ADA CE Program ARTICLE 2

# The time efficiency of intraoral scanners

## An in vitro comparative study

**Sebastian B.M. Patzelt, DMD, Dr med dent; Christos Lamprinos, DDS; Susanne Stampf, Dr rer nat; Wael Att, DDS, Dr med dent habil, PhD**

## ABSTRACT

**Background.** Although intraoral scanners are known to have good accuracy in computer-aided impression making (CAIM), their effect on time efficiency is not. Little is known about the time required to make a digital impression. The purpose of the authors' in vitro investigation was to evaluate the time efficiency of intraoral scanners.

**Methods.** The authors used three different intraoral scanners to digitize a single abutment (scenario 1), a short-span fixed dental prosthesis (scenario 2) and a full-arch prosthesis preparation (scenario 3). They measured the procedure durations for the several scenarios and compiled and contrasted the procedure durations for three conventional impression materials.

**Results.** The mean total procedure durations for making digital impressions of scenarios 1, 2 and 3 were as much as 5 minutes 57 seconds, 6 minutes 57 seconds, and 20 minutes 55 seconds, respectively. Results showed statistically significant differences between all scanners ($P < .05$), except Lava (3M ESPE, St. Paul, Minn.) and iTero with foot pedal (Align Technology, San Jose, Calif.) for scenario 1, CEREC (Sirona, Bensheim, Germany) and CEREC with foot pedal for scenario 2, and iTero and iTero with foot pedal for scenarios 2 and 3. The compiled procedure durations for making conventional impressions in scenarios 1 and 2 ranged between 18 minutes 15 seconds and 27 minutes 25 seconds; for scenario 3, they ranged between 21 minutes 25 seconds and 30 minutes 25 seconds.

**Conclusions.** The authors found that CAIM was significantly faster for all tested scenarios. This suggests that CAIM might be beneficial in establishing a more time-efficient work flow.

**Practical Implications.** On the basis of the results of this in vitro study, the authors found CAIM to be superior regarding time efficiency in comparison with conventional approaches and might accelerate the work flow of making impressions.

**Key Words.** Intraoral scanner; time efficiency; dental impression technique; dental economics.
JADA 2014;145(6):542-551.
**doi:10.14219/jada.2014.23**

Making an accurate dental impression is one of the most essential and time-consuming procedures in dental practice. During this procedure, it is crucial to ensure the reproduction of the intraoral condition as accurately as possible, as errors or inaccuracies could have far-reaching consequences for the quality of the final restoration. Despite improvements in material properties (for example, better taste, shortened setting time), impression making still is considered to be uncomfortable for the patient and time consuming for the clinician. Balkenhol and colleagues[1] showed that the tested elastomeric impression materials had working times longer than those the manufacturer described. With the introduction of computer-aided design/computer-aided manufacturing (CAD/CAM) technologies in the

**Dr. Patzelt** is a visiting research professor and the course director, Prosthetic Lecture Series and Seminar, Implant Periodontal Prosthodontics Program, Department of Periodontics, School of Dentistry, University of Maryland, Baltimore. He also is an assistant professor and a scientific associate, Prosthetic Dentistry, Center for Dental Medicine, University Medical Center Freiburg, University of Freiburg, Baden-Württemberg, Germany. Address correspondence to Dr. Patzelt at Department of Periodontics, School of Dentistry, University of Maryland, 650 W. Baltimore St., Baltimore, Md. 21201, e-mail spatzelt@umaryland.edu.
**Dr. Lamprinos** is an assistant professor and a doctoral candidate, Department of Prosthetic Dentistry, Center for Dental Medicine, University Medical Center Freiburg, University of Freiburg, Baden-Württemberg, Germany.
**Dr. Stampf** was a statistician, Institute of Medical Biometry and Statistics, Center for Medical Biometry and Medical Informatics, University Medical Center Freiburg, Baden-Württemberg, Germany, when this article was written. She now is a biostatistician, Clinical Epidemiology, Department of Clinical Research, University Hospital Basel, Switzerland.
**Dr. Att** is an associate professor and the director, Postgraduate Program, Department of Prosthetic Dentistry, Center for Dental Medicine, University Medical Center Freiburg, Baden-Württemberg, Germany.

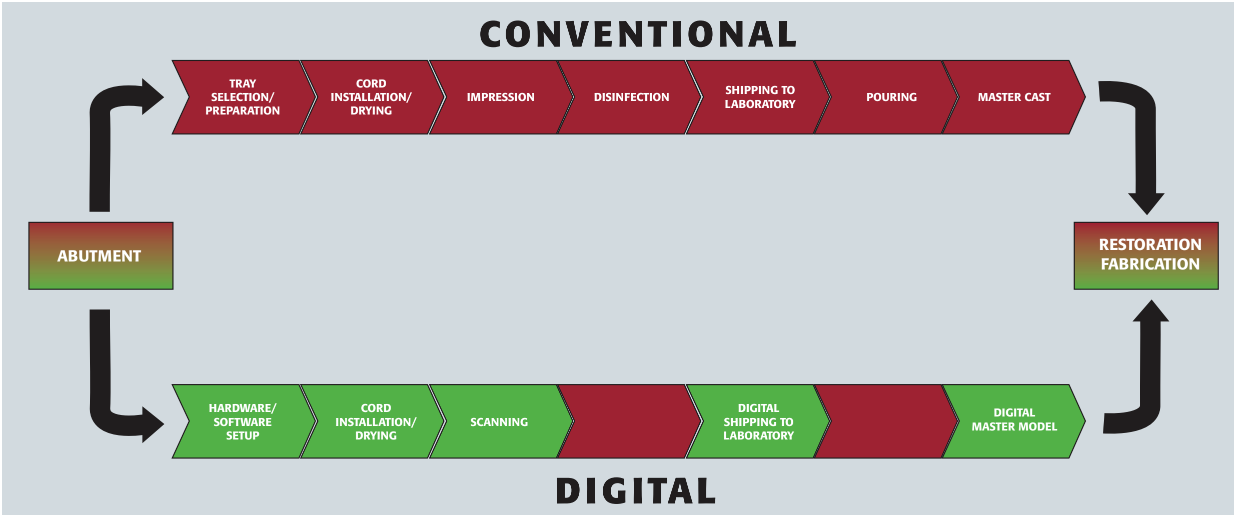


**Figure 1.** Comparison between the conventional and digital work flows for impression making.

late 1980s[2-4] and the development of intraoral scanning devices during the past 20 years, alternatives to conventional impression making exist.

In fixed prosthodontics, CAD/CAM already is far advanced and is complemented by computer-assisted implant planning.[5,6] Ideal meshing of the procedures expertly performed might lead to a more predictable and higher-quality result, while saving time for both the clinician and the patient. Various companies provide computer-aided impression-making (CAIM) systems; however, researchers in only one previous study evaluated the time efficiency of digital versus conventional impression making for single-implant restorations.[7] The conclusions of that study were that digital impression making is more time efficient than are conventional impression-making techniques, with a mean total treatment time of 24 minutes 42 seconds for conventional and 12 minutes 29 seconds for digital impression making. Nevertheless, studies investigating the time efficiency of digital impressions for various clinical scenarios have not been published. Therefore, a validation of the time required for digital impression making is essential to facilitate an efficient work flow in daily practice.

For a better understanding of the issues with which we dealt in our study, it is important to know the similarities and differences of conventional impression making versus CAIM. For both approaches, it is necessary to place retraction cords and to dry the oral cavity thoroughly, whereas the subsequent steps (making actual impressions of abutments, making impressions of antagonist teeth or performing bite registration) can be performed comparably either with conventional impression materials or with CAIM devices (Figure 1).

We conducted a study to compare the time efficiency of three CAIM systems (CEREC Acquisition Center [AC] with Bluecam, Sirona, Bensheim, Germany; iTero, Align Technology, San Jose, Calif.; Lava Chairside Oral Scanner C.O.S., 3M ESPE, St. Paul, Minn.) for three clinical scenarios: a single abutment, the preparation of two abutment teeth for a three-unit bridge, and preparation of 14 abutments in one jaw. Additionally, we compiled durations of the procedures for conventional impression making and contrasted them with procedure durations for the digital approach.

## METHODS

**Scan models and scan procedure.** To obtain information about the time efficiency of CAI, we used a dentate maxillary and mandibular study model (KaVo, Biberach, Germany) to mimic different clinical scenarios. We prepared (by using an equigingival chamfer preparation) the first maxillary right molar (scenario 1: single abutment), the second maxillary right premolar and second molar (scenario 2: two abutments, single-span fixed dental prosthesis [FDP] preparation and the entire maxilla (scenario 3: full-arch preparation, 14 abutments). The study models fixed in a dental simulation unit (KaVo, Biberach, Germany) simulated an actual treatment situation.

**Intraoral scanners.** We used three intraoral scanners and their associated software in this study:

- CEREC AC with Bluecam and CEREC 3D Service Pack Version 3.85;
- Lava Chairside Oral Scanner C.O.S. and Lava Software Version 3.0;
- iTero and iTero software Version 4.0.

For the CEREC AC with Bluecam and the iTero system, an optional foot pedal approach was available for the capture procedure. We investigated this feature for

**ABBREVIATION KEY. CAD/CAM:** Computer-aided design/computer-aided manufacturing. **CAIM:** Computer-aided impression making. **FDP:** Fixed dental prosthesis.

time efficiency as well.

**Scanner setup and scanning procedures.** We switched on all scanner systems, booted the operating system and set up the scanning software, entered essential information (fictional patient's name, hospital, area to be scanned, fictional type of restoration, fictional dental technician's name), performed the scan and processed the scan data. Next, we switched off the scanners and allowed a 10-minute intermission to cool down the scanner units before starting the next scanning sequence. After we set up the software for the CEREC AC with Bluecam, it was necessary to apply an antireflective coating (CEREC Optispray, Sirona Dental Systems). The Lava Chairside Oral Scanner C.O.S. required only a light powdering (Lava Powder, 3M ESPE). The iTero scanner operated without use of an antireflective coating.

We scanned all scenarios five times and limited the scans in scenario 1 and 2 to the abutments and the adjacent teeth. In scenario 3, we placed an anterior (canine-to-canine) interocclusal record (GC Pattern Resin LS, GC Germany, Bad Homburg, Germany) to maintain the jaw relation during the lateral registration scans. The scan sequence was as follows:

- iTero: scanning of scenario 1 (n = 5), scenario 2 (n = 5) and scenario 3 (n = 5);
- iTero with foot pedal: scanning of scenario 1 (n = 5), scenario 2 (n = 5) and scenario 3 (n = 5);
- Lava C.O.S.: coating sprayed; scanning of scenario 1 (n = 5), scenario 2 (n = 5) and scenario 3 (n = 5); coating removed;
- CEREC AC with Bluecam: coating sprayed; scanning of scenario 1 (n = 5), scenario 2 (n = 5) and scenario 3 (n = 5);
- CEREC AC with Bluecam and foot pedal: coating sprayed; scanning of scenario 1 (n = 5), scenario 2 (n = 5) and scenario 3 (n = 5); coating removed.

To standardize the procedure, one dentist (C.L.), who trained himself to use each device by practicing for 16 hours with each, executed all scans according to the manufacturers' manuals.

**Time measurements.** ***Digital approach.*** We performed time measurements for each scanner for the hardware startup, software setting, powdering or coating (if required by the manufacturer), scanning of the abutments, scanning of the antagonists, bite registration scan and data processing. For statistical analyses, we determined three periods: time required for the abutment scan, intraoral time (including scans of the abutment, the antagonists and the interarch registration) and total time (sum of all periods from hardware startup to data manipulation). We used a computer-based stopwatch to time the several steps accurately to one second.

***Conventional approach.*** We compiled durations of making conventional impressions for the aforementioned three scenarios by summing the manufacturers' provided working times for the adhesive, impression material, antagonist impression material, bite registration material and disinfectant. We recorded the following specific times:

- the recommended drying time of the adhesive (from the application of the material until the material is completely dry);
- the processing time (from the mixing of the material until the start of the setting time);
- the setting time (from after processing until final setting of the material) of the impression materials, the bite registration material and the antagonist impression material;
- the time required for application of the disinfectant.

We found that the time frames for all procedures were similar among scenarios 1, 2 and 3 except the time needed for the bite registration; for that, we tripled the time in scenario 3.

Finally, we calculated the total procedure duration for each scenario and material. We included three conventional impression materials: a medium-bodied polyether (Impregum Penta Soft, 3M ESPE), a polyvinylsiloxane (Affinis, Coltène/Whaledent, Altstätten, Switzerland) and a vinylsiloxanether (Identium, Kettenbach, Eschenburg, Germany), as well as the recommended adhesives, Polyether Tray Adhesive (3M ESPE), Adhesive AC (Coltène/Whaledent) and Identium Adhesive (Kettenbach), respectively. We used the times of an additional alginate (Palgat Plus, 3M ESPE) for the antagonist impression material, an additional polydimethylsiloxane (Greenbite Apple, Detax, Ettlingen, Germany) for the interarch registration material, and an additional disinfection procedure (Immersion disinfectant, Picodent, Wipperfürth, Germany). If provided and recommended by the manufacturer, we also included in the calculations the working times of a low-viscosity and a high-viscosity impression material. This was the case for Affinis (Affinis Precious and Affinis heavy body, Coltène/Whaledent) and Identium (Identium Light and Identium Medium, Kettenbach). Furthermore, we compiled the procedure durations for fast-setting versions of the impression materials, if available (Table 1).

**Statistical analysis.** We performed statistical analyses only for the intraoral scanners and separately for scenarios 1, 2 and 3. To evaluate the effect of devices and different time points, we implemented a repeated-measures analysis of variance. We included interaction terms between main effects (device and interval) to detect device differences regarding the intervals (abutment scan time, intraoral time, total time). We calculated least-square (LS) means of main effects (device, direction and jaw) and interaction effects (95 percent confidence interval), respectively. Furthermore, we performed several multiple comparisons of LS means (pairwise comparisons between devices regardless of time points), which required a *P* value adjustment (Tukey-Kramer method). We included relevant comparisons between device and

**TABLE 1**

**Materials used for the time compilation of the normal-setting and fast-setting conventional impression-making approaches.**

| IMPRESSION MATERIAL | OTHER MATERIALS, ACCORDING TO TYPE AND USE | | | |
|---|---|---|---|---|
| | Adhesive | Antagonist Impression | Bite Registration | Disinfectant |
| **Normal-Setting Impression Material** | | | | |
| **Impregum Penta Soft*** | Polyether Tray Adhesive* | Palgat Plus* | Greenbite Apple§ | Immersion disinfectant¶ |
| **Affinis Precious and Affinis heavy body†** | Adhesive AC† | | | |
| **Identium Light and Identium Medium‡** | Identium Adhesive‡ | | | |
| **Fast-Setting Impression Material** | | | | |
| **Impregum Penta Soft Quick Step*** | Polyether Tray Adhesive | Palgat Plus Quick* | Greenbite Apple | Immersion disinfectant |
| **Affinis Precious and Affinis fast heavy body** | Adhesive AC | | | |
| **Identium Light Fast and Identium Medium Fast** | Identium Adhesive | | | |

* Manufactured by 3M ESPE, St. Paul, Minn.
† Manufactured by Coltène/Whaledent, Altstätten, Switzerland.
‡ Manufactured by Kettenbach, Eschenburg, Germany.
§ Manufactured by Detax, Ettlingen, Germany.
¶ Manufactured by Picodent, Wipperfürth, Germany.

time-point groups, which required a *P* value adjustment as well (Benjamini-Hochberg method). We checked model assumptions—that is, normal distribution of residuals—by reviewing histograms and normal probability plots. Furthermore, we did comparisons of the time measurements per device by calculating variation coefficients. Thereby, it was possible to make a statement about the precision of the time measurements (relative standard deviations [SDs] from the mean in percentages). We set statistical significance at $P < .05$. An independent statistician (S.S.) performed all calculations by using statistical software (SAS Version 9.2, SAS Institute, Cary, N.C.). In addition, we contrasted the mean total durations for the digital and conventional approaches.

## RESULTS

**Summary of results.** The CAIM approach was up to 23 minutes faster than conventional impression making in total time for all three scenarios in this study. The fastest devices for each scenario were the CEREC AC with Bluecam for single-abutment scans, the CEREC AC with Bluecam with foot pedal for single-span FDPs and the Lava C.O.S. for full-arch scans (Table 2). We found highest variations in the foot-pedal approaches and in the abutment scan time (Table 3, page 547). The iTero with foot pedal showed the highest and lowest variations (full-arch: abutment scan time, 13.32 percent; single-span FDP: total scan time, 0.77 percent). Focusing on the actual intraoral working time—in other words, the time that the dentist needs to scan or make a conventional impression—revealed the digital approach to be superior. The CEREC AC with Bluecam performed fastest for single abutments and single-span FDPs, whereas the iTero was the fastest system for full-arch scans. The digital approach was up to 11 minutes 36 seconds faster for a single abutment, up to 11 minutes 13 seconds faster for a single-span FDP and up to 7 minutes 55 seconds faster for a full-arch impression (Table 2).

**Digital approach.** ***Scenario 1: Single abutment.*** The mean (SD) total time for digitizing a single abutment ranged between 4 minutes 16 seconds (4.2 seconds) and 5 minutes 57 seconds (8.4 seconds). Procedure durations for the abutment scan, antagonist scan and data processing had the greatest differences. We identified statistically significant differences ($P < .05$) between all scanners, except CEREC AC with Bluecam and CEREC AC with Bluecam and foot pedal ($P = .52$) and iTero and iTero foot pedal ($P = .22$) for the abutment scan; CEREC AC with Bluecam and CEREC AC with Bluecam and foot pedal ($P = .63$) for the intraoral period; and Lava C.O.S. and iTero foot pedal ($P = .26$) for the total time. The fastest system to digitize a single abutment was the CEREC AC with Bluecam (4 minutes 16 seconds [4.2 seconds] without use of the optional foot pedal (Figure 2, page 548).

***Scenario 2: Single-span FDP, two abutments.*** The mean (SD) total time for digitizing a single abutment ranged between 5 minutes 2 seconds (11.4 seconds) and 6 minutes 57 seconds (14.4 seconds). The abutment scan and bite registration showed the highest differences in procedure durations. We identified statistically significant differences ($P < .05$) between all scanners, except in these cases for each of the three periods: for the abutment scan time, CEREC AC with Bluecam and CEREC AC with Bluecam and foot pedal ($P = .08$) and iTero and iTero foot pedal ($P = .54$); for the intraoral time, iTero and iTero with foot pedal ($P = .07$); and for the total time, CEREC AC with Bluecam and CEREC AC with Bluecam and foot pedal ($P = .56$) and iTero and iTero with foot pedal ($P = .08$). The fastest system to digitize

**TABLE 2**

**Summary of total procedure durations and intraoral times for different impression-making scenarios.**

| EQUIPMENT AND MATERIAL | CLINICAL SCENARIO | | |
|---|---|---|---|
| | Single Abutment | Single-Span Fixed Dental Prosthesis Preparation | Full-Arch Prosthesis Preparation |
| | Total time (minute:second) | | |
| **Scanner*** | | | |
| **iTero** | 5:41 | 6:06 | 20:17 |
| **iTero with foot pedal** | 5:57 | 6:15 | 20:55 |
| **CEREC Acquisition Center with Bluecam** | 4:16† | 5:05 | N/A |
| **CEREC Acquisition Center with Bluecam and foot pedal** | 4:30 | 5:02† | N/A |
| **Lava Chairside Oral Scanner C.O.S.** | 5:51 | 6:57 | 17:20† |
| **Material‡** | | | |
| **Impregum Penta Soft** | 23:25 | | 26:25 |
| **Impregum Penta Soft Quick Step** | 18:45 | | 21:45 |
| **Affinis Precious and Affinis heavy body** | 20:55 | | 23:55 |
| **Affinis Precious and Affinis fast heavy body** | 18:15 | | 21:25 |
| **Identium Light and Identium Medium** | 27:25 | | 30:25 |
| **Identium Light Fast and Identium Medium Fast** | 22:45 | | 25:45 |
| | Intraoral working time (minute:second) | | |
| **Scanner** | | | |
| **iTero** | 2:16 | 2:24 | 7:55† |
| **iTero with foot pedal** | 2:29 | 2:41 | 8:36 |
| **CEREC Acquisition Center with Bluecam** | 1:14† | 1:37† | Not applicable |
| **CEREC Acquisition Center with Bluecam and foot pedal** | 1:18 | 1:47 | Not applicable |
| **Lava Chairside Oral Scanner C.O.S.** | 2:50 | 3:35 | 10:51 |
| **Material** | | | |
| **Impregum Penta Soft** | 12:50 | | 15:50 |
| **Impregum Penta Soft Quick Step** | 8:15 | | 11:15 |
| **Affinis Precious and Affinis heavy body** | 9:55 | | 12:55 |
| **Affinis Precious and Affinis fast heavy body** | 7:15 | | 10:15 |
| **Identium Light and Identium Medium** | 12:25 | | 15:25 |
| **Identium Light Fast and Identium Medium Fast** | 7:45 | | 10:45 |

* The scanners' manufacturers are as follows: iTero and iTero with foot pedal, Align Technology, San Jose, Calif.; CEREC Acquisition Center with Bluecam and CEREC Acquisition Center with Bluecam and foot pedal, Sirona, Bensheim, Germany; Lava Chairside Oral Scanner C.O.S., 3M ESPE Dental Products, St. Paul, Minn.
† Shortest time for the particular clinical scenario.
‡ The materials' manufacturers are as follows: Impregum Penta Soft products, 3M ESPE Dental Products; Affinis products, Coltène/Whaledent, Altstätten, Switzerland; Identium products, Kettenbach, Eschenburg, Germany.

a single-span FDP with two abutments was the CEREC AC with Bluecam and the optional foot pedal (mean [SD] at 5 minutes 2 seconds [11.4 seconds]) (Figure 2).

***Scenario 3: Full-arch prosthesis preparation, 14 abutments.*** The mean (SD) total time for digitizing a full-arch preparation (14 abutments) ranged between 17 minutes 20 seconds (29.4 seconds) and 20 minutes 55 seconds (35.9 seconds). The software setting, abutment scan and data processing had the highest differences in procedure durations. We identified statistically significant differences ($P < .05$) between all scanners, except iTero and iTero with foot pedal ($P = .06$), for the abutment scan time and between all scanners for the intraoral and total times. The fastest system to digitize

**TABLE 3**

**Variation coefficients of the different periods for each clinical scenario.**

| CLINICAL SCENARIO AND SCANNER* | VARIATION COEFFICIENT IN PERCENTAGES, ACCORDING TO PERIOD | | |
|---|---|---|---|
| | Abutment Scan Time | Intraoral Working Time | Total Time |
| **Single Abutment** | | | |
| CEREC Acquisition Center with Bluecam | 7.97 | 1.33 | 1.65 |
| CEREC Acquisition Center with Bluecam and foot pedal | 9.85 | 8.27 | 2.44 |
| iTero | 2.56 | 2.58 | 0.94 |
| iTero with foot pedal | 9.63 | 4.04 | 2.34 |
| Lava Chairside Oral Scanner C.O.S. | 4.87 | 6.41 | 6.41 |
| **Single-Span Fixed Dental Prosthesis Preparation** | | | |
| CEREC Acquisition Center with Bluecam | 4.85 | 3.67 | 3.64 |
| CEREC Acquisition Center with Bluecam and foot pedal | 9.42 | 4.17 | 3.77 |
| iTero | 8.77 | 5.59 | 2.18 |
| iTero with foot pedal | 10.98 | 2.38 | 0.77 |
| Lava Chairside Oral Scanner C.O.S. | 1.85 | 2.90 | 3.44 |
| **Full-Arch Prosthesis Preparation** | | | |
| iTero | 3.10 | 1.46 | 0.99 |
| iTero with foot pedal | 13.32 | 6.95 | 2.73 |
| Lava Chairside Oral Scanner C.O.S. | 1.98 | 1.59 | 2.83 |

* The scanners' manufacturers are as follows: iTero and iTero with foot pedal, Align Technology, San Jose, Calif.; CEREC Acquisition Center with Bluecam and CEREC Acquisition Center with Bluecam and foot pedal, Sirona, Bensheim, Germany; Lava Chairside Oral Scanner C.O.S., 3M ESPE Dental Products, St. Paul, Minn.

a full-arch preparation was the Lava C.O.S. (mean [SD], 17 minutes 20 seconds [29.4 seconds]) (Figure 2). It was not possible to capture the procedure durations for the CEREC AC with Bluecam owing to software limitations during the data compilation at the end of the scanning procedure. For this reason, we did not follow full-arch scanning with the CEREC system further in this particular study.

**Conventional approach.** ***Scenarios 1 and 2.*** Predetermined by the manufacturers, the procedure durations for a conventional impression of a single abutment or a single-span FDP preparation ranged between 18 minutes 15 seconds and 27 minutes 25 seconds. The fastest impression material was the fast-setting variant of Affinis Precious and Affinis fast heavy body in combination with Palgat Plus Quick (18 minutes 15 seconds). All materials resulted in different total procedure durations, with the greatest differences being in the adhesives' drying durations and in the processing and setting times (Figure 3, page 549).

***Scenario 3.*** Usually, more than one bite registration is necessary for a full-arch preparation. Consequently, in this scenario we tripled the time for the bite registration. That resulted in total procedure durations for a full-arch conventional impression of up to 30 minutes 25 seconds. As in scenarios 1 and 2, we identified the highest differences in durations for adhesives' drying times and for processing and setting times (Figure 3).

## DISCUSSION

The implementation of CAIM is supposed to improve the work flow of impression making, lead to higher patient satisfaction and provide better restorations in comparison with the conventional approach.[8-15] Several studies have dealt with these research topics; however, their investigators have reported little about the time efficiency of this technology, which might be of high relevance, especially for general practitioners in terms of optimizing work flows.

In this study, we investigated and compared the working times of three intraoral scanners in three different prosthodontic scenarios. Additionally, we compiled the procedure durations for three conventional impression materials and their particular work flows. Compared with the conventional approach, CAIM was up to 23 minutes faster in all scenarios when considering all steps mentioned in our study. Although the CEREC AC with Bluecam system was the fastest system for digitizing a single abutment or a single-span FDP preparation, the Lava C.O.S. performed fastest for a full-arch scan of 14 abutments. We identified the greatest differences between the scanners for the procedure durations of the actual abutment scan and the data processing. Explanations for the differences between the scanners may be

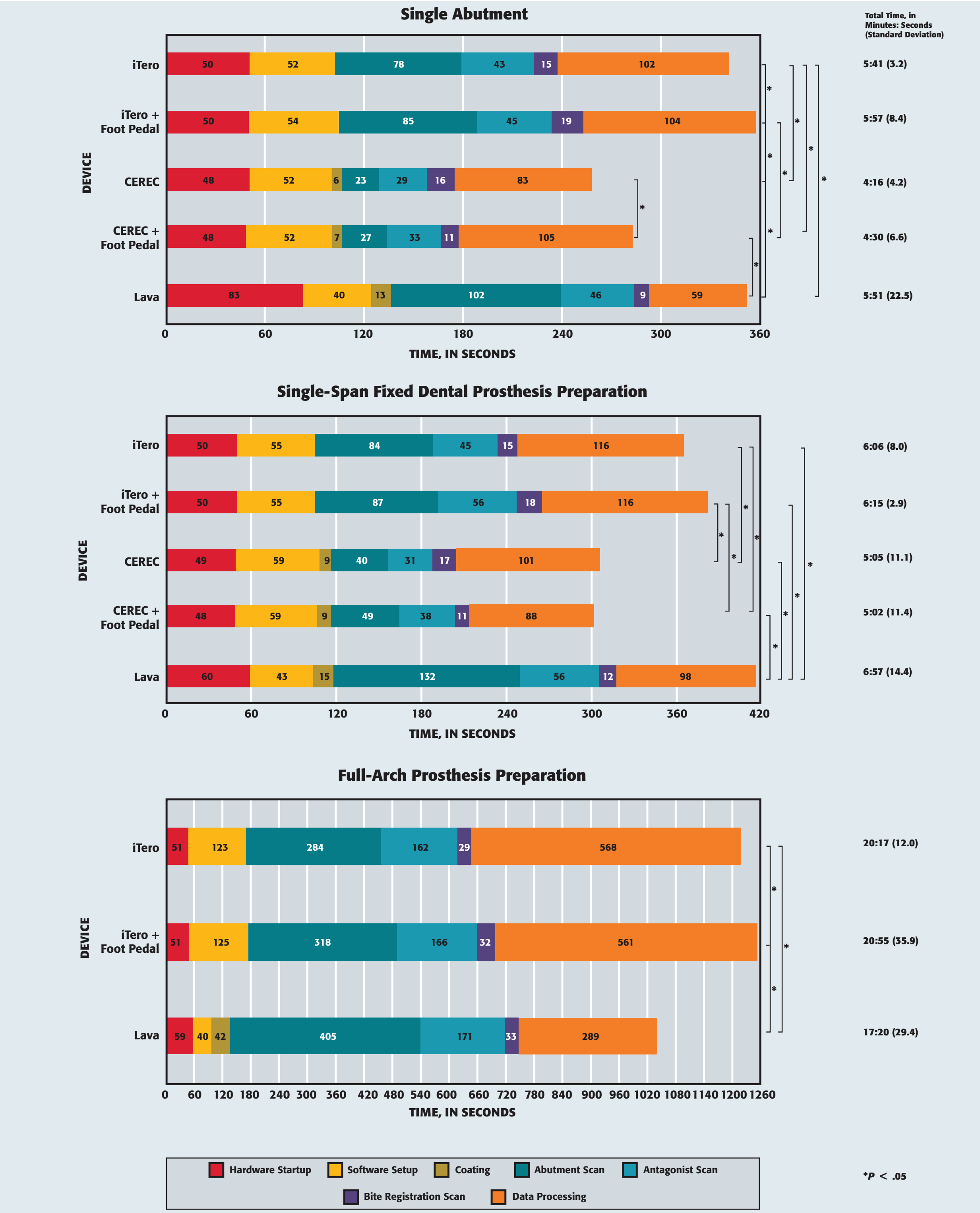


**Figure 2.** Scanning durations for a single-abutment, short-span fixed prosthesis preparation (two abutments) and full-arch prosthesis preparation (14 abutments) according to specific steps in the procedure and statistically significant differences in mean total procedure durations (95 percent confidence interval, $P < .05$). Statistically significant differences are marked by brackets and asterisks. iTero is manufactured by Align Technology, San Jose, Calif. CEREC Acquisition Center with Bluecam is manufactured by Sirona, Bensheim, Germany. Lava Chairside Oral Scanner C.O.S. is manufactured by 3M ESPE, St. Paul, Minn.

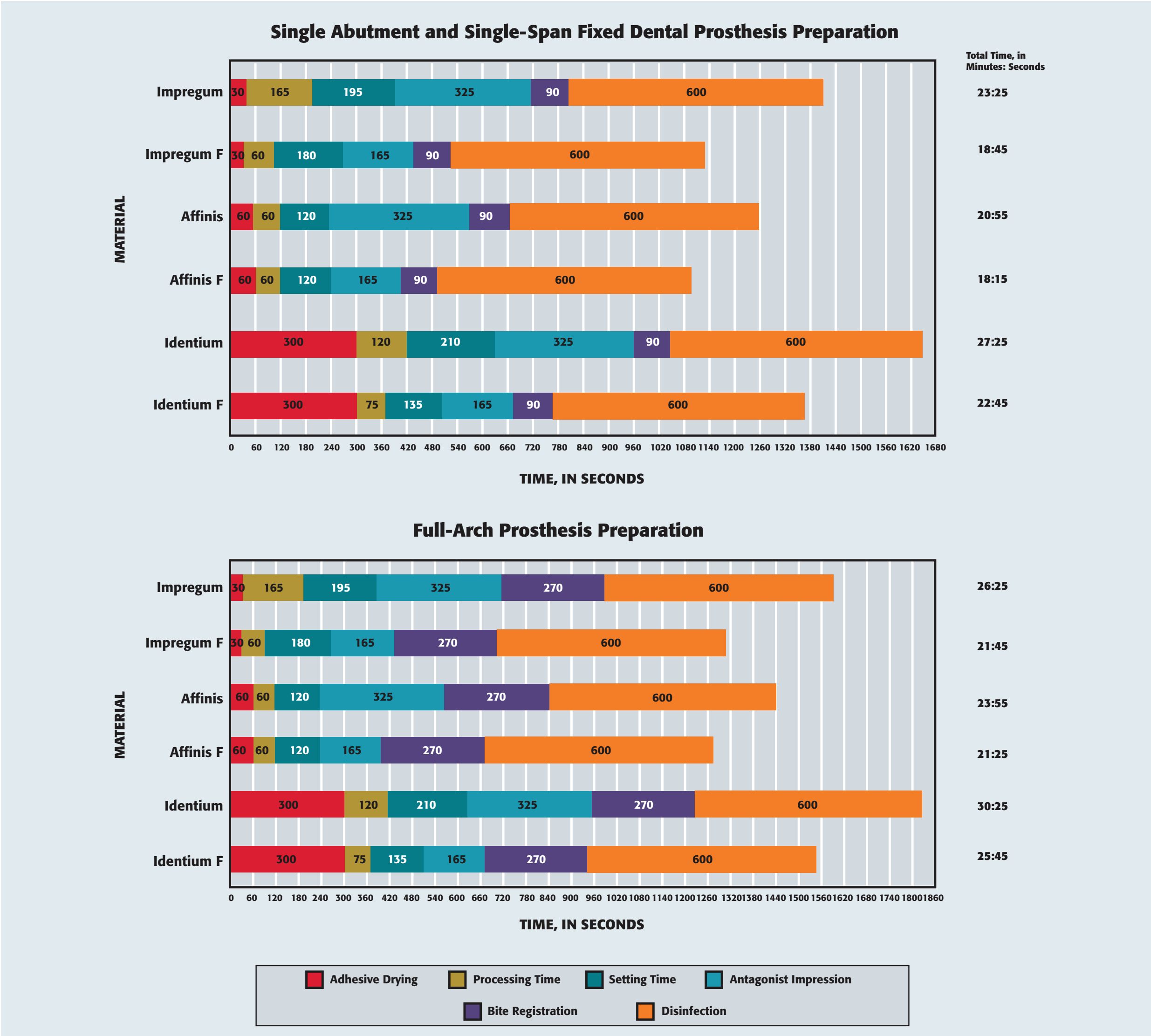


**Figure 3.** Compilation of procedure durations for making conventional impressions of a single-abutment, short-span fixed prosthesis preparation (two abutments) and a full-arch prosthesis preparation (14 abutments) according to specific steps in the procedure and their total durations. The materials are listed according to setting time (normal and fast [F]) without regard to viscosity; for instance, the "Identium" item includes both light and medium viscosities. Impregum Penta Soft and Impregum Penta Soft Quick Step are manufactured by 3M ESPE, St. Paul, Minn. Affinis Precious, Affinis heavy body and Affinis fast heavy body are manufactured by Coltène/Whaledent, Altstätten, Switzerland. Identium Light, Identium Medium, Identium Light Fast and Identium Medium Fast are manufactured by Kettenbach, Eschenburg, Germany.

related to different software and hardware performances, as well as the differing technologies used to capture the images. The wand of the CEREC AC with Bluecam records several images automatically after focusing on the surface to be captured. Capturing a single crown and the adjacent teeth requires five images, an antagonist two or three images and the bite registration one or two images. Similarly, the iTero records a color image when the wand is at a proper focal distance over the teeth. In comparison, the Lava C.O.S. records a video of the teeth. From a time-exposure perspective, a point-and-click system such as the CEREC AC with Bluecam seems beneficial. Furthermore, it might be easier to keep the tooth surfaces in focus when holding the wand still (as with the CEREC AC with Bluecam and iTero) instead of while moving the wand (Lava C.O.S.). During the last step before sending the scan files, the scanning software prepares the data for digital shipment (if applicable), performing modification, conversion and compression. The scan data size—in other words, the number of images taken during the scan process—as well as the applied software algorithms and the computational hardware influence the time needed to perform this step.

Although it is necessary to apply an adhesive before making a conventional impression; to disinfect an impression before shipment; or, when using an intraoral scanner, to start up the hardware, put in the patient information and postprocess the data, these steps do not affect the actual clinical time needed to make an impression. When one focuses on the relevant steps for the dentist—in the conventional approach, processing, setting, making the antagonist impression and confirming the interarch registration; in the digital approach, performing the coating, scanning the abutment, scanning the antagonist and scanning the interarch registration—without considering steps that can be done before, simultaneously with or after the actual impression making, the difference between the conventional and digital approaches is less. However, according to our results, the CEREC AC with Bluecam still is the fastest system for digitizing a single abutment or a single-span FDP, whereas the iTero can be considered the fastest scanner for digitizing a full-arch preparation scenario (14 abutments) when focusing solely on the intraoral working time.

We used study models, fixed in a dental simulator unit, to mimic a standardized patient setting. Such a setting comes close to a real patient situation. Nevertheless, it is not an entire replica of a patient. Therefore, it was not possible to mimic soft-tissue conditions, saliva, movements of the patient, swallowing or limited intraoral space. These factors may influence the scanning procedure and lead to different, expectedly higher procedure durations for CAIM in a real patient scenario. Two scanners, the CEREC AC with Bluecam and the iTero, offer the user an optional foot-pedal feature. This feature allows the clinician to control the capturing procedure manually. Except for the single-span FDP, the durations for a manual release (foot pedal) were slightly higher for the abutment scan time. This suggests that the automatic capturing procedure is superior and helps inexperienced users to capture a focused image more quickly.

In this study, one clinician (C.L.) with no previous experience in CAIM underwent a training process of 16 hours per device. This duration allowed the clinician enough time to become familiar with the software setup and scanning procedure of each system. Thus, the results of this study can be considered as having been obtained by a user new to CAIM, taking into account the aforementioned differences from a real oral cavity. We assume that in comparison with the values we report, highly experienced users may be faster with these systems, whereas inexperienced users may be slower with them or even faster with conventional materials. By using only one clinician, we could standardize the procedure of learning and measuring the time. However, a study design including more testers with different grades of experience (including students, newcomers and experienced users) would represent a wider range of users.

In addition to the time measurements of CAIM, we compiled the procedure durations of using three conventional impression materials along with their work flows. Instead of measuring the procedure durations for each material, we used the timing and approach that were recommended by the manufacturers for each conventional impression material. These represent the minimal setting times that the impression materials need to achieve the ideal properties. Shorter times may lead to an unset material, which means that the clinician at least has to follow these recommendations to guarantee a proper impression.[1,16,17] On the other hand, the temperature in the oral cavity usually is higher than the ambient temperature, which leads to a faster setting of the impression material.[18] Additives (such as disinfectants) can influence the working and setting times as well.[19] Readers should take these aspects into account when interpreting the results of our study. A general disadvantage of conventional impression-making approaches is the need to start over or take additional impressions (for example, mini-tray impressions or partial-arch impressions) if an impression fails. With a CAIM approach, it is possible to visualize the digital impression in real time on a screen, rescan particular areas (for instance, areas not captured in the first scan) or even correct and rescan the preparation without the need to perform the entire scan again.

We did not include the durations for the removal of provisional restorations, cleaning of abutments, cord placement and drying of the oral cavity. These durations are similar for both approaches and have to be accounted for in a clinical setting. We focused on the actual impression-making approach. A general drawback of CAIM is that there is no device on the market, except prototypes,[20] that is able to capture subgingival parts of an abutment tooth with an appropriate accuracy. At this point, all impression approaches, whether CAIM or conventional, still require retraction cord placement.

Improving both approaches would result in a more time-efficient work flow. Not all steps have to be performed by the clinician; the dental assistant can perform several steps of the work flow to optimize time management. A possible sharing of the work flow for the conventional approach might be the assistant's selecting and preparing the tray while the dentist places the cords, dries the oral cavity and, finally, makes the impression. Afterward, while the dentist temporizes the teeth, the assistant disinfects the impression and prepares it for shipment. A similar sharing would be applicable for the CAIM approach: the dental assistant sets up the hardware and software while the dentist places the cords, dries the oral cavity and performs the actual scanning. Afterward, while the dentist is temporizing the teeth, the assistant postprocesses the dataset and prepares it for digital shipment. Both of these work flow–sharing suggestions save chair time and seem to be more realistic than the linear presentation of duration as used in our study. Further studies are necessary to evaluate whether sharing steps among members of the dental team affects needed chair time. Finally, the individual clinician's speed and effort have a substantial influence on the efficiency of his or her work.

The identifiable literature related to the subject matter of our study deals predominantly with procedure durations for conventional impression materials.[18,21-24] Rupp and colleagues[21] reported a mean total clinical application time of 51.2 seconds for single-step/double-mix techniques. Jamani and colleagues[22] determined working and setting times of different materials and compared them with the manufacturers' provided times. They reported measured working times for polysulfides, polyethers, A-silicones and C-silicones as being, respectively, up to 4 minutes 20 seconds, 2 minutes 45 seconds, 3 minutes 7 seconds, and 2 minutes 56 seconds. They reported setting times of, respectively, up to 9 minutes 15 seconds, 6 minutes 0 seconds, 6 minutes 30 seconds, and 7 minutes 45 seconds.[22] Ohsawa and Finger[23] reported working times of 2 minutes for Impregum and up to 3.5 minutes for A-silicones. Investigators in only one previous study compared conventional approaches with digital approaches. Lee and Gallucci[7] evaluated the efficiency of digital and conventional impressions of single-implant restoration models by second-year dental students. The mean total treatment time was 24 minutes 42 seconds for the conventional approach and 12 minutes 29 seconds for the digital approach, with a statistically significant difference of more than 12 minutes ($P < .001$). The authors included in their calculation the procedure durations for retakes or rescans, probably explaining the difference of approximately 10 minutes for the digital approach in comparison with the results for scenario 1 of our study. Nevertheless, the authors stated clearly that the digital approach is more time efficient, preferred by users and even easier to perform for a novice user—findings that are in accordance with ours.

## CONCLUSION

Compared with the compiled times required to make conventional impressions, intraoral scanners were up to 23 minutes faster for single abutments, up to 22 minutes faster for single-span FDP preparations and up to 13 minutes faster for full-arch preparations (14 abutments) when one considers the total procedure duration for each process. The findings suggest that using CAIM results in a more time-efficient work flow than that possible with conventional impression making; however, there are opportunities to reduce the actual chair time for both approaches by sharing several steps among members of the dental team. Further studies are necessary to determine whether these results are applicable in in vivo settings. ■

**Disclosure.** None of the authors reported any disclosures.


1. Balkenhol M, Kanehira M, Finger WJ, Wöstmann B. Working time of elastomeric impression materials: relevance of rheological tests. Am J Dent 2007;20(6):347-352.
2. Lutz F, Krejci I, Mörmann W. Tooth-colored posterior restoration (in German). Phillip J Restaur Zahnmed 1987;4(3):127-137.
3. Mörmann WH, Brandestini M. Cerec-system: computerized inlays, onlays and shell veneers (in German). Zahnarztl Mitt 1987;77(21):2400-2405.
4. Mörmann WH, Brandestini M, Lutz F. The Cerec system: computer-assisted preparation of direct ceramic inlays in 1 setting (in German). Quintessenz 1987;38(3):457-470.
5. Bindl A, Ritter L, Mehl A. Cerec Guide: rapid and streamlined manufacture of surgical guides in dental practice. Int J Comput Dent 2012;15(1):45-54.
6. Neugebauer J, Kistler F, Kistler S, et al. CAD/CAM-produced surgical guides: optimizing the treatment workflow. Int J Comput Dent 2011;14(2):93-103.
7. Lee SJ, Gallucci GO. Digital vs. conventional implant impressions: efficiency outcomes. Clin Oral Implants Res 2013;24(1):111-115.
8. Jacobson B. Taking the headache out of impressions. Dent Today 2007;26(9):74, 76.
9. van Noort R. The future of dental devices is digital. Dent Mater 2012;28(1):3-12.
10. Zweig A. Improving impressions: go digital! Dent Today 2009;28(11):100, 102, 104.
11. Pieper R. Digital impressions: easier than ever. Int J Comput Dent 2009;12(1):47-52.
12. Dalstra M, Melsen B. From alginate impressions to digital virtual models: accuracy and reproducibility. J Orthod 2009;36(1):36-41; discussion 14.
13. Birnbaum NS, Aaronson HB, Stevens C, Cohen B. 3D digital scanners: a high-tech approach to more accurate dental impressions. Inside Dent 2009;5(4):70-77.
14. Birnbaum NS, Aaronson HB. Dental impressions using 3D digital scanners: virtual becomes reality. Compend Contin Educ Dent 2008;29(8):494, 496, 498-505.
15. Fasbinder DJ. Digital dentistry: innovation for restorative treatment. Compend Contin Educ Dent 2010;31(special no. 4):2-11.
16. Richards MW, Zeiaei S, Bagby MD, Okubo S, Soltani J. Working times and dimensional accuracy of the one-step putty/wash impression technique. J Prosthodont 1998;7(4):250-255.
17. Tan E, Chai J, Wozniak WT. Working times of elastomeric impression materials determined by dimensional accuracy. Int J Prosthodont 1996;9(2):188-196.
18. McConnell RJ, Johnson LN, Gratton DR. Working time of synthetic elastomeric impression material. J Can Dent Assoc 1994;60(1):49-50, 53-54.
19. Rosen M, Touyz LZ. Influence of mixing disinfectant solutions into alginate on working time and accuracy. J Dent 1991;19(3):186-188.
20. Mandurah MM, Sadr A, Shimada Y, et al. Monitoring remineralization of enamel subsurface lesions by optical coherence tomography. J Biomed Opt 2013;18(4):046006.
21. Rupp F, Saker O, Axmann D, Geis-Gerstorfer J, Engel E. Application times for the single-step/double-mix technique for impression materials in clinical practice. Int J Prosthodont 2011;24(6):562-565.
22. Jamani KD, Harrington E, Wilson HJ. Consistency, working time and setting time of elastomeric impression materials. J Oral Rehabil 1989;16(4):353-366.
23. Ohsawa M, Finger W. Working time of elastomeric impression materials. Dent Mater 1986;2(4):179-182.
24. Viohl J. Working time and setting time of elastomeric impression materials (in German). Dtsch Zahnarztl Z 1972;27(7):598-603.