



Comparison of two computerized occlusal analysis systems for indicating occlusal contacts

Min-Young Jeong¹, Young-Jun Lim², Myung-Joo Kim², Ho-Beom Kwon^{2*}

¹Department of Prosthodontics, School of Dentistry, Seoul National University, Seoul, Republic of Korea

²Dental Research Institute and Department of Prosthodontics, School of Dentistry, Seoul National University, Seoul, Republic of Korea

PURPOSE. The purpose of this study was to compare the performance of Accura to that of the T-scan for indicating occlusal contacts. **MATERIALS AND METHODS.** Twenty-four subjects were selected. Their maxillary dental casts were scanned with a model scanner. The Stereolithography files of the casts were positioned to align with the occlusal plane. Occlusal surfaces of every tooth were divided into three to six anatomic regions. T-scan and Accura recordings were made during two masticatory cycles. The T-scan and Accura images were captured at the maximum bite force and overlapped to the cast. Photographs of interocclusal records were used as the reference during overlap. The occlusal contacts were counted to compare the T-scan and Accura. McNemar's test was used for statistical significance and the corresponding P-values were calculated from a chi-square distribution with one degree of freedom. The accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of Accura were calculated relative to the T-scan values as a control. **RESULTS.** No statistical differences ($P > .05$) were found between the T-scan and Accura methods. The accuracy of Accura was 75.8%, sensitivity was 82.1%, specificity was 60.1%, PPV was 82.9%, and NPV was 60.1%. **CONCLUSION.** Accura could be another possible option as a computerized occlusal analysis system for indicating occlusal contacts at maximum intercuspation. [*J Adv Prosthodont 2020;12:49-54*]

KEYWORDS: Occlusal indicator; Computerized occlusal analyzer; Occlusal contact; T-scan, Accura

INTRODUCTION

The occlusal contacts and bite force of a patient provide information for diagnosis and prognosis. Moreover, the number of occlusal contacts and occlusal contact areas are related to chewing efficacy.¹⁻⁴ Thus, it is essential to accurately locate the occlusal contacts on restorations, both in the clinic and in the laboratory. In addition, occlusal con-

tacts should be evaluated to find the occlusal interference during occlusal adjustment.^{5,6} If there is an occlusal interference or a premature contact, it may induce changes in the tooth-supporting tissues, masticatory muscles, and the temporomandibular joint.⁷⁻⁹ Hence, analysis and evaluation of occlusal contacts are required for clinicians to achieve appropriate occlusal contacts.

Articulating papers or foils are conventionally used by clinicians to identify the occlusal contacts. However, the number of contacts varies largely depending on the recording method.^{10,11} Moreover, reproducibility of these occlusal indicators is unreliable.¹²⁻¹⁵ For example, false positive marks are often seen when articulating papers are used,¹³⁻¹⁷ and marks from the articulating paper can be interpreted subjectively.^{18,19} Furthermore, contact marks from articulating papers or foils do not indicate the occlusal force, but only the location of the contacts.^{16,17,20,21}

Maness developed the T-scan system as computerized occlusal analysis system and published the first research about the T-scan in 1987.²² Since the first T-scan I in 1984, the T-scan technology has been further developed over the last 30 years, including a T-scan II for Windows (1995), T-scan III with turbo recording (2004), and the newly

Corresponding author:

Ho-Beom Kwon

Dental Research Institute and Department of Prosthodontics, School of Dentistry, Seoul National University, 101, Daehak-ro, Jongno-gu, Seoul 03080, Republic of Korea

Tel. +8227408601; e-mail, proskwon@snu.ac.kr

Received November 27, 2019 / Last Revision February 28, 2020 / Accepted March 4, 2020

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This research was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (grant number: HI17C1911).

updated T-scan v10 (2018).²³ The T-scan is advantageous over conventional methods as it can represent the change of the occlusal force in real time using the intraoral sensor. The thickness of the sensor foil is 100 μm .^{8,24,25} The sensor is composed of conduction lines, which create a grid with small square pressure-sensitive areas called sensels. When a force is exerted on the sensor foil, the voltage drops in the sensels and these changes are digitalized and shown by the T-scan software.^{25,26}

Studies on the T-scan have been reported since 1987. There were some problems with the T-scan I and several studies reported that the T-scan I was not accurate and reliable for recording occlusal contacts and the bite force due to the low-resolution capacity and an excessive variation in sensor sensitivity.²⁷⁻²⁹ Furthermore, there were issues with non-sensible areas.^{27,28} The T-Scan II system, however, has been reported to be a reliable method for analyzing and evaluating the occlusal contact distribution in maximum intercuspation.^{30,31} As for the T-scan III, this software is known to be precise and reliable, and it is a fast way to record the occlusal contacts.^{26,32} Nevertheless, certain reports have indicated that the surface of the sensor film does not always show uniform sensitivity and the sensor film requires pre-conditioning for an accurate recording.³³ Moreover, the T-scan showed lower reliability than transillumination method using additional silicones for measuring occlusal contact areas.³⁴ Furthermore, the T-scan approach needs improvement for accurately finding the intraoral position of the occlusal contact, since the location of occlusal contacts is not sufficiently precise to determine the occlusal contact in the mouth.³⁵ In addition, the sensors could alter the occlusion and interfere with the occlusion.³⁶⁻³⁸

Accura (Dmetec Co., Bucheon, Korea) is a new computerized occlusal analysis system that shows the change of occlusal force in real time, similar to the T-scan. According to the manufacturer's information, it can measure the absolute occlusal force. The sensor film is made of polyimide and is 160- μm thick. The device is connected to the computer through Wireless Fidelity (Wi-Fi) for data transfer.

The purpose of this study was to evaluate the performance of Accura compared to the T-scan for indicating occlusal contacts. The null hypothesis of this study was that the error rate of Accura is not different from that of the T-scan.

MATERIALS AND METHODS

Twenty-four subjects were selected from the students of the Seoul National University, School of Dentistry and the residents of the Seoul National University Dental Hospital. The subjects included 16 males and 8 females (Table 1). The subjects were selected according to the following criteria: (1) Angle class I, (2) no severe crowding, (3) free of signs and symptoms of temporomandibular disorder (TMD), (4) no pathologic periodontal and pulpal conditions, and (5) no current orthodontic treatment. Institutional Review Board

approval (S-D20170046) was obtained for this study with 24 subjects. Consent forms were signed by all participants. Dental casts, interocclusal records, T-scan, and Accura were used to compare the occlusal contacts between the two computerized occlusal analysis systems.

Irreversible hydrocolloid (Aroma fine plus normal set, GC, Tokyo, Japan) impressions of upper and lower arches were taken to create dental stone casts (Snow Rock, Gimhae, Korea). The maxillary cast was scanned using the T-300 model scanner (Medit Corp, Seoul, Korea). Interocclusal records of all subjects were taken by polyvinyl siloxane impression material (O-bite, DMG, Hamburg, Germany) and photographs of each record were taken vertically from the top by a digital camera (Nikon D5500, Nikon Co., Tokyo, Japan).

Occlusal contacts measured through photocclusion methods varied by plane.³⁶ Based on the manufacturer's recommendations, the handle of the computerized occlusal analysis system should be parallel to the occlusal plane. Therefore, in this study, occlusal contacts were analyzed considering the occlusal plane. The Stereolithography (STL) files of the maxillary cast were positioned to be aligned with the occlusal plane using Rapidform XOR (3D systems, Rock Hill, SC, USA). The occlusal plane of the cast was established by a tripod of points from the midpoint between the proximal tip of the maxillary central incisors and the most occlusal point of the right and left mesiopalatal cusp of the maxillary first molar, as used in Park's study.³⁹ Using the method from DeLong *et al.*³⁶ and Plasmans *et al.*,⁴⁰ occlusal surfaces of all teeth were divided into three to six anatomic regions (Fig. 1).

For T-scan and Accura measurements, subjects were seated on the dental chair, and an average width of two maxillary central incisors was measured. As stated in the manufacturer's recommendations, the measured value was put into the T-scan v8.0 (Tekscan Inc., South Boston, MA, USA) to customize the arch size. The T-scan automatically set the average width of the teeth. After the arch size was

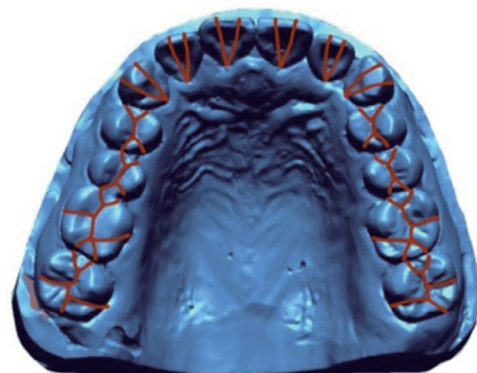


Fig. 1. Occlusal surfaces of all teeth were divided into three to six sections to determine the locations of the occlusal contacts.

set, the position guide of sensor support was placed between the central incisors, and the handle was kept as parallel to the occlusal plane as possible, according to the manufacturer's recommendations. The recording was made during two masticatory cycles. Before the recording, a pre-test of closing 3 times was made and the sensitivity was adjusted until 1 - 3 pink sensels were shown, based on the manufacturer's recommendations. After recording, the contact points were captured at the maximum bite force.

The same procedure was done for Accura. The contact points were captured at the maximum bite force.

To compare occlusal contacts, image files of sectioned dental casts and the interocclusal records were overlapped. Then, captured files of the T-scan and Accura sensors were overlapped and the location of the occlusal contact from each computerized occlusal analysis systems was identified using ImageJ (National Institutes of Health, Washington, DC, USA) (Fig. 2). Silicone interocclusal records were used as a reference to position each subject's captured file to include all contact points in the dental arch. The arch length and width of the cast were used for the exact overlapping.⁹ Any single contact crossing the boundary was considered an occlusal contact. If the occlusal contact was in the anatomic region, it was counted as positive. If the occlusal contact was not in the anatomic region, it was considered negative.

McNemar's test was used for statistical significance with a significance level at 5%.⁴¹ The corresponding P-value was calculated from a chi-square distribution with one degree of freedom. McNemar's test was performed separately for all teeth, anterior teeth, and posterior teeth. The accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of Accura were calculated relative to the T-scan values as a control.

RESULTS

The average concordance that indicates the occlusal contacts between the T-scan and Accura was 75.7%. Maximum

concordance was 89.3% and minimum concordance was 58.9%. Subject concordances are described in Table 1.

Table 1. Subject information and concordance between the T-scan and Accura based on indicating occlusal contacts

Subject	Sex	Age	Concordance (%)
A	male	31	58.9
B	female	26	62.5
C	female	26	64.3
D	male	30	69.6
E	female	23	69.6
F	male	23	69.7
G	male	27	70.8
H	male	23	73.2
I	male	30	73.2
J	female	27	75.0
K	male	27	75.0
L	male	28	76.8
M	male	27	76.8
N	male	24	78.6
O	male	28	78.6
P	female	25	80.4
Q	male	26	80.4
R	male	30	80.4
S	male	27	80.4
T	female	26	82.0
U	female	26	82.1
V	female	30	82.1
W	male	30	87.5
X	male	30	89.3
Average		27.1	75.7

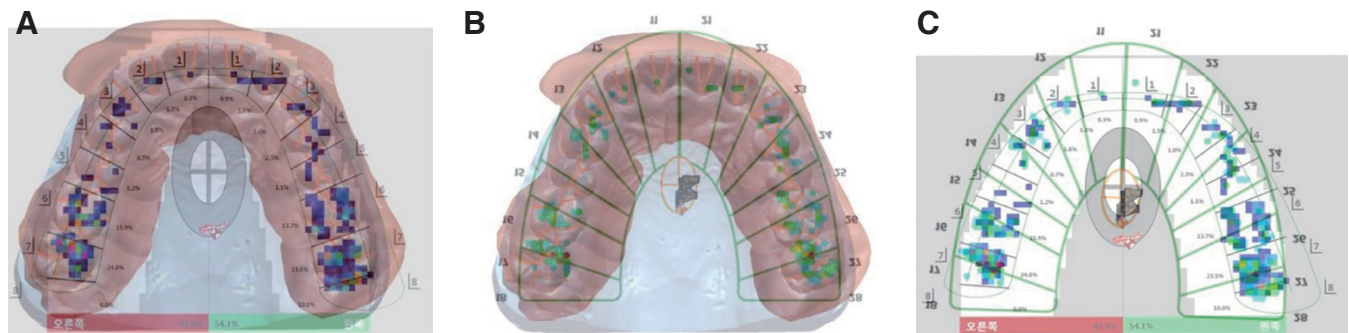


Fig. 2. T-scan and Accura sensor films were overlapped to the cast and interocclusal records to determine the location of the occlusal contact from each computerized occlusal analysis system using ImageJ. (A) Overlapping images of sectioned dental casts, the interocclusal records, and T-scan. (B) Overlapping images of sectioned dental casts, the interocclusal records, and Accura. (C) Overlapping images of T-scan and Accura.

Table 2. Comparison of occlusal contacts at the maximum bite force between T-scan and Accura for all teeth, the anterior teeth, and the posterior teeth

	All teeth			†Anterior teeth			‡Posterior teeth		
	Accura positive	Accura negative	Raw total	Accura positive	Accura negative	Raw total	Accura positive	Accura negative	Raw total
T-scan positive	766	167	933	150	56	206	616	111	727
T-scan negative	158	252	410	73	153	226	85	99	184
Column total	924	419	1343	223	209	432	701	210	911
Chi-square value		0.249			2.240			3.449	
P value		.617			.134			.063	

†Anterior teeth involved the right canine to the left canine.

‡Posterior teeth involved the premolars and molars on both sides.

Table 3. Accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of Accura when the T-scan was set as the control (unit: %)

	All teeth	Anterior teeth	Posterior teeth
Accuracy	75.8	70.1	78.5
Sensitivity	82.1	72.8	84.7
Specificity	60.1	73.2	47.1
PPV	82.9	67.3	87.9
NPV	60.1	73.2	47.1

Comparisons of the occlusal contacts between the two computerized occlusal analysis systems for all teeth, anterior teeth, and posterior teeth are described in Table 2. McNemar’s test was performed separately for all teeth, anterior teeth, and posterior teeth.⁴¹ No statistically significant differences were identified in any of the cases. The *P*-value of all teeth was 0.617, while those of anterior and posterior teeth were 0.134 and 0.063, respectively. Chi-square values and *P*-values are described in Table 2.

The accuracy of Accura was 75.8% in all teeth, 78.5% in posterior teeth, and 70.1% in anterior teeth relative to the T-scan values as a control. Sensitivity, specificity, accuracy, positive predictive value (PPV) and negative predictive value (NPV) are described in Table 3. Several sensor films on both devices showed a positive signal on the region where no force was applied.

DISCUSSION

The objective of this study was to evaluate the performance of Accura compared to the T-scan for assessing occlusal contacts. The null hypothesis was not rejected at assessments of all teeth, anterior teeth, and posterior teeth. (*P* >

.05) This indicates that the error rates of the T-scan and Accura were not statistically significantly different for indicating occlusal contacts at the maximum intercuspation (Table 2). The sensitivity and PPV of Accura were 82%, which means that the probability of indicating an occlusal contact on the T-scan and an occlusal contact with Accura was 82%. In contrast, the specificity and NPV, was 60% (Table 3). Based on the accuracy, sensitivity, specificity, PPV, and NPV values, the T-scan and Accura did not seem to be concordant. However, this result was deduced from the fact that T-scan was set as a control. The differences in sensor films between the T-scan and Accura could cause the discrepancies in the values for the accuracy, sensitivity, specificity, PPV, and NPV to be distinct, while the error rate remains not significantly different between the two devices. The T-scan sensor film is composed of polyethylene terephthalate and is 100-µm thick, while Accura film is made of polyimide and is 160-µm thick. The connection between the sensor film and the connector also differs, as the pogo fin is the connection for the T-scan while a flexible printed circuits board (FPCB) is used in Accura. The sensor film of Accura is thicker and stiffer than that of the T-scan. These distinct features may account for the differences in detecting occlusal contacts. Moreover, based on the manufacturer’s information, the sensel spatial resolution of the T-scan is 400 sensels/in², whereas Accura has 361 sensels/in² of sensel resolution.^{24,33} This might be one reason for the differences between the two devices because more sensels in the same area could detect pressure more precisely.

The sensitivity and accuracy of Accura were higher at the posterior teeth but were lower at the anterior teeth. This is because the sensor film of Accura is stiff and has a 160-µm thickness, which is greater than that of the T-scan (100-µm). Therefore, the occlusion could be altered due to differences in the stiffness and thickness of the sensor films. Even though the subject firmly bit the sensor film, the pressure in the anterior teeth could be weak which could impact the lower sensitivity and PPV values at the anterior teeth.

This study analyzed and compared occlusal contacts of computerized occlusal analysis systems by overlapping their respective images, rather than the previously used transillumination method. The transillumination method that uses transmission of light through the interocclusal record from additional silicones could be helpful for finding the occlusal contacts.^{32,36} In a recent study, the transillumination method showed higher reliability and validity than the T-scan for measuring occlusal contact areas.³⁴ However, the transillumination results can differ, depending on the orientation of the light source.^{36,42} Solaberrieta *et al.*³⁵ suggested using an individual alignment device to accurately align the dental cast and T-scan image. However, it is difficult to make individual alignment devices, and an individual device could be too large and interfere with the occlusion. This previous study indicated that an objective reference is necessary to align the T-scan image and the dental cast.³⁵ In this study, the interocclusal record from additional silicones was used as the reference for the occlusal contacts when adjusting and overlapping images from two occlusal analysis systems. One of the limitations of the T-scan is finding the accurate intraoral position of the occlusal contact. In this study, occlusal contacts are determined by overlapping images of the dental cast, the interocclusal record, T-scan, and Accura. This method might help further researches on occlusal contacts of the computerized occlusal analysis system.

The McNemar's test results indicate that there was no significant difference in the error rate between the T-scan and Accura.⁴¹ However, the limitation when interpreting the results of this study is that it only shows the comparison of error rate between the two devices, and the T-scan might not be the ideal control as a computerized occlusal indicator device. Based on several studies, there are also other limitations to the T-scan. The sensor film of the T-scan did not show uniform sensitivity throughout the surface, and also the T-scan sensor could alter the occlusion.^{33,36-38} It has been reported that the direction of the mandible on closing can be shifted by the sensor film of the T-scan, therefore the occlusal contact force and occlusal contact points could also be inaccurately detected.³⁸ Therefore, it is difficult to determine whether the T-scan is an ideal computerized occlusal indicator control. In addition, some regions of the sensor films on both devices malfunctioned, which was confirmed by regions showing positive signal even though no force was applied. This could be due to a manufacturing error, which makes neither device ideal. Therefore, further study is needed to evaluate the accuracy of Accura itself.

Based on the manufacturer's information, the sensel spatial resolution of the T-scan is 400 sensels/in². There is one sensel in 1.61 mm².^{24,33} Even though there are two contact points in 1 mm², these computerized occlusal analysis systems show only one contact point which is a current limitation of computerized occlusal analysis systems. If the sensel is smaller in size and placed closer to other sensels, the sensitivity of the computerized occlusal analysis system would be improved.

Compared to the conventional occlusal indicator, the

computerized occlusal analysis system could characterize not only the static occlusion but also the transition of occlusal force over time. This study was focused on the presence or absence of occlusal contacts in the region of the teeth. Based on this analysis and other research, additional studies on dynamic occlusion and occlusal force are needed to better understand and optimize computerized occlusal analysis systems.

CONCLUSION

Accura, a new computerized occlusal analysis system, shows comparable accuracy to the T-scan system for indicating occlusal contacts at maximum intercuspation. However, there are some differences between the Accura and the T-scan with respect to sensor films and the sensel spatial resolution. Use of either of these two computerized occlusal analysis systems with dental casts and silicone interocclusal records could be helpful for precise occlusal analysis in clinics.

ORCID

Min-Young Jeong <https://orcid.org/0000-0002-0757-6462>

Young-Jun Lim <https://orcid.org/0000-0003-2504-9671>

Myung-Joo Kim <https://orcid.org/0000-0003-2020-5284>

Ho-Beom Kwon <https://orcid.org/0000-0003-4973-7727>

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