Effect of different composite materials used as core build-ups on the trueness of intraoral scanning

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Purpose: To evaluate the trueness of digital impressions of different composite resin materials that can be used for core build-ups in clinical practice. Materials and Methods: A maxillary central incisor was prepared and scanned with an intraoral scanner (Primescan, Dentsply Sirona). Ten composite resin specimens (in three groups: universal composite; flowable composite; and bulk fill resin composite) were milled in the same dimensions of the prepared tooth and scanned. The data of the prepared tooth were used as reference, and the data obtained from the composite resin specimens were aligned with the evaluation software (Geomagic Studio 12) to determine deviation values. Kruskal-Wallis with Dunn post hoc test was performed (α = .05). Results: There
were significant differences in the trueness of digital impressions between some composite resin groups \( P < .05 \). The mean trueness deviation values were in the range of 12.75 µm (G-aenial Posterior) to 17.06 µm (Filtek Bulk Fill Posterior). The trueness of G-aenial Posterior (12.75 µm) was higher than that of Core-X Flow (14.62 µm), Clearfil Majesty Flow (16.93 µm), and Filtek Bulk Fill Posterior (17.06 µm). Filtek Bulk Fill Posterior exhibited lower trueness than Clearfil Majesty Esthetic (12.93 µm), Clearfil Majesty Posterior (13.50 µm), and Charisma Classic (13.81 µm). Conclusion: Different composite resins used for core build-up can impact the trueness of digital impressions, with universal composite resin scans being the truest compared to flowable and bulk fill composite resin scans. All scanned substrate groups can be regarded as within a clinically acceptable range. *Int J Prosthodont 2021. doi: 10.11607/ijp.7275*

**INTRODUCTION**

Digitalization in dentistry is spreading day by day with the use of computer-aided impression (CAI) and computer-aided design/computer-aided manufacturing (CAD/CAM) technology. Digital systems are developing continuously to achieve the most expeditious and precise dental applications.\(^1\), \(^2\) The first step of a complete digital workflow is to obtain an impression using an intraoral scanner. Digital impressions have many benefits compared to conventional impression techniques, such as eliminated dimensional stability concerns about the impression material, elimination of conventional laboratory steps, reduced chair time, and improved patient comfort and acceptance.\(^1\), \(^3\) Additionally, digital systems support the production of high-quality, standardized restorations with the usage of different CAD/CAM blocks according to patients’ preferences.\(^4\) In clinical practice, almost every prosthetic process can be performed with digital workflow.\(^5\) Single and multiple crown restorations in particular are frequently implemented for a wide variety of indications.\(^6\) In-vitro studies have shown that crowns fabricated with digital workflow exhibit better fit, interproximal contacts, and marginal integrity than those obtained via conventional workflow.\(^3\), \(^7\) On the other hand, the success of a digital impression is affected by factors such as scanner technology, scanning strategy, ambient lighting conditions, substrate type, translucency, and preparation design.\(^8\), \(^9\), \(^10\) In practice, substrate-based factors may vary due to pre-existing or incoming restoration materials in the oral environment.\(^8\), \(^11\), \(^12\)
It is recommended to restore severely damaged endodontically treated teeth with crown restorations with posts and core build-ups underneath to avoid tooth fracture and protect the remaining sound tooth structure over the long term. Different post and core systems have been used to reconstruct the damaged coronal proportion of endodontically treated teeth. Fiber posts and composite resin core build-ups combined with crowns have been found to offer a better survival rate for endodontically treated teeth than restorations without crowns. Fiber post systems are closely associated and combined with core build-ups, which is important, especially when more than half of the crown has been lost. After adhesive cementation of fiber posts, the tooth’s coronary part needs a core build-up to support the forthcoming crown restoration. Materials used for core reconstruction should possess sufficient mechanical strength and have a good connection with the remaining dental hard tissues, posts, and luting agents. If an esthetic, glass, ceramic-based crown restoration with translucency is to be applied, the core build-up material’s color and opacity also become important factors because a visible core can result in esthetic failure. Today, composite resins are the first choice for core build-ups. For this purpose, restorative composite resin materials can be used as well as materials specially manufactured for core build-ups.

Composite resins used for core build-ups can vary in filler content, viscosity, polymerization type, and build-up technique. The optical properties of a restorative composite material may change due to the filler content and resin matrix. Optical properties are related to how light interacts with objects in the environment. When light collides with a composite surface, it will be reflected and refracted to a certain degree. The scattering of the light is determined by refraction and reflection at the interface between the resin matrix and filler particles. Considering the trueness of the actual intraoral scanners, the optical properties of a material to be scanned become important because the reflectivity, refractive index, and translucency of the substrate may change the amount of light received by the sensor of an intraoral scanner. According to The International Organization for Standardization (ISO) 5725, accuracy requires both trueness and precision of measurement. The trueness of a measure is evaluated by the deviation amount from an optimal value, and the precision of a measure is judged by its repeatability. It is important for an intraoral scanner to be true and precise and therefore accurate.

The purpose of this study was to evaluate the intraoral scanning effects of different composite resin materials that can be used for core build-ups in dental practice. The null hypothesis was that no significant difference would be found among scans of different composite resin substrates.
MATERIALS AND METHODS

A maxillary complete arch model (ANA-4V, Frasaco, Tettnang, Germany) was used as the reference model. The right central incisor typodont tooth was removed, and an extracted maxillary central incisor tooth was adapted into the socket. The tooth was secured using light-curing filling material (Clip F; Voco GmbH, Cuxhaven, Germany). The tooth preparation was simulated by an incisal reduction of 2.0 mm, a chamfer finish line of 1.0 mm, and a convergence angle of approximately 8° for a full coverage crown. The incisal edge and chamfer finish line were rounded. The study was approved by the Istanbul Okan University Non-Interventional Clinical Research Ethics Committee (56665618-204.01.07). The individual was informed about the study, and signed consent was obtained.

Trueness measurement

A total of 10 composite resin materials, all commonly preferred and/or used for core build-up in the clinic, were used to evaluate the effects of different composite resin materials on the trueness of digital impressions. The composite resin materials were classified into three groups: (1) a universal composite group (Clearfil Majesty Posterior (Kuraray Noritake Dental, Kurashiki, Japan), Clearfil Majesty (Kuraray Noritake Dental, Kurashiki, Japan), Charisma Classic (Heraeus Kulzer GmbH, Germany), Charisma Topaz (Heraeus Kulzer GmbH, Germany), G-aenial (GC Corporation, Tokyo, Japan)), (2) a flowable composite group (Clearfil Majesty (Kuraray Noritake Dental, Kurashiki, Japan), Core-X Flow (Dentsply DeTrey, Konstanz, Germany), Clearfil DC Core Plus (Kuraray Noritake Dental Inc, Kurashiki, Japan)), and (3) a bulk fill composite group (Filtek Bulk Fill Posterior (3M ESPE, St. Paul, MN, USA), Filtek Bulk Fill Flowable (3M ESPE, St. Paul, MN, USA)).

The prepared tooth was scanned with an intraoral scanner (Prismescan version 5.0.0, Denstply-Sirona Dental Systems, Bensheim, Germany) after calibrating the scanner according to the manufacturer’s instructions. None of the subsequent scans needed calibration because no reinstallation or transportation of the scanner was done. The obtained reStructuredText (RST) file was sent to a milling machine (inLab MC X5, Denstply-Sirona Dental Systems, Bensheim, Germany) to produce all composite resin specimens in the same size and shape. The evaluated composite materials were built as a milling block using the layering technique according to the standard size of a C14 block to standardize prepared blocks. For this purpose, a mold of CEREC C14 block was made using additional silicone (Adisil rapid, Siladent Dr. Böhme&Schöps, Goslar, Germany) for each composite
resin specimen (Fig. 1). The composite blocks were milled according to the RST file of the prepared tooth (Fig. 2). To minimize the instrumental errors, all specimens were milled with the extra-fine milling mode, using new diamond bur sets each time. To confirm proper dimensions and to ensure standardization, all produced composite resin specimens were examined with a digital caliper at four regions (incisal edge, junction of incisal and middle third, junction of middle and cervical third, and cervical finish line) on the mesiodistal and buccolingual sections. Each composite resin specimen was respectively inserted into the socket of a maxillary arch model. A custom-made, transparent, acrylic-based guide was used to standardize the placing of the composite resin specimens to prevent misalignment, which can affect the comparison of the 3D images. The composite resin specimens were scanned with the intraoral scanner (Primescan) to evaluate the effects on the digital impression trueness of different composite materials. Eight scans were taken for each composite resin specimen with the intraoral scanner (Primescan) by one investigator (BE) (a total of 80 scans). Each scan time was standardized between 35 and 45 seconds by the investigator. The scan data of the prepared extracted tooth was used as reference data. The datasets of scans were converted to a standard tessellation language (STL) file format. The files were loaded into three-dimensional (3D) evaluation software (Geomagic Studio 12, 3D Systems, USA) for the evaluation of the trueness. First, the scan data were trimmed, leaving only the right central incisor tooth to be aligned. To obtain the trueness measurement, the trimmed composite datasets were superimposed onto the prepared tooth dataset with a best-fit algorithm of the software. The deviation spectrum was set at 13 color segments. Blue to turquoise represents negative deviation and red to yellow represents positive deviation. Figure 3 shows a representative color map image from each composite resin specimen to display the deviations between the test scan and reference scan.

**Statistical analysis**

After the 3D comparison analysis, mean positive and negative deviations were recorded in micrometers. The trueness values were calculated from the absolute mean deviations obtained by calculating the arithmetic mean of the absolute values of the positive and negative deviations. All scan data were analyzed statistically to measure their trueness. The homogeneity and normality of distributions were tested via the Kolmogorov–Smirnov and Shapiro–Wilk tests. The non-parametric Kruskal–Wallis with Dunn’s post-hoc test was performed to compare the differences among the composite resin groups (n=8). All statistical analyses were performed
using statistical software (PASW Statistics 18.0, SPSS Inc, Chicago, IL, USA). The statistical significance level was set at 0.05.

RESULTS

According to the Kruskal–Wallis with Dunn’s post-hoc test (p<.05), there were significant differences in the trueness of digital impressions between some composite resin groups. The p-values for the trueness deviation value differences among the composite resin specimens are given in Table 1.

The deviation values for the trueness measurements were in the range of 12.75 µm to 17.06 µm. The mean trueness deviation values for each group are given in Table 2.

G-aenial Posterior (12.75±0.59 µm) showed the lowest deviation value among all composite resin groups, and its trueness deviation value was not statistically significantly different from those of Clearfil Majesty Esthetic (12.93±0.49 µm), Clearfil Majesty Posterior (13.50±0.53 µm), Charisma Classic (13.81±0.25 µm), Clearfil DC Core Plus (14.25±0.37 µm), Charisma Topaz (14.43±0.41 µm), or Filtek Bulk Fill Flowable (14.68±1.03 µm).

However, the trueness of G-aenial Posterior was statistically significantly higher than those of Core-X Flow (14.62±0.79 µm), Clearfil Majesty Flow (16.93±0.90 µm), and Filtek Bulk Fill Posterior (17.06±0.67 µm). Filtek Bulk Fill Posterior had higher deviation values than the other composite resin groups, and its trueness deviation value was not statistically significantly different from those of Clearfil Majesty Flow, Filtek Bulk Fill Flowable, Core-X Flow, Charisma Topaz, and Clearfil DC Core Plus. However, Filtek Bulk Fill Posterior showed a statistically significantly higher deviation than G-aenial Posterior, Clearfil Majesty Esthetic, Clearfil Majesty Posterior, and Charisma Classic. Additionally, the differences between the trueness of Clearfil Majesty Flow and Charisma Classic (p=.014), Clearfil Majesty Flow and Clearfil Majesty Posterior (p=.001), and Clearfil Majesty Flow and Clearfil Majesty Esthetic (p=.000) were statistically significant.

DISCUSSION

Significant differences were found among some composite resin groups scanned with an intraoral scanner; consequently, the null hypothesis was partially rejected.

In in vitro research, specimen preparation in a standardized protocol is important to obtain the most reliable results and the best answer for the tested hypothesis. Some studies have aimed to achieve methodological
homogeneity via improved methods for specimen preparation, such as a cavity preparation machine,\textsuperscript{33} and have described methodologies for the standardized preparation of tooth specimens.\textsuperscript{34} In the current study, composite resin core specimens were prepared with the help of CAD/CAM technology to achieve the most identical samples. With digital intraoral scanner and computer-aided manufacturing systems, it could be possible to fabricate standardized composite resin samples, which would be impossible to do with conventional composite resin layering techniques due to polymerization shrinkage. In addition, in a study by Fernández-Estevan et al.,\textsuperscript{34} a similar specimen fabrication method was described using the benefits of CAD/CAM technology, but unlike the present study, the standardized specimens were prepared from extracted teeth.

When combined treatments with various materials are to be applied, precision in every step becomes vital to the integrity of the final restoration. Final crown restorations with adhesive post and core systems underneath are affected by the materials chosen for core build-ups. When intraoral scanners are also involved in the treatment plan, a core material’s impact on the accuracy of digital scanning is another factor that should be taken into consideration. Most of the literature about scanning accuracy contains comparisons among different intraoral scanning devices and systems.\textsuperscript{1, 9, 31, 32, 35} Only a few studies have evaluated disparate substrates and their effects on the trueness of the scanning process.

In an in vitro study, the trueness and precision of eight intraoral scanners (Cerec Omnicam, Cerec Primessan, Medit i500, iTero Element 2, iTero Element, Emerald, Emerald S, Trios3) and the effects of 14 different substrates (natural dentin, blue core, white core, unpolished amalgam, bulk fill composite, enamel composite A2, dentin composite A2, dentin composite A3, enamel composite A3, lithium disilicate MT A2, polished amalgam, full contour zirconia, polished type III gold, and natural enamel) on the accuracy of intraoral scanning were evaluated. Five different composite resin materials were involved in the study and located in a customized typodont model to be scanned. The composite resin substrate groups were as follows: A2 and A3 enamel composites, A2 and A3 dentin composites, and a bulk fill composite. Unlike the present study, different shades of composite resin materials were also examined. According to the study, rather than shade, translucency had an negative effect on the precision and trueness of some intraoral scanners, except Trios 3. Bulk fill and dentin composites yielded better accuracy than enamel composites that are more translucent.\textsuperscript{8} Optical properties of a composite resin material are affected by the organic and inorganic content of the composition. Bulk fill resin composites have a higher depth of cure than universal composites because bulk fill resin composites have a more
active initiator mechanism and/or higher translucency levels, which results in more effective light penetration. In the present study, the bulk fill resin composite group showed a higher deviation than universal composites, which can be attributed to higher translucency levels. It has also been reported that flowable composites exhibit higher translucency levels due to their lower filler content compared with universal resin composites. In the present study, the second and third highest deviation values were observed in the flowable composite group. The Clearfil Majesty flowable composite resin group (16.93 μm) showed results similar to those of the Filtek Bulk Fill Posterior group (17.06 μm), and both groups showed the lowest trueness among all the groups. With a trueness deviation of 14.68 μm, the Filtek Bulk Fill flowable composite had the next highest deviation value; however, the difference between this composite and others was not statistically significant. Dual-cure core composites showed higher trueness than flowable and bulk fill composites but not at significant levels (p<.05). The chemical structure and the quantity of the opacifiers have an important effect on the translucency of resin composites. The superior results of core composites in comparison to other flowable composites may be due to opacifying agents in their composition that make them similar to dentin shade and mask the color of the post material used beneath.

In a previous study, seven intraoral scanners were compared, and a freshly resected cadaveric human maxilla was used as a scanning substrate. The maxilla specimen contained different substrates, such as amalgam restorations and various composite fillings, in addition to dental hard tissues and surrounding soft tissues. The features of the composite materials were not specified, and all the substrate surface areas differed from each other. It was concluded that intraoral scanner accuracy was impacted by the substrate type. Enamel showed the least accurate results among the other scanned substrates, a result that may also be associated with translucency. Hong Li et al. evaluated scanning accuracy related to substrate translucency using a powder-free intraoral scanner (Dios Flyer, RK Organical CAD/CAM GmbH), and their results support those of the present study and studies mentioned previously, namely that specimens with lower translucency showed higher scanning accuracy than specimens with higher translucency.

In the present study, the smallest trueness deviation (12.75 μm) was seen in the G-aenial Posterior universal composite group, and the greatest deviation (17.06 μm) was seen in the Bulk-Fill Posterior composite group. Trueness of a digital impression, like other steps of digital workflow and/or conventional workflow (impression, pouring stone model, casting, etc.), may affect the fit of the final restoration. The upper limit for a clinically
acceptable marginal misfit value was considered to be 120 µm in several studies.\textsuperscript{41,42} Medina-Sotomayor et al. regarded the clinically acceptable upper limit for deviation as 120 µm in their studies.\textsuperscript{42} Both conventional and digital techniques may lead to errors in the workflow, resulting in deviations. The summation of errors occurring at different stages may affect the overall fit of a restoration.\textsuperscript{43,44} Zarauz et al.\textsuperscript{45} reported that the mean internal misfit of conventionally prepared molar crowns was 173.0 µm, and the mean marginal misfit was 133.5 µm, whereas the mean internal misfit and mean marginal misfit of crowns prepared from digital impressions were 111.40 µm and 80.2 µm, respectively. In another study, mean marginal gap values were evaluated in crowns that were prepared from an intraoral digital impression system or from a conventional silicone impression. For the conventional impression group and for the digital impression group, the mean marginal gap values were 91.46 µm and 76.33 µm, respectively.\textsuperscript{7} The upper deviation value measured in the present study (17.06 µm) was much lower than the presumed limit of clinical acceptance (120 µm) and the misfit values that were reported in the studies mentioned previously.

There were some limitations of the present study. Only an intraoral scanner was used, and the composite resin groups were prepared from a single shade with a standard core design. Different preparation designs, different shaded composites, and different conventional and/or digital impression techniques should also be considered for future studies.

**CONCLUSION**

Within the limitations of this in vitro study, different composite resins that can be used as core build-up materials in clinical practice were shown to affect the trueness of digital impressions within the range of 12.75 µm–17.06 µm. Universal composite resins showed better trueness results than bulk fill and flowable composites. Considering clinical applications, even the maximal deviation value that was obtained from the bulk fill composite group can be regarded as within clinically acceptable limits.

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The authors report no conflicts of interest related to this study.
CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

REFERENCES


**Figures and Tables**

**Table 1.** P-values for the differences among composite resin specimens, according to Kruskal–Wallis with Dunn’s post-hoc test.

**Table 2.** The mean trueness deviation value of each composite resin specimen.

**Figure 1.** A) Composite resin block produced by a layering technique and a silicone mold.
Figure 1. B) Composite resin block attached with an adaptor used for CEREC.

Figure 2. A) Placing the prepared composite resin block on a milling machine.

Figure 2. B) Milled composite resin specimen.

Figure 3. Representative images from color maps of each composite resin specimen for evaluation of trueness. Max/min nominal ± 20 µm (green) and max/min critical ± 200 µm.

Fig 1a

Fig 1b
Fig 3g

Fig 3h
Fig 3i

Fig 3j