Journal of Biomedical Optics

BiomedicalOptics.SPIEDigitalLibrary.org

Micrometric precision of prosthetic dental crowns obtained by optical scanning and computer-aided designing/computer-aided manufacturing system

Flávio Domingues das Neves
Thiago de Almeida Prado Naves Carneiro
Célio Jesus do Prado
Marcel Santana Prudente
Karla Zancopé
Letícia Resende Davi
Gustavo Mendonça
Carlos José Soares

SPIE.

Journal of Biomedical Optics 19(8), 088003 (August 2014)

Micrometric precision of prosthetic dental crowns obtained by optical scanning and computer-aided designing/computer-aided manufacturing system

Flávio Domingues das Neves,[a,*] Thiago de Almeida Prado Naves Carneiro,[a] Célio Jesus do Prado,[a] Marcel Santana Prudente,[a] Karla Zancopé,[a] Letícia Resende Davi,[a] Gustavo Mendonça,[b] and Carlos José Soares[c]
[a]Federal University of Uberlândia, Department of Occlusion, Fixed Prostheses and Dental Materials, Av. Pará, 1720, Bloco 4LA sala 4LA-42, Campus Umuarama, 38405-320, Uberlândia, Minas Gerais, Brazil
[b]University of Michigan, School of Dentistry, Department of Biologic and Material Sciences, Division of Prosthodontics, 1011 N. University, Ann Arbor, Michigan 48109-1078, United States
[c]Federal University of Uberlândia, Department of Operative Dentistry and Dental Materials, Av. Pará, 1720, Bloco 4LA sala 4LA-42, Campus Umuarama, 38405-320, Uberlândia, Minas Gerais, Brazil

Abstract. The current study evaluated prosthetic dental crowns obtained by optical scanning and a computer-aided designing/computer-aided manufacturing system using micro-computed tomography to compare the marginal fit. The virtual models were obtained with four different scanning surfaces: typodont (T), regular impressions (RI), master casts (MC), and powdered master casts (PMC). Five virtual models were obtained for each group. For each model, a crown was designed on the software and milled from feldspathic ceramic blocks. Micro-CT images were obtained for marginal gap measurements and the data were statistically analyzed by one-way analysis of variance followed by Tukey's test. The mean vertical misfit was $T = 62.6 \pm 65.2$ μm; $MC = 60.4 \pm 38.4$ μm; $PMC = 58.1 \pm 38.0$ μm, and $RI = 89.8 \pm 62.8$ μm. Considering a percentage of vertical marginal gap of up to 75 μm, the results were T = 71.5%, RI = 49.2%, MC = 69.6%, and PMC = 71.2%. The percentages of horizontal overextension were T = 8.5%, RI = 0%, MC = 0.8%, and PMC = 3.8%. Based on the results, virtual model acquisition by scanning the typodont (simulated mouth) or MC, with or without powder, showed acceptable values for the marginal gap. The higher result of marginal gap of the RI group suggests that it is preferable to scan this directly from the mouth or from MC. [DOI: 10.1117/1.JBO.19.8.088003]

Keywords: computer-aided designing/computer-aided manufacturing; CEREC Vita blocks; ceramics; micro-computed tomography; marginal fit; dental materials; optical devices.

Paper 140184R received Mar. 30, 2014; revised manuscript received Jun. 23, 2014; accepted for publication Jul. 14, 2014; published online Aug. 11, 2014.

1 Introduction

Chairside computer-aided designing/computer-aided manufacturing (CAD/CAM) systems are a reality in modern dentistry and the virtual model can be obtained with different methods. The crowns are manufactured based on the generated digital model by optical scanning of the mouth, regular impression (RI), or master cast (MC), which is directly controlled by the operator. After scanning, the crown is designed with a specific software using the virtual model, and a ceramic block is milled.

Historically, fixed prostheses are fabricated on MC made from a dental stone after the RI procedure. CAD/CAM equipment allows for obtaining the final restoration from an optical scanning directly from the mouth or from the MC in the laboratory. Therefore, most software allows its users to create a virtual model from the RI scanning without the need to obtain an MC.

The scanner CEREC 3D Bluecam (Sirona Dental Systems GmbH, Bensheim, Germany) allows one to obtain the virtual model from the three methods reported above and requires the intraoral powder application to scan directly in the mouth. The technical principle of the CEREC Bluecam scanner is that it projects a light stripe pattern on the object. As each light ray is reflected back to the sensor, the distance between the projected ray and reflected ray is measured. Because the fixed angle between the projector and sensor is known, the distance to the object can be calculated through the Pythagoras theorem, as one side and one angle (the fixed angle) of the triangle are now known.[1] The aerosol powder has to cover the prepared tooth, adjacent tooth, and mucosa, with a thickness sufficient to create an optimum image quality with a uniformly reflective surface for better scanning. Although there is the possibility to obtain the virtual model from all three methods, it is important to know if one has an advantage over the others regarding the marginal fit of the final crown.

The measurement of the marginal gap, which is a perpendicular measurement from the internal surface of the crown to the margin of the prepared tooth,[2] has been reported in the literature to establish a comparison of methods to obtain the virtual model.[3] Precise marginal fit of all-ceramic crowns is vital for long-term success because cement is the weak restorative link.[4] When cement dissolution occurs,[5] a fissure is established between the dentin and crown.

*Address all correspondence to: Flávio Domingues das Neves, E-mail: neves@triang.com.br

0091-3286/2014/$25.00 © 2014 SPIE

Different techniques have been chosen to evaluate the marginal fit of crowns. Most demand a transversal section of crown/tooth to measure the gap.[6–8] A new technique that uses micro-computed tomography (micro-CT) has been used to investigate the marginal gap and has the advantage of being nondestructive.[9–11] This technique allows the three-dimensional investigation of small objects with high resolution. The marginal gap is obtained within the range of a few micrometers at multiple sites and in multiple directions.[12] Furthermore, even very proximate sections are possible.[11]

Therefore, the current study evaluated the different methods for obtaining the virtual model with the chairside CEREC CAD/CAM system, using micro-CT to compare the marginal gap of feldspathic ceramic crowns. The null hypothesis was that different methods for obtaining a virtual model with the chairside CEREC CAD/CAM system would be similar.

2 Methods and Materials

2.1 *Sample Preparation*

A human lower left first premolar (#21) was mounted with its adjacent teeth on a typodont (T) and prepared by an experienced operator for an all-ceramic crown (Ethics Committee approval 381/06). A standard set of diamond burs (1014, 3145, 3098, 3098F - KG Sorensen, Barueri, Sao Paulo, Brazil) suitable for ceramic preparations was used. The preparation was free from undercuts, the angles were rounded, and the walls were tapered 6 deg to the occlusal surface. The margins were prepared with shoulders and rounded axiogingival line angles.[13] The groups were divided based on the method for obtaining the virtual model, with or without titanium dioxide powder using an aerosol (CEREC powder, VITA-Zahnfabrik, Bad Säckingen, Germany), according to Table 1.

Digital impressions were made for each group with the CEREC 3D Bluecam scanner (Sirona Dental Systems GmbH, Salzburg, Germany). The Bluecam was positioned as per manufacturer's instructions, and the optical images were taken.

All crown designs were made in CEREC 3D software 3.8 (Sirona Dental Systems GmbH) and the luting space and adhesive gap were set at 0 μm. The milling unit in Lab MC XL (Sirona Dental Systems GmbH) was used for CAM processing all designed crowns, using blocks of VITABLOCS Mark II (VITA-Zahnfabrik, Bad Säckingen, Germany). One experienced operator obtained all the crowns and the scanner and milling unit had been recently calibrated for this study.

2.2 *Measuring Procedure*

No internal adjustments, glazing, or polishing were made to the crowns before the marginal gap measurements to avoid any human interference. The prepared tooth was removed from the typodont and each crown was fitted and fixed. The fixing procedure was made for each crown at the same prepared tooth with a silicone material (Fit Checker, GC Dental Industrial Corp, Tokyo, Japan), by digital pressing, simulating a clinical situation (by a prosthetic specialist). To obtain images for marginal gap measurements, all samples were scanned using micro-CT (Micro-CT Scanco CT40, Scanco Medical AG, Zürich, Switzerland) at the Biological Research Imaging Center (University of North Carolina). Imaging was performed at 70 kVp and 112 μA with a resolution of 1024×1024 pixels. Pixel size and slice width were both 8 μm and the scan time was ~1 h. A total of ~600 two-dimensional images were

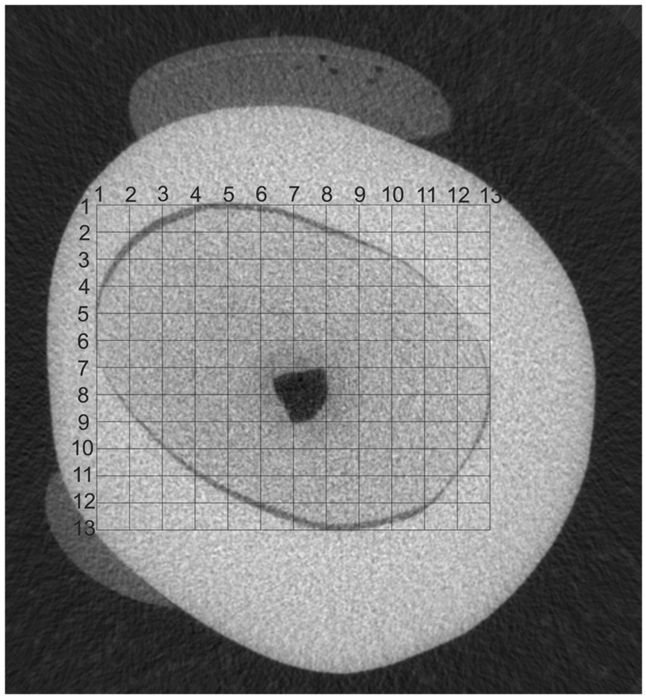
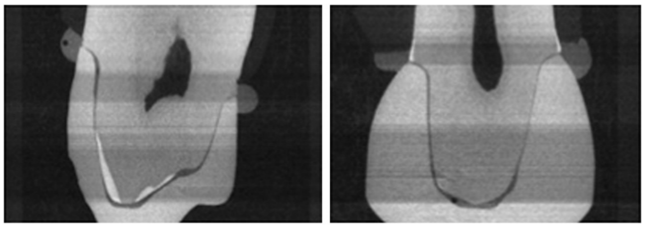


Fig. 1 Micro-computed tomography transaxial image of the crown and prepared tooth.

Table 1 Methods for obtaining the virtual model.

Group	Use of powder	Surface scanned	Material
Typodont (T)	X	Powdered tooth preparation	Human teeth
Regular impression (RI)	X	Powdered impression material	Polyvinyl siloxane impression material (Futura AD Regular, putty and light body, DFL Indústria e Comércio S/A, Rio de Janeiro, Brazil)
Master cast (MC)		Cast	Type IV dental stone (GC Fujirock EP, GC America Inc., Alsip, USA)
Powdered MC (PMC)	X	Powdered cast	Type IV dental stone (GC Fujirock EP, GC America Inc.)



(a) (b)

Fig. 2 (a) Sagittal image. (b) Coronal image.

acquired for each specimen. The transaxial images of the crown and prepared tooth were first obtained, as shown in Fig. 1.

Thirteen images from the sagittal set [Fig. 2(a)] and 13 from the coronal set [Fig. 2(b)] were selected to show the sample extension in two dimensions. From the total amount of the obtained images, the authors selected 13 images that were equally distributed between the first and last image in which the cervical margins appear. In each image, two measurements for horizontal fir and two for vertical misfit were done at 400× magnification using the CTAn processing software (Version 1.12.0.0, Skyscan, Kontich, Belgium).

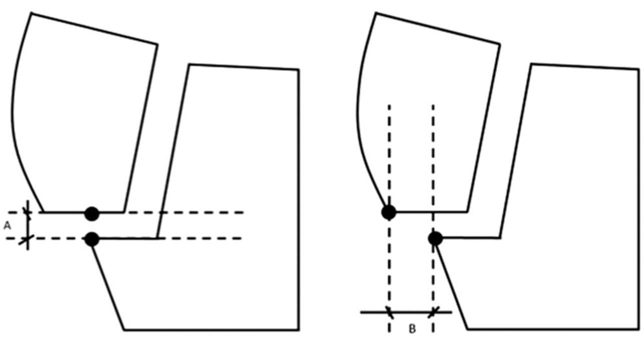
For vertical misfit, the measurements were made from the most external point at the preparation margin of the tooth to the crown margin [Fig. 3(a)]. For horizontal misfit, the measurements were made from the external crown margin to the most external point of the tooth [Fig. 3(b)].

The marginal gaps were measured at 52 sites for each sample, following Groten et al.'s[14] recommendations. In this way, 260 vertical misfit and 260 horizontal misfit measurements were done per group. Three independent examiners were involved in the measurements and the mean value was obtained. To ensure standardization among examiners, they were calibrated prior to the measurements.

2.3 *Statistical Analysis*

The values of the vertical measurements were submitted to statistical analysis by one-way analysis of variance followed by Tukey's *post hoc* test for pair-wise comparisons ($\alpha = 0.05$), using the statistical program Sigma Plot (Systat Software Inc. version 12.0, San Jose, California).

The vertical marginal gap values were grouped according to the following values: (1) up to 75 μm;[15] (2) 75 to 100 μm;[2,16,17] (3) 100 to 120 μm;[18] and (4) >120 μm.[19] These values were based on different reference values obtained in the literature.



(a) (b)

Fig. 3 (a) Vertical misfit. (b) Horizontal misfit.

However, in this study, we considered 75 μm as the maximum acceptable vertical gap to be considered clinically acceptable. Additionally, the horizontal measurement values were divided in three categories: (1) underextension, (2) equally extended, and (3) overextension of crowns fitted to the prepared finish line. The percentage for each category was calculated.

3 Results

The values of vertical marginal gap for each group are presented in Table 2.

The vertical marginal gap of VITABLOCS Mark II crowns made by RI protocol showed most of the measurements to be >75 μm (50.8%); for the other groups, most of the measurements were <75 μm. Vertical misfit values <75 μm were considered the ideal value in this study (Table 3).[2,15–19]

The horizontal measurement values were divided into the following categories: (1) underextension, (2) equally extended, and (3) overextension of the crowns fitted to the prepared finish line (Fig. 4).

4 Discussion

Although it is known that the smaller the marginal gap, the better the fit at the tooth/crown interface, there is no consensus about the acceptable value. Over the years, the criteria used range from 75 to >120 μm, as reported by several researchers.[2,15–19] For this study, because of the lack of consensus and the current technology available, the vertical gap values were categorized and grouped according to the different values presented in the literature.[2,15–19]

The conditions to evaluate the restoration for clinical acceptability depends on several factors, such as method of evaluation (clinical), instrument (explorer probe), examiner ability, and analyzed materials, all of which can lead to different results. *In vitro* studies evaluated the marginal fit of ceramic crowns with 5 to 25 samples for each test group and 6 to 50 sites for each crown, resulting in 60 or more marginal gap values analyzed per group.[3,7,8,10,20,21] Other studies performed only four

Table 2 Mean and standard deviation of vertical misfit (μm).

Typodont	Master cast	Powdered master cast	Regular impression
$62.6 \pm 65.2A$	$60.4 \pm 38.4A$	$58.1 \pm 38.0A$	$89.8 \pm 62.8B$

Note: Values with same letter are not significantly different ($p < 0.05$).

Table 3 Marginal fit percentage for each group.

	Up to 75 μm	75 to 100 μm	100 to 120 μm	>120 μm
T	71.5%	9.6%	3.9%	15.0%
RI	49.2%	12.3%	10.8%	27.7%
MC	69.6%	15.4%	7.3%	7.7%
PMC	71.2%	16.5%	7.7%	4.6%

Note: T, Typodont; RI, regular impression; MC: master cast; PMC, powdered master cast.

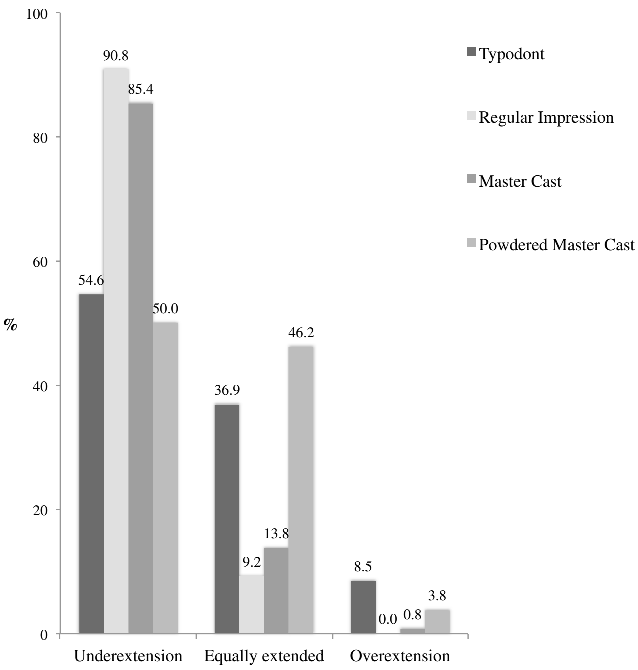


Fig. 4 Percentage of underextension, equally extended or overextension of crowns fitted to the prepared finish line.

measurements per sample,[2,15] which could not be representative of the marginal gap. This study evaluated five different crowns for each group fixed to the same tooth. Measurements were made at 52 sites in each crown, totaling 260 values for each group, in order to obtain clinically relevant information about the marginal gap (Table 2). The suggestion comes from a previous study[14] that reports that at least 50 measurements well distributed in the margin of a sample are necessary to obtain clinically relevant information. The methodology used in the present study permitted a larger number of measurements per sample. With a greater number of measurements, more confidence and accuracy can be achieved.

The measurements were performed in images originated from a micro-CT. Such equipment has been used to investigate the marginal fit and has the advantage of being a nondestructive technique compared to others. The stereomicroscope requires a transverse section of the crown and tooth to measure an internal misfit[7,20,22] and it can cause deformations.[7] Moreover, micro-CT allows the analysis in slices without any sample sections, so there is no overlap, unlike other techniques, such as scanning electron microscopy.[17,23] Measurements can occur at different distances along each section and the marginal zone, providing true three-dimensional reconstructions.[10] In the present study, it was possible to perform measurements at 400× magnification, facilitating the measurement procedure. In other studies, the maximum magnification described was ∼250×.[2,24] This method is a useful tool for the evaluation of the marginal fit of dental restorations.[10,11] However, micro-CT analysis can be expensive and time consuming.[25]

Another important issue to be considered is how the crown is fixed on the teeth for micro-CT scanning. Recent studies have used occlusal loading or a constant torque control device to keep the crown on the tooth with no need for cementation.[3,20,21] Another study used a clinical cementation process.[7] In this case, the sample is subjected to a transverse cutting method to measure its internal portion using a technique that can cause destructive deformation to the prosthesis.[26] The cementation process can damage the teeth and interfere with the results of the depth measurement.[9,27] Furthermore, the cement can increase the discrepancy of the marginal extent, since the excesses adhere to the tooth surface and to the restoration.[24] In our study, the same tooth was used with each crown and all the crowns were fixed by a prosthetic specialist with a silicone material, by digital pressing, simulating a clinical situation and standardizing the comparisons. It is noteworthy that after fixing, the crowns showed high resistance to being removed from the tooth, confirming that there was no movement during measurement.

Table 2 shows the percentage values related to the vertical misfit. The vast majority of problems related to failure in fixed prosthesis is caries due to microleakage at the cement line.[28] Thus, while the literature is still controversial,[2,15–19] the authors of the present study believe that the limit of acceptable misfit should be up to 75 μm, because it was the lower value described in the literature[15] for ceramic crowns.

Restorations with horizontal misfit facilitates food and bacteria retention,[29,30] making hygiene more difficult and leading to periodontal problems and cavities, reducing the longevity of rehabilitation. The authors handled the horizontal and the vertical misfit differently because it seems to have different clinical implications. When a horizontal misfit occurs, there is a possibility to make adjustments[31] in the crown or in the teeth before the cementation. When the vertical misfit occurs, there are no adjustment possibilities, leading to an increased risk of periodontal disease, microleakage, and recurrent caries.[30,32] So the authors presented the vertical misfit as being divided into four categories according to the literature[2,15–19] and, for horizontal classification,[33] considered the overextension as negative because it seems to be the worst situation, increasing the potential for plaque accumulation.

The marginal fit in CAD/CAM is dependent on the size of the drill, precision of the milling unit, digital model obtention,[3,21] and also the machine calibration and system for image capturing. So to make a fair comparison, it is necessary to consider the system, its version, the measurement technique, the type of restoration (crowns, inlays, onlays), and restorative material.[3] In this study, all machines were calibrated prior to the study and the parameters of the software were the same for all groups.

The groups scanned from MC showed good values for marginal fit. These MC all originate from the typodont RIs, suggesting that the RI was precise. The worst values found in the RI group should be related to a possible difficulty of scanning the surface of the impression material, even with the application of powder. The fact is that the groups T, MC, and powdered MC had a very similar behavior, inferring that restorations obtained by these three ways may achieve optimum fit, although direct scanning from the mouth provides restorations in a shorter time.

The position of the sample was not standardized into the micro-CT. In this way, it was impossible to correlate the marginal gap and at which site it occurred. In future studies, to standardize measurements, it would be interesting to use an index. Another interesting study is to variate the luting space parameters in the software to verify whether it interferes with the marginal gap of all-ceramic crowns obtained by CAD/CAM. Moreover, long-term clinical data are necessary to verify the efficacy and importance of these techniques.

5 Conclusions

Based on the results of this study, it was concluded that the virtual model obtained by scanning the mouth or the MC, with or without powder, showed acceptable values of marginal gap on feldspathic ceramic crowns (VITABLOCS Mark II) manufactured with a chairside CEREC CAD/CAM system, considering the ideal vertical misfit up to 75 μm. The higher values of the marginal gap for scanning the regular impression suggest that it is preferable to directly scan the mouth or the MC.

Acknowledgments

The authors would like to thank EIKON for CEREC CAD/CAM assistance. Also, the authors would like to acknowledge the Biological Research Imaging Center (University of North Carolina) for micro-computed tomography support and the University of North Carolina at Chapel Hill, School of Dentistry. This study was supported by FAPEMIG (Technical Scientific Fellowship—ETC00056/11).

References

1. O. Schenk, "The new acquisition unit Cerec AC," *Int. J. Comput. Dent.* **12**(1), 41–46 (2009).
2. J. R. Holmes et al., "Marginal fit of castable ceramic crowns," *J. Prosthet. Dent.* **67**(5), 594–599 (1992).
3. J. B. da Costa et al., "Evaluation of different methods of optical impression making on the marginal gap of onlays created with CEREC 3D," *Oper. Dent.* **35**(3), 324–329 (2010).
4. T. M. Lin et al., "Fracture resistance and marginal discrepancy of porcelain laminate veneers influenced by preparation design and restorative material in vitro," *J. Dent.* **40**(3), 202–209 (2012).
5. M. S. Jacobs and A. S. Windeler, "An investigation of dental luting cement solubility as a function of the marginal gap," *J. Prosthet. Dent.* **65**(3), 436–442 (1991).
6. C. Grenade, A. Mainjot, and A. Vanheusden, "Fit of single tooth zirconia copings: comparison between various manufacturing processes," *J. Prosthet. Dent.* **105**(4), 249–255 (2011).
7. A. Keshvad et al., "Marginal gap, internal fit, and fracture load of leucite-reinforced ceramic inlays fabricated by CEREC inLab and hot-pressed techniques," *J. Prosthodont.* **20**(7), 535–540 (2011).
8. B. A. Vanlioglu et al., "Internal and marginal adaptation of pressable and computer-aided design/computer-assisted manufacture onlay restorations," *Int. J. Prosthodont.* **25**(3), 262–264 (2012).
9. M. Borba et al., "Adaptation of all-ceramic fixed partial dentures," *Dent. Mater.* **27**(11), 1119–1126 (2011).
10. M. E. Krasanaki et al., "X-ray microtomographic evaluation of the influence of two preparation types on marginal fit of CAD/CAM alumina copings: a pilot study," *Int. J. Prosthodont.* **25**(2), 170–172 (2012).
11. S. Pelekanos et al., "Micro-CT evaluation of the marginal fit of different In-Ceram alumina copings," *Eur. J. Esthet. Dent.* **4**(3), 278–292 (2009).
12. D. Seo, Y. Yi, and B. Roh, "The effect of preparation designs on the marginal and internal gaps in Cerec 3 partial ceramic crowns," *J. Dent.* **37**(5), 374–382 (2009).
13. C. J. Goodacre, W. V. Campagni, and S. A. Aquilino, "Tooth preparations for complete crowns: an art form based on scientific principles," *J. Prosthet. Dent.* **85**(4), 363–376 (2001).
14. M. Groten et al., "Determination of the minimum number of marginal gap measurements required for practical in-vitro testing," *J. Prosthet. Dent.* **83**(1), 40–49 (2000).
15. S. H. Hung et al., "Marginal fit of porcelain-fused-to-metal and two types of ceramic crown," *J. Prosthet. Dent.* **63**(1), 26–31 (1990).
16. D. R. Davis, "Comparison of fit of two types of all-ceramic crowns," *J. Prosthet. Dent.* **59**(1), 12–16 (1988).
17. S. Reich et al., "Marginal fit of heat-pressed vs. CAD/CAM processed all-ceramic onlays using a milling unit prototype," *Oper. Dent.* **33**(6), 644–650 (2008).
18. J. W. McLean and J. A. von Fraunhofer, "The estimation of cement film thickness by an in vivo technique," *Braz. Dent. J.* **131**(3), 107–111 (1971).
19. F. Sulaiman et al., "A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns," *Int. J. Prosthodont.* **10**(5), 478–484 (1997).
20. M. R. Baig, K. B. Tan, and J. I. Nicholls, "Evaluation of the marginal fit of a zirconia ceramic computer-aided machined (CAM) crown system," *J. Prosthet. Dent.* **104**(4), 216–227 (2010).
21. K. B. Lee et al., "Marginal and internal fit of all-ceramic crowns fabricated with two different CAD/CAM systems," *Dent. Mater. J.* **27**(3), 422–426 (2008).
22. E. Yuksel and A. Zaimoglu, "Influence of marginal fit and cement types on microleakage of all-ceramic crown systems," *Braz. Oral Res.* **25**(3), 261–266 (2011).
23. R. C. Oyague, M. I. Sanchez-Jorge, and A. S. Turrion, "Evaluation of fit of zirconia posterior bridge structures constructed with different scanning methods and preparation angles," *Odontology* **98**(2), 170–172 (2010).
24. H. S. Pak et al., "Influence of porcelain veneering on the marginal fit of Digident and Lava CAD/CAM zirconia ceramic crowns," *J. Adv. Prosthodont.* **2**(2), 33–38 (2010).
25. P. Rungruanganunt, J. R. Kelly, and D. J. Adams, "Two imaging techniques for 3D quantification of pre-cementation space for CAD/CAM crowns," *J. Dent.* **38**(12), 995–1000 (2010).
26. L. Lu et al., "An open CAM system for dentistry on the basis of China-made 5-axis simultaneous contouring CNC machine tool and industrial CAM software," *J. Huazhong Univ. Sci. Technol. Med. Sci.* **31**(5), 696–700 (2011).
27. K. B. May et al., "Precision of fit: the Procera AllCeram crown," *J. Prosthet. Dent.* **80**(4), 394–404 (1998).
28. M. Goldman, P. Laosonthorn, and R. R. White, "Microleakage—full crowns and the dental pulp," *J. Endodont.* **18**(10), 473–475 (1992).
29. N. P. Lang, R. A. Kiel, and K. Anderhalden, "Clinical and microbiological effects of subgingival restorations with overhanging or clinically perfect margins," *J. Clin. Periodontol.* **10**(6), 563–578 (1983).
30. J. A. Sorensen, "A rationale for comparison of plaque-retaining properties of crown systems," *J. Prosthet. Dent.* **62**(3), 264–269 (1989).
31. J. Ng, D. Ruse, and C. Wyatt, "A comparison of the marginal fit of crowns fabricated with digital and conventional methods," *J. Prosthet. Dent.* **11** (2014).
32. I. Naert, A. Van der Donck, and L. Beckers, "Precision of fit and clinical evaluation of all-ceramic full restorations followed between 0.5 and 5 years," *J. Oral Rehabil.* **32**(1), 51–57 (2005).
33. F. D. Neves et al., "Micro-computed tomography evaluation of marginal fit of lithium disilicate crowns fabricated by using chairside CAD/CAM systems or the heat-pressing technique," *J. Prosthet Dent.* [Epub ahead of print] (2014).

Flávio Domingues das Neves is an associate professor in the Department of Occlusion, Fixed Prostheses, and Dental Materials at the Federal University of Uberlândia, Brazil since 1989. He received his DDS degree in 1987, specialist in prosthodontics in 1989, implant dentistry in 1994, master's degree in 1996, and PhD in 2000. He was a fellow at the UNC at Chapel Hill in 2012. He is a coauthor of the book CAD/CAM in restorative dentistry.

Thiago de Almeida Prado Naves Carneiro received his DDS degree from the Federal University of Uberlândia, School of Dentistry in 2010, specialist in implantology in 2011, master's degree in dentistry in 2013, and is a PhD student since 2013. He started private practice in 2010. He was a fellow at UNC in Chapel Hill in 2012. He is a coauthor of the book CAD/CAM in restorative dentistry.

Célio Jesus do Prado is an associate professor in the Department of Occlusion, Fixed Prostheses, and Dental Materials at the Federal University of Uberlândia, Brazil since 1993. He received his DDS degree in 1989, specialist in prosthodontics in 1992, master's degree in 1999, and PhD in 2003. He is a coauthor of the book CAD/CAM in restorative dentistry.

Marcel Santana Prudente received his DDS degree from the Federal University of Uberlândia, School of Dentistry in 2010, master's degree in dentistry in 2013, and is a PhD student since 2013. He was a fellow at UNC in Chapel Hill in 2012. He is a coauthor of the book CAD/CAM in restorative dentistry.

Karla Zancopé received her DDS degree from the Federal University of Uberlândia, specialist in prosthodontics in 2007, master's degree in

oral rehabilitation in 2011 and PhD in 2014 at the Federal University of Uberlândia, School of Dentistry, Uberlândia, Brazil.

Letícia Resende Davi is an associate professor in the Department of Occlusion, Fixed Prostheses, and Dental Materials at the Federal University of Uberlândia, School of Dentistry, Uberlândia, Brazil since 2012. She received her DDS degree in 2000, master's degree in oral rehabilitation in 2006, specialist in prosthodontics in 2009, PhD in 2010, and postdoctoral in 2013.

Gustavo Mendonça is a clinical associate professor in the Department of Biologic and Material Sciences at University of Michigan School of Dentistry. In 1999, he received his DDS degree from the Federal University of Uberlândia, School of Dentistry, Brazil. He completed his postgraduate training in prosthodontics and master's degree in oral rehabilitation in 2003. In 2008, he finished his PhD in genomic sciences and biotechnology at the Catholic University of Brasília, Brazil.

Carlos José Soares is an associate professor in the Department of Operative Dentistry and Dental Materials at Federal University of Uberlândia, School of Dentistry, Uberlândia, Brazil and researcher level 1C of National Council for Scientific and Technological Development. In 1991, he received his DDS degree, postgraduate training in operative dentistry in 1994, master's degree in operative dentistry in 2000, and PhD in 2003. In 2009, he finished his postdoctoral at Minnesota University, Minnesota.