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RESEARCH AND EDUCATION

Marginal and internal fit of CAD-CAM-fabricated composite resin and ceramic crowns scanned by 2 intraoral cameras

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ABSTRACT

Statement of problem. The precision of fit of chairside computer-aided design and computer-aided manufacturing (CAD-CAM) complete crowns is affected by digital impression and restorative material.

Purpose. The purpose of this in vitro study was to evaluate by microcomputed tomography (μCT) the marginal and internal adaptation of composite resin and ceramic complete crowns fabricated with 2 different intraoral cameras and 2 restorative materials.

Material and methods. Ten extracted human third molars received crown preparations. For each prepared molar, 2 digital impressions were made with different intraoral cameras of the CEREC system, Bluecam and Omnicam. Four groups were formed: LB (Lava Ultimate+Bluecam), EB (Emax+Bluecam), LO (Lava Ultimate+Omnicam), and EO (Emax+Omnicam). Before measuring the precision of fit, all crowns were stabilized with a silicone material. Each unit (crown + prepared tooth) was imaged with μCT, and marginal and internal discrepancies were analyzed. For the 2D analysis, 120 measurements were made of each crown for marginal adaptation, 20 for marginal discrepancy (MD), and 20 for absolute marginal discrepancy (AMD); and for internal adaptation, 40 for axial space (AS) and 40 for occlusal space (OS). After reconstructing the 3D images, the average internal space (AIS) was calculated by dividing the total volume of the internal space by the contact surface. Data were analyzed with 2-way ANOVA and quantile regression.

Results. Regarding marginal adaptation, no significant differences were observed among groups. For internal adaptation measured in the 2D evaluation, a significant difference was observed between LO and EO for the AS variable (Mann-Whitney test; $P<.008$). In assessment of AIS by the 3D reconstruction, LB presented significantly lower values than the other groups (Tukey post hoc test; $P<.05$). Bluecam presented lower values of AIS than Omnicam, and composite resin crowns showed less discrepancy than did ceramic crowns.

Conclusions. The marginal adaptations assessed in all groups showed values within the clinically accepted range. Moreover, the composite resin blocks associated with the Bluecam intraoral camera demonstrated the best results for AIS compared with those of the other groups. (J Prosthet Dent 2017;117:386-392)

The computer-aided design and computer-aided manufacturing (CAD-CAM) system is an innovative technology in which the planning and production of prostheses are carried out with the aid of a computer. For planning the restoration, this system contains a scanning tool for creating a virtual model of the prosthetic preparation on the computer screen. After virtual planning, information is sent to a milling unit for fabrication of the restoration[1] without intermediate manufacturing steps, thereby decreasing cost, time, and the risk of contamination during the interim restoration phase.[2] Three different production approaches are available: dental laboratory, centralized milling center, and chairside. For the chairside approach, the scanning instrument is an intraoral camera that replaces the conventional impression. This digital impression has the advantage of simplifying the workflow and allowing for the preparation and cementation of the crown in a single session.[3] Moreover, the single treatment session eliminates the need for an interim crown and consequently does not compromise the adhesion of the crown to the dentin surface because of residual interim cement.[4]

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Clinical Implications

Although both intraoral cameras and restorative materials showed clinical acceptability in terms of marginal and internal adaptation values, the average internal space was lower for composite resin crowns scanned by the intraoral camera that requires antireflective powder.

Presumably, all-digital systems would allow for better control of restoration fit because of the onscreen magnification of the scanned teeth and the ability to reexamine insufficiently reproduced areas.[5] However, no consensus has been reached, with many studies comparing the marginal and internal fit of conventional and digital impressions[6-15] and also those created by new methods such as cone-beam computed tomography.[16] Multiple factors may influence marginal and internal fit, including preparation design, margin location, impression and waxing techniques,[17] precision of the milling system, size of the milling bur, thickness of the cementation space and restorative material, and calibration of the milling machine and image-capturing system.[18-25] Thus, the longevity of dental restorations depends directly on the quality of the digital impression and the material of choice.

The Sirona CEREC AC system (Sirona Dental Systems GmbH) offers 2 options for intraoral cameras: Bluecam and Omnicam. Both cameras aim to eliminate the need for traditional impression procedures, generating data that will be electronically transmitted and used for the manufacture of in-office restorations in a single visit.[12] The CEREC AC Bluecam has a parallel blue LED beam and extended depth of field, which ensures image quality and usability. For this system, a titanium dioxide spray is applied to the entire dental surface to allow for detailed recording of the dentition.[13] The CEREC AC Omnicam is the first intraoral scanner of the CEREC system that does not require the application of titanium dioxide powder, resulting in a faster and easier scanning process. Furthermore, this system has the advantage of having a compact camera tip, with rounded outer edges, ensuring ease of movement inside the mouth. While the Omnicam system generates a color video recording, the Bluecam system works with overlapping photographs, which are later treated in the virtual model.[14]

Among the different materials used for CAD-CAM systems, ceramics represent the most studied category because of their esthetics, low thermal conductivity, and biocompatibility.[26,27] Lithium disilicate blocks have high resistance to fracture and a low material wear rate and are widely used in the fabrication of crowns, resulting in restorations with color and translucency similar to those of dental enamel. Because of the relative fragility and excessive wear of the antagonist tooth by ceramics, considerable progress has been made in composite resin materials. A recently marketed block of composite resin (Lava Ultimate; 3M ESPE) has been introduced to the CEREC system, featuring a nanoceramic resin technology developed with materials that combine the advantages of ceramic materials with those of highly cross-linked composite resins. This material is intended to absorb masticatory forces better, to reduce stress on the restoration, to present resistance to wear, to feature a good polishing surface and color stability, and to produce continuous and well-adjusted margins after the milling process.[28]

The purpose of the present study was to evaluate the marginal and internal adaptation of ceramic and resin crowns fabricated with the CAD-CAM CEREC system, with 2 intraoral cameras (Bluecam and Omnicam). Microcomputed tomography (μCT) was used to evaluate marginal and internal adaptation from average values of different cuts in the buccolingual and mesiodistal direction and the average internal space by means of 3-dimensional reconstruction. The first null hypothesis was that no difference would be found in the marginal and internal fit of ceramic and composite resin crowns. The second null hypothesis was that no difference would be found in the marginal and internal fit of crowns obtained by using either of the 2 intraoral cameras.

MATERIAL AND METHODS

This study was approved by the Ethics Committee at the School of Health Science of the University of Brasília (no. 43445315.0.000.0030). Ten sound and freshly-extracted third molars were collected from 16- to 20-year-old patients who provided informed consent. Before tooth preparation, each tooth was scanned with the intraoral cameras (Bluecam and Omnicam) to obtain images of the sound teeth to be used for planning the future restoration.

A complete-coverage preparation was made for each tooth with a coarse, tapered diamond rotary instrument with a rounded end (446KRF.017; KG Sorensen). The preparations had a total occlusal convergence of 12 degrees, an occlusal reduction of 2 mm, and a rounded shoulder finish line of 1.5 mm with rounded internal angle margins.

Another digital impression was made with both intraoral camera systems (Bluecam and Omnicam). For the Omnicam camera, after the clarity of the scan was ascertained, data were stored with the computer software (CEREC inLab SW4 v4.2.4; Sirona Dental Systems GmbH), which was used to design each complete crown. For the Bluecam camera, the specimen surfaces were covered with a homogenous amount of antireflection powder (CEREC Optispray; Sirona Dental Systems

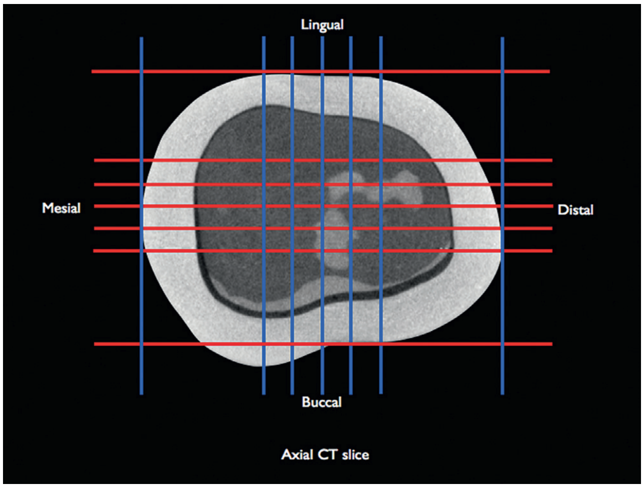

Figure 1. Central third of horizontal cut of microcomputed tomography scan image with 5 equidistant vertical cuts in buccolingual direction and 5 equidistant vertical cuts in mesiodistal direction.

GmbH). After the clarity of the scanning process was evaluated, data obtained from the Bluecam were stored (CEREC inLab software, v4.02; Sirona Dental Systems GmbH). For both intraoral cameras, the restoration design was based on the image made before the preparation. After each crown was designed, the information was sent to the milling unit (CEREC inLab MCXL SW4, v4.2.5; Sirona Dental Systems GmbH). The following parameters were used according to the manufacturing instructions: spacer=80 μm; occlusal-milling offset=125 μm; proximal contact strength=25 μm; occlusal contact strength=0; dynamic force of contacts=0; minimal thickness (radial)=500 μm; margin thickness (occlusal)=100 μm; instrument geometry considered=yes; and undercuts removed=yes.

Twenty complete crowns were fabricated with lithium disilicate ceramic blocks (IPS e.max CAD; Ivoclar Vivadent AG), and 20 complete crowns were fabricated with composite resin blocks (LAVA Ultimate; 3M ESPE). The ceramic blocks underwent a crystallization process under heat treatment (Programat P300; Ivoclar Vivadent AG) according to the manufacturer's recommendations. Four groups were formed: LB (Lava Ultimate+Bluecam), EB (Emax+Bluecam), LO (Lava Ultimate+Omnicam), and EO (Emax+Omnicam).

The marginal and internal discrepancies were evaluated by means of microcomputed tomography (Skyscan 1076 μCT; Bruker microCT) without internal adjustments. Before the precision of fit was measured, all crowns were stabilized with a silicone material (GC Fit Checker Advanced; GC Dental Industrial Corp). Each unit (crown + prepared tooth) was then stabilized in the scanning tube and positioned perpendicularly to the x-ray beam for scanning, which was performed at 100 kVp, 100 μA, and 9.05 mm pixels, with a 1-mm aluminum filter and a scanning time of around 140 minutes. Between approximately 1000 and 1200 slices were reconstructed with the imaging software (NRECON v1.6.3.3 Skyscan; Bruker microCT). Both CTan (v1.10.11.0; Bruker microCT) and Data Viewer (v1.4.3; Bruker microCT) software were used for the 2D quantitative analysis.

With the Data Viewer software, a central horizontal cut was used to define the upper and lower limits, with a central third for selection of the measured points. From this central third, 5 equidistant vertical cuts were made in the buccolingual direction and 5 in the mesiodistal direction (Fig. 1). This measuring method was adapted from Mously et al.[29] The number of slices between the cuts depended on the slice numbers of each specimen and usually varied between 45 and 50 cuts. The selection of measurement points was based on a description from Holmes et al[30] for the evaluation of internal and marginal discrepancies. For the 2D evaluation, 2 points of measurement for marginal discrepancy (MD) and 2 for absolute marginal discrepancy (AMD) were defined for measurement of the marginal adaptation, while 4 points of measurement for occlusal space (OS) and 4 points for axial space (AS) were defined for the internal adaptation (Fig. 2). With MD as the perpendicular distance between the intaglio of the crown and the tooth preparation, AMD was measured by the distance between the outer point of the crown margin and the tooth preparation. In total, 120 points of measurement were evaluated for each crown, and the mean of each outcome was used.

To measure the average internal space (AIS) with the 3D reconstruction, CT-analyzer software (CTan Skyscan; Bruker microCT) was used. For every transverse slice, a region of interest (ROI) was defined by selecting the limited area between the restoration and the tooth. Subsequently, all ROI images were grouped to form the volume of interest (VOI). The raw files were then converted into bitmap (bmp) files with NReconr Skyscan (Bruker microCT) and CTan Skyscan (Bruker microCT) to reconstruct the 3D images. The AIS was calculated by dividing the total volume of the internal space by the contact surface, which was a method used by Seo et al.[22] All measurements were made by a blinded calibrated examiner (A.C.S.).

Initially, a descriptive analysis was performed of the 2D and 3D evaluations for all outcomes. All outcomes were evaluated separately, with consideration given to the mean of each representative of that sample. The normal distribution and homogeneity of variance assumptions were verified. For the outcomes that did not violate those assumptions, a 2-way ANOVA (material and intraoral cameras) and Tukey-Kramer post hoc test were used. For those outcomes that violated the assumptions, a quantile (median) regression was performed, and the Mann-Whitney post hoc test was used.

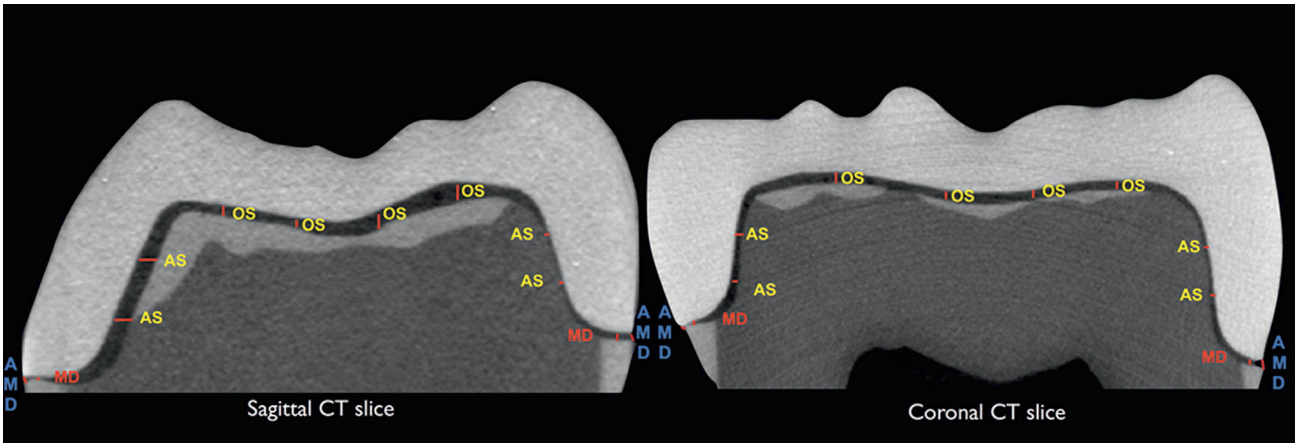

Figure 2. Sagittal and coronal cuts of microcomputed tomography scan image with measurement points for axial space (AS), occlusal space (OS), marginal discrepancy (MD), and absolute marginal discrepancy (AMD).

Table 1. Results of 2-way ANOVA for marginal discrepancy

Source	Sum of Squares	*df*	Mean Square	F	*P*
Model	616.8	3	205.6	0.33	.80
Material	102.4	1	102.4	0.17	.69
Intraoral camera	200.3	1	200.3	0.32	.57
Material×intraoral camera	314.2	1	314.1	0.51	.48
Residual	22 252.3	36	618.1		
Total	22 869.1	39	586.4		

Table 2. Results of two-way ANOVA for absolute marginal discrepancy

Source	Sum of Squares	*df*	Mean Square	F	*P*
Model	2313.5	3	771.2	0.76	.52
Material	1969.1	1	1969.1	1.95	.17
Intraoral camera	84.5	1	84.5	0.08	.77
Material×intraoral camera	259.8	1	259.8	0.26	.62
Residual	36438.4	36	1012.2		
Total	38751.9	39	993.6		

Table 3. Descriptive analysis for variables marginal discrepancy and absolute marginal discrepancy

Group	MD, Mean ±SD	AMD, Mean ±SD
LB (Lava Ultimate-Bluecam)	52 ±123	118 ±25
EB (Emax-Bluecam)	62 ±33	126 ±30
LO (Lava Ultimate-Omnicam)	61 ±25	138 ±34
EO (Emax-Omnicam)	60 ±24	135 ±36

Table 4. Results of quantile regression for occlusal space

Source	Coefficient	SE	*t*	*P*	95% CI
Material	34.125	32.82	1.04	.302	-31.25 to -99.5
Intraoral camera	17.7	32.82	0.54	.591	-47.68 to 83.07
Material×intraoral cameras	-0.47	46.42	-0.01	.992	-92.92 to 91.98
Constant	47.85	51.89	0.92	.359	-55.52 to 151.21

RESULTS

For marginal adaptation, the results of 2-way ANOVA regarding the variables MD and AMD are presented in Tables 1, 2. No difference was observed among the experimental groups for either outcomes for material, intraoral camera interaction, or each of these factors alone. Descriptive analysis of MD and AMD is presented in Table 3.

Tables 4, 5 present quantile regression analyses for OS and AS. The interaction between material and intraoral cameras was considered significant only for the AS variable. Both were described by medians and interquartile range (Table 6). For AS, a significant difference was observed between LO median (87 μm) and EO median (52 μm) (Mann-Whitney test; $P<.008$). No difference was observed compared with the other groups.

The results of 2-way ANOVA for AIS are presented in Table 7, while the mean, standard deviation, and minimum and maximum values are described in Table 8. Regarding the results obtained from 2-way ANOVA, both variable effects alone (restorative material and intraoral camera) as well as their interaction were considered significant ($P<.05$). The lowest value for AIS was obtained for LB, which was statistically significantly different from those for LO ($P=.003$), EO ($P=.001$), and EB ($P=.009$). When the isolated variables were analyzed by the Tukey-Kramer post hoc test, with only the intraoral cameras considered, the Bluecam showed lower values of AIS compared with those for Omnicam ($P=.021$). Regarding the variable material, the composite resin presented lower values of AIS compared with those presented by the ceramic ($P=.005$).

DISCUSSION

Only limited comparisons have been made of different intraoral cameras from CAD-CAM systems and restorative materials.[2,5,18] Thus, the present study evaluated the marginal and internal adaptations of complete crowns fabricated with ceramics and composite resin with 2 types of intraoral cameras and with μCT as the evaluation method. The results of the present study

Table 5. Results of quantile regression for axial space

Source	Coefficient	SE	*t*	*P*	95% CI
Material	20.675	7.99	2.59	.014*	4.48 to 36.87
Intraoral camera	-30.15	7.986714	-3.78	.001*	-46.34 to -13.95
Material×intraoral camera	40.025	11.29492	3.54	.001*	17.12 to 62.93
Constant	74.3	12.6281	5.88	<.001*	48.68 to 99.91

*Indicates statistical significance.

Table 6. Descriptive analysis for variables occlusal space and axial space

Group	OS, Median (IQR)	AS, Median (IQR)
LB (Lava Ultimate-Bluecam)	139 (35)	65 (5)[a,b]
EB (Emax-Bluecam)	166 (67)	74 (23)[a,b]
LO (Lava Ultimate-Omnicam)	188 (66)	87 (26)[a]
EO (Emax-Omnicam)	139 (47)	52 (26)[b]

IQR, interquartile range. Groups identified with same superscript letter do not indicate statistically significant difference (Mann-Whitney post hoc test, *P*<.05).

Table 7. Results of two-way ANOVA for average internal space

Source	Sum of Squares	*df*	Mean Square	F	*P*
Model	0.00104	3	0.000348	7.71	<.001*
Material	0.000502	1	0.000502	11.12	.002*
Chairside system	0.000353	1	0.000353	7.81	.008*
Material×chairside system	0.000189	1	0.000189	4.20	.048*
Residual	0.001625	36	0.0000451		
Total	0.00267	39	0.0000684		

*Indicates statistical significance.

Table 8. Descriptive statistical analysis for average internal space variable (3D)

	Average Internal Space (μm)				
Group	N	Mean	±SD	Minimum	Maximum
LB (Lava Ultimate-Bluecam)	10	34[a]	4	28	42
EB (Emax-Bluecam)	10	45[b]	9	29	58
LO (Lava Ultimate-Omnicam)	10	46[b]	7	34	55
EO (Emax-Omnicam)	10	47[b]	6	40	58

SD, standard deviation. Groups identified with same letter do not indicate statistically significant difference (Tukey post hoc test, *P*<.05).

support the rejection of the first and second null hypotheses regarding the internal fit of single crowns. Conversely, both null hypotheses were accepted for the marginal fit measures. The improvement of intraoral cameras for high-precision scanning procedures, sophisticated software, and milling standardization[6] has reduced the marginal discrepancy of crowns produced by CAD-CAM systems.[3] A recent systematic review found no significant difference in the marginal discrepancies of single-unit ceramic restorations fabricated with digital impressions and those fabricated with conventional impressions.[3]

In the 2D evaluation, no statistically significant differences were observed among the experimental groups for the MD and AMD variables. Several studies that used μCT reached the consensus that a marginal discrepancy below 120 μm is clinically acceptable[2,18] in terms of longevity. Regarding the MD variable, the experimental groups showed values that varied from 52 to 62 μm, similar to those in the study by Mously et al,[29] who reported values of 55.18 and 49.35 μm for crowns with 30- and 60-μm spacing. These values are within the acceptable limits of horizontal marginal discrepancy for cemented restorations. Differences of marginal discrepancy in the in vitro studies are directly related to the space given to the cementing agent, since, according to Anadioti et al,[13,14] the choice of spacing less than 40 μm prevents the crown from settling, resulting in increased marginal discrepancy.

Regarding the AMD variable, several authors have suggested that its maximum value should be between 50 and 120 μm.[23,31] However, higher values of marginal discrepancies and thicknesses of cementation spaces have already been reported, ranging from 120 to 250 μm.[32] In the present study, values ranging from 118 to 137 μm were obtained for AMD, and no significant difference was found among groups. Despite being slightly above the maximum value suggested (120 μm), the values obtained by the analysis methodology (μCT) were more precise than those obtained by the methodologies mentioned in the previous studies. Moreover, the difference found was relatively small, which suggests that it is not significant in clinical practice.

In the 2-dimensional evaluation of the internal discrepancy, significant differences were observed for the AS variable, for which the Bluecam intraoral camera showed no statistically significant difference regarding the choice of the restorative material used. Omnicam, in turn, in the evaluation of the type of material used, presented a significant difference between LO and EO. In spite of this difference, these values are within the limit established by Borba et al,[2] who reported that an axial space (AS) value similar to 122 μm may reduce the crown resistance to fracture. For the OS variable, LB presented the lowest value (138 μm), although it was not considered statistically significantly different from those of the other groups.

In the 3D evaluations (AIS), LO had the lowest value of discrepancy between the crown and the preparation, statistically significantly different from that of the other groups. This 3D evaluation allowed for determination of the dimensions of the entire internal discrepancy volume with the contact surface. The 3D analysis takes into account the entire delimitation of the existing space between the crown and the preparation, giving a general overview. The 2D analysis is more subjective, as the average of the measurements is obtained in selected cuts from the μCT images and this selection is performed arbitrarily by the researcher. When vertical marginal discrepancy increases (internal adaptation), the resistance to fracture of the ceramic restorations may decrease, since these regions with high internal discrepancy values may induce different load concentrations, making the crown more susceptible to fracture.[18,28] Uniformity of the cement space is important to avoid compromising the forms of retention and resistance, especially for ceramic restorations that have brittle behavior.

According to Seo et al,[22] although marginal fit from CAD-CAM crowns has become more acceptable, internal fit is still a concern and is dependent on the milling tool of the CAM machine. Depending on the design of the tooth preparation and the internal angles, the sizes and shapes of the milling burs may not be accurate enough to reproduce. Moreover, the die spacer is also reported to influence internal adaptation.[29] In our study, a single milling unit was used to produce all crowns, and the 80-μm spacer was used for all to avoid variances among groups.

When only the intraoral cameras were considered, a better adaptation for the Bluecam groups was obtained. The use of antireflective powder is suggested to improve image capturing and detailing, showing a better result and making it possible to state that the intraoral camera interferes with the results of discrepancy between the crown and dental preparation of single crowns manufactured with the CAD-CAM system. When the material was evaluated, significant differences were observed between the ceramic and composite resin. Physical characteristics such as hardness, extra steps, and crystallization may have interfered with the results obtained, leading to differences between the materials.[26,27] The composite resin presented the lowest values of internal discrepancy, probably because of the properties provided by the organic matrix, such as resilience.

The marginal adaptation of crowns fabricated with the CAD-CAM technology depends on the precision of the milling system, the scanning of the model, the size of the milling bur, and the calibration of the machine and the image capture system. Thus, for a fair comparison to be made, the system, its version, its measurement technique, the type of restoration (crowns, inlays, or onlays), and the restorative material should be considered.[24] Despite the limitations of the present study, which included the scanning of a single tooth in the absence of proximal contacts and noncementation simulation, among others, the results indicated that all experimental groups had marginal and internal adaptation values within clinically acceptable standards. The use of CAD-CAM technology ensures an adequate marginal adaptation, adding speed associated with efficiency and precision in clinical applications.

CONCLUSIONS

Based on the results of this in vitro study, the following conclusions were drawn:

1. All experimental groups presented clinically acceptable marginal and internal adaptation.
2. The restoration material and the intraoral camera used for the digital impression may affect the internal adaptation of CAD-CAM-fabricated complete crowns, with the Bluecam system and resin material presenting the lowest values of internal discrepancy.

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Noteworthy Abstracts of the Current Literature

Frequency and type of prosthetic complications associated with interim, immediate loaded full-arch prostheses: A 2 year retrospective chart review

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Purpose. The purpose of this report was to retrospectively evaluate implant and immediate full-arch prosthesis survival rates over a 24-month period; patients were consecutively treated with immediate occlusal loading. Dental arch, gender, and implant orientation (vertical vs. tilted) were also noted.

Materials and Methods. All Brånemark System implants (Nobel Active) and interim, all-acrylic resin prostheses placed in patients following an All-on-Four™ protocol, in a single private practice were assessed by retrospective patient chart review. The amount of space provided surgically for implant restorative components and prostheses was determined from measurements of the vertical heights of the interim prostheses in the right/left anterior and posterior segments. These measurements were made in the laboratory. Interim prosthetic repairs (type, frequency, length of time from insertion) were analyzed by type, arch, gender, and implant orientation. Implant survival and insertion torque values were also measured. Inclusion criteria consisted of all Brånemark System implants placed with the All-on-Four protocol from September 1, 2011, until August 31, 2013. Specific dietary instructions were given for the first 7 days immediately postoperatively and for the weeks prior to insertion of the definitive prostheses.

Results. One hundred twenty-nine patients, comprising 191 arches (766 implants) from September 1, 2011, until August 31, 2013, were included in the study. One patient experienced implant failure yielding an overall implant survival rate (SR) of 99.5% (762 of 766). Four hundred twenty-six of 430 maxillary implants and 336 of 336 mandibular implants survived for SRs of 99.1% and 100%, respectively. Regarding implant orientation, 415 of 417 tilted implants (SR 99.5%) and 343 of 345 (CSR 95.6%) vertical implants were noted to be clinically stable. Interim, all-acrylic resin prostheses were in place for a mean of 199.2 days; mandibular prostheses were in place for an average of 195.4 days; maxillary prostheses were in place for an average of 202.0 days. Thirty four of the 191 interim prostheses (17.8%) warranted at least one repair during the treatment period. The average overall implant insertion torque value was 60.74 Ncm; mandibular torque values averaged 63.08 Ncm; maxillary torque values averaged 59.00 Ncm.

Conclusion. The results from this study suggest that dental arch, gender, and implant orientation for implants placed and immediately restored with interim, all-acrylic resin, full-arch prostheses per the All-on-Four protocol did not have significant statistical or clinical effects on prosthetic complications of the interim prostheses or implant survival. Only one of the 129 patients experienced implant failures, indicating that the All-on-Four treatment protocol used in this study is a viable alternative to other protocols for rehabilitating edentulous patients.

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