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Factors Affecting the Accuracy of Surgical Guide

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Abstract

To compare the accuracy of surgical guides manufactured with two different 3D printers, two resins, two different occlusal designs (OS: original shape, and GS: groove sealing), and interactions of these factors were used. Forty surgical guides were printed on a digital light processing (DLP) printer and a Liquid Crystal Display (LCD) printer, with two resin types (SG guide and V-guide) and two occlusal designs. The region where the implant was planned was digitally removed from the cast, allowing passive positioning of the implant through the guide. A scan body was inserted in the implant, and the cast was scanned with an intraoral scanner. The planned implant compared with the actual implant position. Six measurements representing the accuracy of implant placement: (depth, angular, global apical, horizontal apical, global coronal, and horizontal coronal) deviations. Descriptive statistics and a multivariate analysis of variance (MANOVA) were conducted. Printer type had a statistically significant multivariate effect (Wilks' Lambda = 0.015, $p < 0.001$, Partial $\eta^2 = 0.985$). The resin type had no multivariate effect on the combined dependent variables, as indicated by Wilks' $\Lambda = 0.727$, $p = 0.161$. Occlusal shape showed a significant multivariate effect (Wilks' Lambda = 0.015, $p<0.001$). The univariate tests revealed that printer type and the shape of the occlusal surface had a statistically significant effect on all six deviation parameters ($p < 0.001$ for all); however, resin type had a significant effect only on horizontal coronal deviation ($p = 0.018$). The multivariate analysis using Wilks' Lambda revealed a significant interaction effect between printer and resin (Wilks' $\Lambda = 0.593$, $F(6,27) = 3.094$, $p = 0.019$, Partial $\eta^2 = 0.407$), A significant interaction was also observed between printer and occlusal design (Wilks' $\Lambda = 0.445$, $F(6,27) = 5.606$, $p = 0.001$, Partial $\eta^2 = 0.555$) and between printer, resin, and occlusal surface (Wilks' $\Lambda = 0.414$, $F(6,27) = 6.380$, $p < 0.001$, Partial $\eta^2 = 0.586$). The DLP printer group and groove sealing group were more accurate than the LCD printer, and occlusal surface group. The accuracy of both SG and V-guide resins was the same.

Introduction

Implant-based rehabilitation is better treatment for patients who have lost teeth [1,2]. Implant dentistry was focused on implant geometry and osseointegration. Implant success depends on surface topography, especially roughness, which improves osseointegration [3-7]. Modern implantology puts the most emphasis on osseointegration, cosmetic restoration, and tissue health [8,9]. If an implant is poorly designed, it might irritate soft tissue and induce bone loss around the implant. There may be several problems with dental care [10,11]. 3D digital technology can help with these problems by making things more accurate and better in the clinic [12]. Intraoral scanners can make 3D virtual models without the need for impression. They also help keep digital data safe for future and more comfortable for patient [13,14].

Additive manufacturing, which deposits layers of material repeatedly, enables the fabrication of precision dental components [15,16]. The concept of prosthetically driven implant surgery entails that the desired final restoration must be initially designed and utilized as a reference for the placement of the dental implant. It is a multi-factorial

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approach that necessitates radiographic assessment, arch scanning, virtual creation of the treatment plan, surgical guide design and fabrication, and implant insertion with an implant drill kit [17,18].
Digital surgical guidance enhances implant placement accuracy; however, errors in depth and angulation can still occur [19]. Implant displacement can result from issues with the accuracy of 3D-printed surgical guides, including variations in printing technology, printer type, and resin composition [20]. Furthermore, the occlusal surface often presents intricate anatomical features—such as fissures and grooves that can hinder the proper seating and adaptation of the surgical guide [21].
The aims of this study were to compare accuracy of implants placed with 3D printed surgical guides made by two different types of 3D printers (DLP and LCD), to compare the accuracy of the surgical guide made by two different resins, and to compare the accuracy of the surgical guide made by two different occlusal surfaces.

Materials and Methods

Samples (40 implants and 40 surgical guides) were categorized into two groups based on the type of 3D printer (DLP and LCD). Within each 3D printer category, they were further divided into two groups according to the resin material (SG guide and V-guide). Subsequently, each group was split into two subgroups based on the sealing of grooves on the occlusal surfaces of posterior teeth: (A) original shape (OS) and (B) groove sealing (GS). Patients included were older than 18 years, with good oral hygiene, missing one tooth with low bone height and width, good gingival health and no periodontal or systemic disease that prevented implant placement.
A cone-beam computed tomography (CBCT) scan and an intraoral scan by (MD-ISO300, Medit i700, bf2203100023, made in Korea) were obtained from a patient who presented to the Department of Prosthodontics at Mosul University Dental Clinics with a single missing lower left first molar (tooth no. 36). The diagnostic images used in this in vitro study were collected after obtaining informed consent and ethical approval (Reference No.: UoM.Dent. 25/1010). Two digital designs of the surgical guide were created. In the first design, the STL file preserved the original occlusal anatomy of the posterior teeth, whereas in the second, the occlusal surface was digitally sealed using *Exocad 3.1 Rijeka* software. The implant site was virtually outlined and segmented from the same digital model to avoid any effect of the drilling process on the final implant position and to allow easy removal of the implant after placement for subsequent scanning [21]. Finally, twenty resin casts with sealed occlusal surfaces and twenty casts maintaining the original occlusal morphology were fabricated using 3D printing technology. As this study was in vitro, CBCT and oral scanner of one patient was enough to plan and print 40 cast for implant placement.
The Digital Imaging and Communication in Medicine (DICOM) files obtained from the CBCT scan and the Standard Tessellation Language (STL) files generated from the intraoral scan were imported into the implant planning software and accurately aligned using a best-fit alignment algorithm [23]. The virtual implant planning was conducted with Blue Sky Bio Plan 4 software (Blue Sky Bio, LLC, USA) as shown in Figure 3. Considering both the prosthetic requirements and the patient's anatomical conditions, an implant of appropriate dimensions was virtually positioned within the software environment [24]. A C-TECH implant (C-TECH Implant, Italy; Lot no. EL-6070) with a diameter of 4.3 mm and a length of 11 mm was selected for this study.
The design parameters for the master surgical guide were standardized to ensure precision and consistency. The guide was created with a wall thickness of 3 mm, an offset of 0.5 mm from the adjacent teeth, and a sleeve offset of 0.05 mm. A guide tube with a diameter of 5.9 mm was intended for the chosen implant system, which meant that a guide hole of 6.2 mm needed to be printed. To make it easier for doctors to check that the seating was correct, each template had viewing windows that were placed symmetrically, so that the guides' fit could be seen directly during placement [25]. Surgical guides were used fully guided implant placement and cover the whole arch.
Forty surgical guides were made and split evenly based on the 3D printing technology. A DLP printer (Phrozen Luimi 8K, Phrozen Technology, China) made twenty (n = 20) guides, and an LCD printer (Creality HALOT-MAGE Pro 8K, Creality, China) made another twenty (n = 20). Two separate resins were employed for each printing technology: V-GUIDE resin (Crown for Dental and Medical Supply, USA) and SG GUIDE resin (Senertek, Turkey; Batch No. 9342EEC). Ten samples were printed with the first resin, and 10 samples were printed with the second resin for each printer.
There were two design subgroups for each resin group, one for each cast design: OS and GS. Thus, for every resin type, five (n = 5) OS-design and five (n = 5) GS-design guides were fabricated, resulting in a balanced design across printer types, resin materials, and guide designs.
Both systems used the same printing settings to make sure the comparison was fair. The layer thickness, lifting height, lifting speed, and light-off delay were all adjusted to 0.04 mm, 5 mm, 5 mm/s, and 1 s, respectively, for the Phrozen Luimi 8K (DLP) and Creality HALOT-MAGE Pro 8K (LCD) printers. To help the samples stick together better while printing, all of them had three bottom layers.
DLP and LCD technologies use different ways to project light (digital micromirror device vs. masked LCD illumination). To make sure the selected resin materials polymerized properly, the exposure times for both the first and second layers were changed according to each manufacturer's instructions. This method is based on earlier studies that looked at DLP and LCD printers for dental use. In those studies, most of the printing settings were the same, but the exposure settings were changed to account for differences in light intensity and projection efficiency [23,26]. After printing, using an ultrasonic cleaning device (Digital Ultrasonic Cleaner, China), the 3D printed surgical guides were carefully taken off the build platform and cleaned twice in 99% isopropyl alcohol (IPA) for 5 minutes each. This was done to get rid of any uncured resin residues.
The Phrozen Post-Curing Unit (Phrozen, China) was used to post-cure samples printed using the DLP printer (Phrozen Luimi 8K, Phrozen Technology, China). This unit uses 405 nm LEDs to cure the samples.
The Anycubic Wash & Cure Plus machine (Anycubic, China) was used to wash and cure the samples made using the LCD printer (Creality HALOT-MAGE Pro 8K, China). It has a single chamber and a 405 nm LED light source. According to the manufacturer's instructions, printed guides were air-dried for 10 minutes and then cured for 15 minutes on each side in both systems.
To make sure the fit was right, each surgical template was carefully seated onto its corresponding master cast. A guided implant mounter with a stop-wide that connected with a ratchet connection was used to set the final position of the implant. This made sure that the insertion depth and stability were controlled during installation. The implants utilized in this investigation (C-TECH Implant, Italy; Lot no. EL-6070) were held in place on the master cast with a medium-viscosity elastomeric A-silicone material (Silginat, Kettenbach GmbH & Co. KG, USA; Lot no. 1382611). Before further investigation, this process made sure that each implant was correctly indexed to its cast.
To assess the precision of the final implant placement, scan bodies were affixed to the placed implants in each printed model. This study used the EL Scan Body, which is made

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of PEEK and titanium (C-TECH Implant, Italy; Lot no. EL-6070). Each model with its attached scan body was scanned using an intraoral scanner (*MD-ISO300, Medit i700, BF2203100023; Medit Corp., Korea*), generating a digital representation of the cast and implant position. The scan body was then digitally aligned with the corresponding library file within the software environment [11].

An intraoral scanner was selected over an extraoral scanner because the Medit I500 intraoral system has demonstrated higher accuracy in transferring implant positions compared to the Rainbow extraoral scanner [27]. The preoperative virtual plan and the postoperative implant positions were superimposed [28] using Blue Sky Bio software to assess positional deviations [29]. The overall accuracy of the 3D-printed surgical guides was analyzed following international standards and previously validated methodologies [23,30,31].

Trueness was evaluated by measuring the linear deviation (in millimeters) between each virtually planned implant and its corresponding actual implant position using Blue Sky Plan software (Blue Sky Bio, USA). The printed models were superimposed on the reference STL files through the software's built-in alignment function, and deviation values were calculated using a digital caliper on software at the selected reference points at the coronal, apical, and angular positions [11].

Six deviation metrics were recorded for each sample that represent trueness: angular deviation (°), depth deviation (mm), horizontal coronal deviation (mm), global coronal deviation (mm), horizontal apical deviation (mm), and global apical deviation (mm). To find the precision, we found the standard deviation (SD) of the deviation values in each subgroup (n = 10). A smaller SD number meant that the printing process was more repeatable when the conditions were the same. After that, we used both the mean deviation and the SD data to evaluate the dimensional accuracy of the two printing technologies (DLP vs. LCD), two resins (SG and V-guide) and the two occlusal guide designs (OS vs. GS).

The study's data were statistically analyzed using version 25 of the SPSS (Statistical Package for the Social Sciences) program. Mean (M), standard deviation (SD), and number of specimens (N) measured in descriptive statistics.

Using a multivariate analysis of variance (MANOVA), we looked at how the form of the occlusal surface (Occlusal), resin material (Resin), and the type of printer (Printer) affected the six dependent variables. The results of the univariate tests showed which of the six dependent variables each independent variable had a significant impact on (Printer, Resin, and Occlusal). A P value of 0.05 or less was considered statistically significant, a P value of 0.01 or less was considered very significant, and a P value greater than 0.05 was considered not statistically significant.

Results

Table 1 shows descriptive statistics for all six parameters—angular, depth, horizontal coronal, global coronal, horizontal apical, and global apical— for printer type, resin type, and occlusal design.

A multivariate analysis of variance (MANOVA) was performed to investigate the effect of printing technology (Printer), resin material (Resin), and occlusal surface design (Occlusal) on six dependent variables indicative of implant placement accuracy: depth deviation, angular deviation, global apical deviation, horizontal apical deviation, global coronal deviation, and horizontal coronal deviation. Table 2 shows that Wilks' Lambda was used to measure the multivariate effect. The results showed that printer type had a statistically significant multivariate effect on the combined dependent variables. The kind of resin did not have a multivariate influence on the combined dependent variables. Occlusal shape exhibited a significant multivariate effect. The multivariate analysis using Wilks' Lambda revealed a significant interaction effect between printer and resin (Wilks' Λ = 0.593, F = 3.094, p = 0.019, Partial η^2 = 0.407), A significant interaction was also observed between printer and occlusal design (Wilks' Λ = 0.445, F = 5.606, p = 0.001, Partial η^2 = 0.555) and between printer, resin, and occlusal surface (Wilks' Λ = 0.414, F = 6.380, p < 0.001, Partial η^2 = 0.586). In contrast, the resin × occlusal interaction was not significant (p = 0.390, Partial η^2 = 0.196), indicating that these two factors did not jointly affect the measured deviations

The univariate tests (Table 3) revealed that the printer type exerted a statistically significant influence on all six deviation measures (p < 0.001 for all). The corresponding Partial Eta Squared (η^2) values ranged from 0.794 to 0.957, showing that all parameters had large effect sizes. The univariate analysis demonstrated that resin type significantly influenced horizontal coronal deviation (p = 0.018), indicating a modest impact size. There were no significant changes (p > 0.05) for angular, depth, global coronal, horizontal apical, or global apical deviations. The univariate tests (Table 3) showed that the shape of the occlusal surface had a statistically significant effect on all deviation parameters (p < 0.001). The univariate tests revealed that the interaction between printer and resin had a statistically significant effect on global apical deviation (F = 6.768, p = 0.014, Partial η^2 = 0.175). This indicates that the combination of printer type and resin material influenced the accuracy at the apical region, with the interaction explaining approximately 17.5% of the variance — a moderate effect size. No significant interaction effects were observed for the other deviation parameters (p > 0.05). The univariate tests (as in Table 4) indicated that the interaction between printer type and occlusal surface shape had a statistically significant effect on horizontal apical deviation (F = 34.215, p < 0.001, Partial η^2 = 0.517). The univariate tests showed that the interaction between resin type and occlusal surface shape did not have a statistically significant effect on any of the measured deviation parameters (p > 0.05). The univariate tests demonstrated that the interaction between printer, resin type and occlusal surface shape had statistically significant effects on both horizontal coronal and global apical deviations (F = 25.510, p < 0.001, Partial η^2 = 0.444; F = 6.017, p = 0.020, Partial η^2 = 0.158).

Discussion

Possible deviations between the preoperative plan and the postoperative implant positions require attention because they may lead to undesirable clinical consequences. Deviations at the shoulder of the implant can significantly affect prosthetic planning, whereas deviations at the apex of the implant can lead to the violation of important anatomic landmarks and perforations [32].

The null hypothesis rejected for Printer type and Occlusal surface design and accepted for Resin type.

The results indicated that the kind of printer exerted a statistically significant multivariate effect on the combined dependent variables. This shows that the type of 3D printer (DLP or LCD) had a big impact on the overall accuracy findings, with a big effect size. This indicates that the type of 3D printer (DLP or LCD) significantly influenced the overall accuracy results, exhibiting a substantial effect size. The univariate tests demonstrated that the printer type exerted a statistically significant influence on all six deviation measures. The Partial Eta Squared (η^2) values indicated that all parameters had substantial impact sizes.

The fundamental difference between DLP and LCD printers is how the light source is set up. Using only one digital micromirror device, DLP printers show the whole layer at once. In contrast, LCD printers employ a pixel-based mask that is illuminated by UV LEDs, which may result in uneven light distribution and distinct curing at the print area's edges. This increases the size and

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polymerization stability of the DLP system. Because DLP printers project light precisely, they are incredibly accurate. Each of the DMD's millions of tiny mirrors can be manipulated to direct light in a specific direction. Because the UV projector is more powerful than LCD printers, you can precisely control the curing process, which smoothers the surfaces [26].
The results of the present investigation agree with those of Sim et al [33], who concluded that DLP and SLA printers were more accurate, with DLP performing better in both linear and angular deviations. DLP 3D printers are also more accurate than LCD 3D printers, according to Moon et al. [31] and Tsolakis et al. [34] as well. This study disagrees with Kim et al. [35] who suggested that, for dental casts, all 3D printers analyzed performed similarly.
The type of resin did not have a big effect on the aggregated accuracy metrics, as shown by the results of the multivariate analysis of variance (MANOVA). there was no significant difference between the two resin groups when all types of deviation were looked at together.
The univariate tests, on the other hand, showed a small effect size and a big difference in the horizontal coronal deviation. This suggests that the resin type may have influenced the coronal level lateral precision, possibly due to slight variations in mechanical rigidity, light transmission, or polymerization shrinkage between the two materials. The angle, depth, global coronal, horizontal apical, and global apical deviations didn't alter much ($p > 0.05$). It demonstrates that both resins effectively preserved precise measurements during the construction of the surgical guide, as most features are identical. These results are consistent with a recent study by Tsolakis et al. [26], which indicated that resin material does not influence overall accuracy and precision when similar printing processes and post-processing methods are utilized.
This study disagrees with Keßler et al. [20] who concluded that the resin material affected the precision of 3D-printed surgical guides.
A significant multivariate effect was observed in the occlusal design. The results of the univariate tests showed that all deviation parameters were statistically significantly impacted by the occlusal surface's shape. Angular, depth, horizontal, and global coronal and horizontal and global apical deviations were all significantly different. All Partial Eta Squared values showed large effect sizes indicating that the shape of the occlusal surface explained a significant amount of the variance in deviation values, which is consistent with Lim et al. [36] who concluded that taking occlusal groove sealing into consideration before designing and manufacturing a 3D-printed surgical guide can greatly increase its accuracy and fit. Because sealing the grooves does the following: Simplify the anatomy, occlusal morphology of the model Simplify the design as the fitting surface will less corrugated features. Eventually producing fitting surface via 3D printing to fit on simplified anatomy is much more predictable than on more detailed anatomical model. This study agrees with Dong et al. [21] who concluded that the occlusal surfaces of posterior teeth displayed greater deviations than other regions, especially in pits and fissures.
The mix of printer and resin had a big effect on the apical area. There were no notable interaction effects for the other deviation indicators ($p > 0.05$). The current data indicates that although both printing techniques can attain high accuracy, the selection of resin may influence printer settings, leading to minor discrepancies in dimensional accuracy, especially in the apical region of the implant site.
The multivariate analysis showed a strong and statistically significant link between the kind of printer and the occlusal design. This shows that the effect of occlusal morphology on deviation was different for each printer; each printer reacted differently depending on the occlusal design being printed. The Wilks' Lambda value was very low, and the p-value was quite high. This means that this interaction had a substantial effect on the combined set of deviation parameters.
The univariate tests demonstrated that the interaction between printer type and occlusal surface shape exerted a statistically significant influence on horizontal apical deviation. This means that the combined effect of the printer and occlusal design had a big effect on the horizontal deviation at the apical level, accounting for about 51.7% of the variation, which is a big effect size. There were no significant interaction effects for angular, depth, horizontal coronal, global coronal, or global apical deviations ($p > 0.05$).
The interaction between resin type and occlusal surface shape did not reach statistical significance for any of the evaluated deviation metrics. This means that the shape of the resin and the occlusal surface don't change anything. The form or complexity of the occlusal surface, on the other hand, influences the accuracy of the guide on its own.
The multivariate analysis using Wilks' Lambda revealed a significant interaction effect between printer, resin, and occlusal. The univariate analysis demonstrates that the interaction among printer type, resin composition, and occlusal surface morphology substantially influences accuracy, although exclusively for certain deviation measurements. This three-way interaction had a big impact on horizontal coronal deviation and a small impact on global apical deviation. The high F-values and low p-values demonstrate that these parts don't work on their own. Instead, the way they interact directly influences how much the guide moves horizontally at the coronal level and globally at the apex.

Conclusion

The DLP printer group and groove sealing group were more accurate than the LCD printer group and occlusal shape group, but all the printed guides were accurate within an acceptable range. Both resins (SG guide and V-guide) had the same level of accuracy, which means that the type of material used doesn't have a big effect on the printing process while the same conditions are kept.

Conflicts of Interest

There are no conflicts of interest.

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Table 1. Mean deviation values (trueness) and standard deviation values (precision) for the DLP and LCD printers, occlusal design (OS and GS) and Resins (V-GUIDE and SG guide) across six parameters: angular deviation, depth deviation, horizontal coronal deviation, global coronal deviation, horizontal apical deviation, and global apical deviation.

Descriptive statistic			**angular deviation**	**depth deviation**	**horizontal coronal deviation**	**global coronal deviation**	**horizontal apical deviation**	**global apical deviation**
Printer type	DLP	Mean (trueness)	1.792	0.6	0.4255	0.7965	0.998	1.3865
		N	20	20	20	20	20	20
		Std. Deviation (precision)	0.04225	0.05749	0.07487	0.04452	0.05845	0.09505
	LCD	Mean (trueness)	1.9825	0.689	0.508	0.876	1.2195	1.551
		N	20	20	20	20	20	20
		Std. Deviation (precision)	0.07078	0.05675	0.07481	0.04828	0.10169	0.09629
	Total	Mean	1.8873	0.6445	0.4668	0.8363	1.1088	1.4688
		N	40	40	40	40	40	40
		Std. Deviation	0.11232	0.07218	0.08486	0.061	0.13886	0.12593
Occlusal design	OS	Mean (trueness)	1.9340	0.6965	0.533	0.878	1.182	1.559
		N	20	20	20	20	20	20
		Std. Deviation (precision)	0.11278	0.04913	0.05823	0.04467	0.14047	0.08879
	GS	Mean (trueness)	1.8405	0.5925	0.4005	0.7945	1.0355	1.3785
		N	20	20	20	20	20	20
		Std. Deviation (precision)	0.09259	0.05087	0.04639	0.04442	0.09248	0.08671
	Total	Mean	1.8873	0.6445	0.4668	0.8363	1.1088	1.4688
		N	40	40	40	40	40	40
		Std. Deviation	0.11232	0.07218	0.08486	0.061	0.13886	0.12593
Resin	V-GUIDE	Mean (trueness)	1.8830	0.6435	0.4575	0.8365	1.105	1.463
		N	20	20	20	20	20	20
		Std. Deviation (precision)	0.11051	0.08035	0.08441	0.0658	0.14051	0.13127
	SG-guide	Mean (trueness)	1.8915	0.6455	0.4760	0.8360	1.1125	1.4745
		N	20	20	20	20	20	20
		Std. Deviation (precision)	0.11681	0.06509	0.08647	0.05753	0.14075	0.12348
	Total	Mean	1.8873	0.6445	0.4668	0.8363	1.1088	1.4688
		N	40	40	40	40	40	40
		Std. Deviation	0.11232	0.07218	0.08486	0.06100	0.13886	0.12593

N: number of specimens, OS: original shape of occlusal surface, GS: groove sealing of occlusal surface.

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Table 2. Multivariate analysis of variance (MANOVA) results using Wilks' Lambda to evaluate the overall effects of printer type, Resins type and occlusal shape.

Effect	**Wilks' Lambda**	**F**	**Sig.**	**Partial Eta Squared**
Printer	0.015	301.124	0.000	0.985
Resin	0.727	1.692	0.161	0.273
Occlusal	0.015	293.729	0.000	0.985
Printer & Resin	0.593	3.094	0.019	0.407
Printer & Occlusal	0.445	5.606	0.001	0.555
Resin & Occlusal	0.804	1.096	0.39	0.196
Printer & Resin & Occlusal	0.414	6.380	0.000	0.586

Table 3. Univariate tests of between-subjects effects for the variable printer type, occlusal design and Resins type on each of the six deviation parameters

Variable	**Deviations**	**F-value**	**p-value**
Printer type	angular deviation	363.812	0.000
	depth deviation	196.795	0.000
	horizontal coronal deviation	123.469	0.000
	global coronal deviation	187.267	0.000
	horizontal apical deviation	713.633	0.000
	global apical deviation	598.017	0.000
Occlusal design	angular deviation	87.642	0.000
	depth deviation	268.72	0.000

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	horizontal coronal deviation	318.481	0.000
	global coronal deviation	206.585	0.000
	horizontal apical deviation	312.178	0.000
	global apical deviation	720.006	0.000
Resin type	angular deviation	0.724	0.401
	depth deviation	0.099	0.755
	horizontal coronal deviation	6.209	0.018
	global coronal deviation	0.007	0.932
	horizontal apical deviation	0.818	0.372
	global apical deviation	2.923	0.097

Table 4. Univariate tests of between-subjects effects for the interactions of variable printer type, occlusal design and Resins type on each of the six deviation parameters.

Variable	Deviations	F-value	p-value
Printer and resin	angular deviation	1.566	0.22
	depth deviation	3.578	0.068
	horizontal coronal deviation	2.0	0.167
	global coronal deviation	3.919	0.056
	horizontal apical deviation	0.178	0.676
	global apical deviation	6.768	0.014
Printer and occlusal	angular deviation	3.812	0.06
	depth deviation	0.398	0.533
	horizontal coronal deviation	0.222	0.641
	global coronal deviation	0.007	0.932
	horizontal apical deviation	34.215	0.000
	global apical deviation	0.05	0.825
	angular deviation	2.108	0.156

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Resin and occlusal	depth deviation	2.012	0.166
	horizontal coronal deviation	1.637	0.21
	global coronal deviation	0.067	0.798
	horizontal apical deviation	0.033	0.858
	global apical deviation	0.934	0.341
Printer, resin and occlusal	angular deviation	1.566	0.22
	depth deviation	1.217	0.278
	horizontal coronal deviation	25.51	0.000
	global coronal deviation	0.185	0.67
	horizontal apical deviation	0.818	0.372
	global apical deviation	6.017	0.02