita Enamic and Lava Ultimate showed the highest roughness, whereas IPS e.max CAD and Vita Suprinity, the lowest. The hardness result was Lava Plus > (Vita Suprinity=IPS e.max CAD) > Vita Enamic >Lava Ultimate. Lava Ultimate exhibited a higher coefficient of friction than IPS e.max CAD and Lava Plus. Lava Plus and IPS e.max CAD showed significantly higher potential to wear Lava Ultimate. These two materials, together with Vita Suprinity, provided the highest wear of enamel and Vita Enamic. Vita Suprinity and IPS e.max CAD exhibited the highest wear against Lava Plus, and the inverse also occurred. Vita Enamic and Lava Ultimate were among the materials that caused the lowest wear of enamel and all other evaluated materials. **Conclusion.** The nanofilled composite resin and polymer-infiltrated ceramic

were more antagonist-friendly (whether enamel or CAD-CAM material) than glass-ceramics and zirconia. Care should be taken when selecting the material that will contact mainly with glass-ceramics. Hardness should also be considered when selecting a material.

**Second study.** **Aim**. To evaluate the effect of grinding and polishing on the roughness and fracture resistance of Lava Ultimate, Vita Enamic, Vita Suprinity, and IPS e.max CAD, submitted to mechanical aging. **Methods.** Disks from these materials were analyzed for roughness: 1) after polishing with silicon carbide papers (Lava Ultimate and Vita Enamic) or glazing (IPS e.max CAD and Vita Suprinity) (control); 2) after grinding with 30-µm grit diamond rotary instruments; 3) and after grinding and polishing with the polishing kit Ceramiste Polishers. For fracture resistance, a simplified tri-layer model consisting of restorative disk, epoxy resin disk, and a steel ring was used. The bonded tri-layer disks received the same conditions described for the roughness analysis. Half of the specimens underwent mechanical aging for $1\times10^6$ cycles. All specimens were loaded until failure. The Weibull modulus was calculated. **Results.** Among the control groups, no significant difference was found between the IPS e.max CAD and Vita Suprinity and between the Lava Ultimate and Vita Enamic, which were rougher than the glass-ceramic materials. After grinding, this behavior was maintained, except for the Vita Enamic, whose roughness was similar to that of the IPS e.max CAD. After polishing, the Vita Enamic showed the highest roughness, whereas the other materials were not statistically different. IPS e.max CAD and Vita Suprinity showed the lowest roughness in the control groups. For Lava Ultimate and Vita Enamic, polishing provided the lowest roughness. Grinding followed or not by polishing, and mechanical aging, did not adversely affect fracture resistance or the reliability of the materials. **Conclusions.** Polishing did not recover the initial roughness of

the glass-ceramic materials. Fracture resistance was not affected by grinding, followed or not by polishing, even after mechanical aging.

**Keywords:** CAD-CAM. Ceramics. Composite resins. Occlusal adjustment. Dental polishing. Material resistance.

# *Summary*

# 1 INTRODUCTION

Thanks to the continuing scientific advancement, CAD-CAM technology has recently made tremendous progresses and it is able to easily satisfy many of the prosthetic requirements in Dentistry[1]. The great interest in dental prosthesis aesthetics, has led to an increased research of materials that mimic natural teeth behavior, both from the functional point of view and from the aesthetic one[2,3]. Nowadays the use of materials for CAD-CAM technology has shown different results with many options available to realize dental restorations[4]. Thanks to its good mechanical characteristics and aesthetic clinical results, the most used material for indirect CAD-CAM restorations is lithium disilicate (IPS e.max CAD, Ivoclar Vivadent)[5,6]. Recently, new materials with different composition and indications, including the Vita Suprinity (Vita Zahnfabrik), Vita Enamic (Vita Zahnfabrik), Lava Ultimate (3M ESPE), are being studied as viable substitutes to realize anterior and posterior crowns, implant supported crowns, anterior veneers and 2 or 3 elements bridges[7]. Vita Enamic contains feldspathic ceramic matrix (86 wt%) infiltrated with a low-viscosity copolymer (urethane dimethacrylate and triethylene glycol dimethacrylate)[8]. Vita Suprinity is composed by a lithium silicate glassy matrix and zirconia fillers[9]. Lava Ultimate is a resin nanoceramic material, consisting of 80 wt% zirconia/silica nanoparticles embedded in a highly cross-linked polymer matrix (BisGMA, UDMA, BisEMA, TEGDMA)[10]. Since their composition is different, it can be assumed that the mechanical and physical properties might change depending on the material, and literature still has gaps regarding both the surface characteristics and the mechanical behavior of these new materials.

In restorative dentistry, an ideal material should present a wear potential similar to that of the human enamel[11]. As reported by literature[12,13], some of the recently introduced dental ceramic systems seem to present this relevant property. Different Authors in many studies, showed that lithium disilicate (e.max CAD Ivoclar Vivadent), Lava Plus (3M ESPE), Vita Enamic (VITA) and the zirconia reinforced glass ceramic do not show statistically significant difference in wear potential when compared with human enamel[12,13,26]. Even if wear potential is considered as "key role" material property in indirect restorative dentistry, studying it may not be sufficient, due to the multifactorial nature of this process which might be influenced by several other surface characteristics such as roughness, coefficient of friction and hardness.

Materials roughness is a known data provided by the manufacturer, but clinically, due to various adjustments and aging, it may drastically change. Surface clinical interventions lead to different roughness values, thus material roughness and its changes have to be investigated as they may predict the opposing teeth wear[14,15,16]. Ghazal et al.[17] (2009) and Janyavula et al.[14] (2013) studied how surface roughness may influence wear of human enamel and composite resin and of polished, glazed, polished and re-glazed zirconia respectively. They found that, when surface roughness increases, human enamel wear increased dramatically too. Authors explain that this could be caused by the frictional resistance: when surface roughness increases, coefficient of friction increases, and this results in a greater wear. They both concluded that surface roughness plays a fundamental role in the wear of opposing materials.

As previously seen, material roughness and coefficient of friction seems to be related and since friction forces occur in almost every oral cavity movement and they may negatively influence dental materials properties, Authors suggested that a better understanding of the relation between friction coefficient, roughness and wear may help in indirect restorative materials behavior investigation[18,19]. Ghazal et al.[17] (2009) showed that high surface roughness increases the friction coefficient, which results in greater wear. In the literature review of Oh et al.[20] (2002) was suggested that roughness, high loads, and high sliding speeds increases the coefficient of friction and this lead to a greater wear potential.

Finally, literature is still divided about material hardness influence on wear potential. Some authors exclude it as a wear influencing property[20,21], some others suggest that as wear is a multifactorial process, hardness could influence it[22,23]. As explained in the literature review of Oh et al.[20] (2002), wear potential of some materials, such as metals, is highly influenced by hardness: gold based casting alloys are relatively soft in comparison with harder metals, and they are more antagonist friendly. But when it comes to ceramics, material hardness would not able to affect wear potential by itself, but it can be seen as a co-factor (Seghi et al.[23] 1991, D'Arcangelo et al.[13] 2015). This may be explained due to the different wear mechanism of metal and ceramics. In metal wear mechanism is by plastic deformation while in dental ceramic materials it occurs by material micro-fractures.

The different composition of these materials could result in a different behavior in the wear of antagonist elements. Moreover, clinically, when they are submitted to adjustment processes, this difference may be greater as the surface characteristics change depending on the surface treatment adopted[24,25]. The ideal order for glass ceramics would be to adjust the restoration when it is still not cemented, then glaze it and cement it in mouth[26]. For Vita Enamic (VITA) and Lava Ultimate (3M ESPE), the ideal procedure would be to cement the restoration right after it has been milled[8,10]. However, clinically this situation is not always reachable due to premature contacts that may appear after cementation. This lead to the need of occlusal adjustments and though to surface roughness increase, which could change the wear potential of the material[27]. In the attempt to decrease adjustment-caused roughness, a commonly used clinical protocol is to polish adjusted restorations with one of the numerous polishing systems available. However, literature has not still achieved a consensus regarding how material resistance could be affected by adjustments and polishing protocols and a better understanding of how different finishing material protocols may change their properties may lead to greater predictability in prosthesis duration and in its behavior towards antagonist teeth. This led to the second part of this thesis, where a situation as similar as possible to what we can find “in vivo” was analyzed. Manufacturer recommendations suggest that, after cementing prosthetic elements, no occlusal adjustments should be performed, but from the clinical point of view, this order is not always respectable. Often, it happens that, after cementation, there is a need for adjustments. For this reason, we wanted to reproduce realistic clinical situations that lead the dentist to deviate from the manufacturer recommendations. For this reason, we investigated if mechanical resistance of the studied materials could have undergone variations due to the adjustments procedures and tested this situation with non-aged and aged materials to assess if, in addition to adjustments, aging can alter the mechanical resistance. The ultimate goal of this thesis is to provide clinicians a guide in choosing the most suitable material for prosthetic rehabilitation, according to the different situations that can be found “in vivo”, since today there are  countless possibilities in terms of prosthetic materials, and decision making can be complicated and not always correct. Therefore, in this thesis the influence of hardness, coefficient of friction and roughness material properties on wear potential and how different finishing surface clinical protocols influence the material mechanical strength on the short and on the long time were investigated.

# 5 CONCLUSION

- The nanofilled composite resin and polymer-infiltrated ceramic were the most antagonist-friendly materials when sliding against enamel and any other material.
- Lithium disilicate, zirconia-reinforced lithium silicate, and zirconia caused high wear rates on the enamel and materials, with the difference that zirconia did not damage the surface of the materials, except for the enamel.
- Hardness should be considered in the selection of materials, especially in patients with bruxism.
- The grinding increased the roughness of the materials, except for the Vita Enamic. The smoothness of the glazed glass-ceramics was not achievable by the common polishing kits, while the Lava Ultimate and Vita Enamic showed a smoother surface compared with the baseline.
- The grinding followed or not by polishing did not affect adversely the fracture resistance of the materials.
- Mechanical aging did not reduce the fracture resistance of the materials, not even in the ground groups.
- The reliability of the evaluated materials under the scenario of the current study was not influenced by the material, surface treatment or aging.

# REFERENCES*

1. Van Noort R. The future of dental devices is digital. Dent Mater. 2012; 28: 3-12.

2. Sajjad A. Computer-assisted design/computer-assisted manufacturing systems: A revolution in restorative dentistry. Case Report. 2016; 16(1): 96-9.

3. Sannino G, Germano F, Arcuri L, Bigelli E, Arcuri C, Barlattani A. CEREC CAD/CAM Chairside System. Oral Implantol (Rome). 2015;7(3): 57-70.

4. Li RWK, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: state of the art. J Prosthodont. 2014; 58(4): 208–16.

5. Badawy R, El-Mowafy O, Tam LE. Fracture toughness of chairside CAD/CAM materials - Alternative loading approach for compact tension test. Dent Mater. 2016; 32(7): 847-52.

6. Fasbinder DJ, Dennison JB, Heys D, Neiva G. A clinical evaluation of chairside lithium disilicate CAD/CAM crowns: a two-year report. J Am Dent Assoc. 2010; 2: 10S- 4S.

7. Weyhrauch M, Igiel C, Scheller H, Weibrich G, Lehmann KM. Fracture strength of monolithic all-ceramic crowns on titanium implant abutments. Int J Oral Maxillofac Implants. 2016; 31(2): 304-9.

8. Della Bona A, Corazza PH, Zhang Y. Characterization of a polymer-infiltrated ceramic-network material. Dent Mater. 2014; 30: 564-9.

* [*] De acordo com o Guia de Trabalhos Acadêmicos da FOAr, adaptado das Normas Vancouver. Disponível no site da Biblioteca: http://www.foar.unesp.br/Home/Biblioteca/guia-de-normalizacao-atualizado.pdf

9. Monteiro JB, Oliani MG, Guilardi LF, Prochnow C, Rocha Pereira GK, Bottino MA, et al. Fatigue failure load of zirconia-reinforced lithium silicate glass ceramic cemented to a dentin analogue: effect of etching time and hydrofluoric acid concentration. J Mech Behav Biomed Mater. 2018; 77: 375-82.

10. Krejci I, Daher R. Stress distribution difference between Lava Ultimate full crowns and IPS e.max CAD full crowns on a natural tooth and on tooth-shaped implant abutments. Odontology. 2017; 105(2): 254-6.

11. Wang L, Liu Y, Wenjie S, Haliang F, Yongqing T, Zhizuo, M. Friction and wear behaviors of dental ceramics against natural tooth enamel. J Eur Ceram Soc 2012; 32: 2599-606.

12. Zandparsa R, El Huni RM, Hirayama H, Johnson MI. Effect of different dental ceramic systems on the wear of human enamel: an in vitro study. J Prosthet Dent. 2016; 115(2): 230-7.

13. D'Arcangelo C, Vanini L, Rondoni GD, De Angelis F. Wear properties of dental ceramics and porcelains compared with human enamel. J Prosthet Dent. 2016; 115(3): 350-5.

14. Janyavula S, Lawson N, Cakir D, Beck P, Ramp LC, Burgess JO. The wear of polished and glazed zirconia against enamel. J Prosthet Dent. 2013; 109(1): 22-9.

15. Amer R, Kürklü D, Kateeb E, Seghi RR. Three-body wear potential of dental yttrium-stabilized zirconia ceramic after grinding, polishing, and glazing treatments. J Prosthet Dent. 2014; 112(5): 1151-5.

16. Amer R, Kürklü D, Johnston W. Effect of simulated mastication on the surface roughness of three ceramic systems. J Prosthet Dent. 2015; 114(2): 260-5.

17. Ghazal M, Kern M. The influence of antagonistic surface roughness on the wear of human enamel and nanofilled composite resin artificial teeth. J Prosthet Dent. 2009; 101(5): 342-9.

18. Freddo RA, Kapczinski MP, Kinast EJ, de Souza Junior OB, Rivaldo EG, da Fontoura Frasca LC. Wear Potential of Dental Ceramics and its Relationship with Microhardness and Coefficient of Friction. J Prosthodont. 2016; 25(7): 557-62.

19. Schuh C, Kinast EJ, Mezzomo E, Kapczinski MP. Effect of glazed and polished surface finishes on the friction coefficient of two low-fusing ceramics. J Prosthet Dent 2005; 93: 245-52.

20. Oh WS, Delong R, Anusavice KJ. Factors affecting enamel and ceramic wear: a literature review. J Prosthet Dent 2002; 87: 451-9.

21. Suputtamongkol K, Wonglamsam A, Eiampongpaiboon T, Malla S, Anusavice KJ. Surface roughness resulting from wear of lithia-disilicate-based posterior crowns. *Wear* 2010; 269: 317-22.

22. Mair LH, Stolarski TA, Vowles RW, Lloyd CH. Wear: mechanisms, manifestations and measurement. Report of a workshop. J Dent 1996; 24: 141-8.

23. Seghi RR, Denry IL, Rosenstiel SF. Relative fracture toughness and hardness of new dental ceramics. J Prosthet Dent 1995; 74: 145-50.

24. Heintze SD, Cavalleri A, Forjanic M, Zellweger G, Rousson V. Wear of ceramic and antagonist-- a systematic evaluation of influencing factors in vitro. Dent Mater. 2008; 24(4): 433-9.

25. Preis V, Grumser K, Schneider-Feyrer S, Behr M, Rosentritt M. Cycle-dependent in vitro wear performance of dental ceramics after clinical surface treatments. J Mech Behav Biomed Mater. 2016; 53: 49-58.

27. Lawson NC, Janyavula S, Syklawer S, McLaren EA, Burgess JO. Wear of enamel opposing zirconia and lithium disilicate after adjustment, polishing and glazing. J Dent. 2014; 42(12): 1586-91.

28. Akar GC, Pekkan G, Çal E, Eskitaşçıoğlu G, Özcan M. Effects of surface-finishing protocols on the roughness, color change, and translucency of different ceramic systems. J Prosthet Dent. 2014; 112(2): 314-21.