Comparison of digital intraoral scanners and alginate impressions: Time and patient satisfaction

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Introduction: Recent technological advances have made intraoral scans and digital models a possibility and a promising alternative to conventional alginate impressions. Several factors should be examined when considering an intraoral scanner, including patient acceptance and efficiency. The objectives of this study were to assess and compare patient satisfaction and time required between 2 intraoral scanners and conventional alginate impressions. **Methods:** An initial pilot study was completed to create a valid and reliable survey instrument that would measure 3 areas of patient satisfaction with the impression experience. A visual analog scale survey was developed and administered to 180 orthodontic patients receiving 1 of 3 types of impressions: (1) iTero Element intraoral scan (Align Technologies, San Jose, Calif), n = 60; (2) TRIOS Color intraoral scan (3Shape, Copenhagen, Denmark), n = 60; and (3) conventional alginate impression (imprEssix Color Change; Dentsply Sirona, York, Pa), n = 60, and the time required to obtain the impressions was recorded. **Results:** Reliability was evaluated with intraclass correlation coefficient values for 17 paired questionnaires, and all questions were found to be reliable (intraclass correlation coefficient, ≥0.65). For the main study, 180 subjects completed timed impressions and surveys. Data indicated that subjects receiving intraoral scans preferred the digital impressions, and subjects receiving alginate impressions were neutral regarding impression preference, and that efficiency varied based on the impression method. **Conclusions:** Intraoral scanners are accepted by orthodontic patients, and they have comparable efficiency with conventional impression methods depending on the type of scanner. (Am J Orthod Dentofacial Orthop 2018;153:534-41)

Orthodontists frequently use dental models for diagnostic and treatment planning purposes such as evaluation of tooth positions and occlusal relationships, space assessment, simulation of tooth and jaw movements, appliance design and fabrication, and treatment effects.[1] Methods of making dental impressions have greatly evolved over the past several decades; in recent years, dental models have been conventionally made using alginate impressions and plaster casts. However, current interest in 3-dimensional and digital technology in the medical and dental fields has led to the development of 3-dimensional scanning and digital casts. Advantages of digital casts include more efficient storage and retrieval, increased diagnostic versatility, easier transferability, superior durability, and decreased processing time.[2]

Previous studies to evaluate the accuracy of 3-dimensional models have shown that they are comparable with plaster models using both linear and angular measurements as well as shell-shell deviation and arch-registration measurements.[3-7] With evidence supporting the accuracy of digital impression techniques, their adaptation in orthodontic practices is increasing. Nevertheless, intraoral scanning has not been fully integrated into orthodontic private practices because of the endurance of conventional impression methods. The advantages of conventional materials are that they are accurate, well accepted,[8,9] and traditionally inexpensive. However, these types of impressions are not always favored by patients and have been reported to be unpleasant and burdensome.[10,11] Additionally, conventional impression methods require inventory and stocking of raw materials as well as storage space for the plaster models. A number of dental and orthodontic

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suppliers have produced digital scanners, and some provide high-tech software analysis programs that allow operators to complete model analysis and diagnosis, occlusal setups, treatment predictions, and evaluation of treatment outcomes.[12] Digital models are also compatible with many laboratories, allowing efficient digital communications while still providing quality fabrication of restorations, prostheses, and appliances.

Questions remain regarding the acceptance and use of intraoral scanners. Clinicians should consider the technical aspects of these devices, some of which have been evaluated and include performance, ease of use, portability, features and options, vendor company, compatibilities, and cost. But they also should consider patient-oriented aspects of scanner use. Some of these aspects have been investigated, but all used previous generation technology that required coating the teeth before scanning for adequate performance. These studies provided conflicting results.[6,13,14]

Two types of information are currently missing from the literature regarding scanners: data generated from contemporary scanners not requiring the powder coating of teeth, and more information related to the patient perspective. This latter point has been emphasized in dentistry and orthodontics, in particular, in 2 recent articles.[15,16] Most dental research reports disease activity as the primary or secondary outcome, whereas quality of life and functional measures were rarely considered.[15]

In orthodontics, morphology is most frequently measured (63% of the time). Health resource usage, adverse effects of orthodontic treatment, quality of life, functional status, and physical consequences of malocclusion are evaluated much less frequently (32%-2% of the time).[16] Evaluating patient-centered issues related to intraoral scanning then clearly addresses 2 central issues in this area—a lack of information related to contemporary scanners and a patient-centric viewpoint.

The aim of this study was to assess important factors related to digital scanners: patient acceptance and impression efficiency. We compared 2 currently available and popular digital intraoral scanners with each other and with alginate impressions.[12] For each impression method, patient satisfaction was measured, and the time required to complete a full-mouth impression was recorded.

MATERIAL AND METHODS

Approval to conduct this study was obtained from the institutional review board at Ohio State University. Informed consent was obtained from legal guardians and adult subjects, and assent was obtained from minor subjects.

A survey was designed to test 3 areas of patient satisfaction regarding the impression experience: comfort, time, and novelty. The proposed survey was administered to a group of orthodontic practitioners, technicians, and patients to confirm the validity of the questions. After adjustments and corrections to the survey instrument, the finalized survey (Fig 1) consisted of 7 statements with a 100-mm visual analog scale (VAS) below each statement anchored with "agree" and "disagree." The survey also included questions to determine whether the patient had previous experience with impressions.

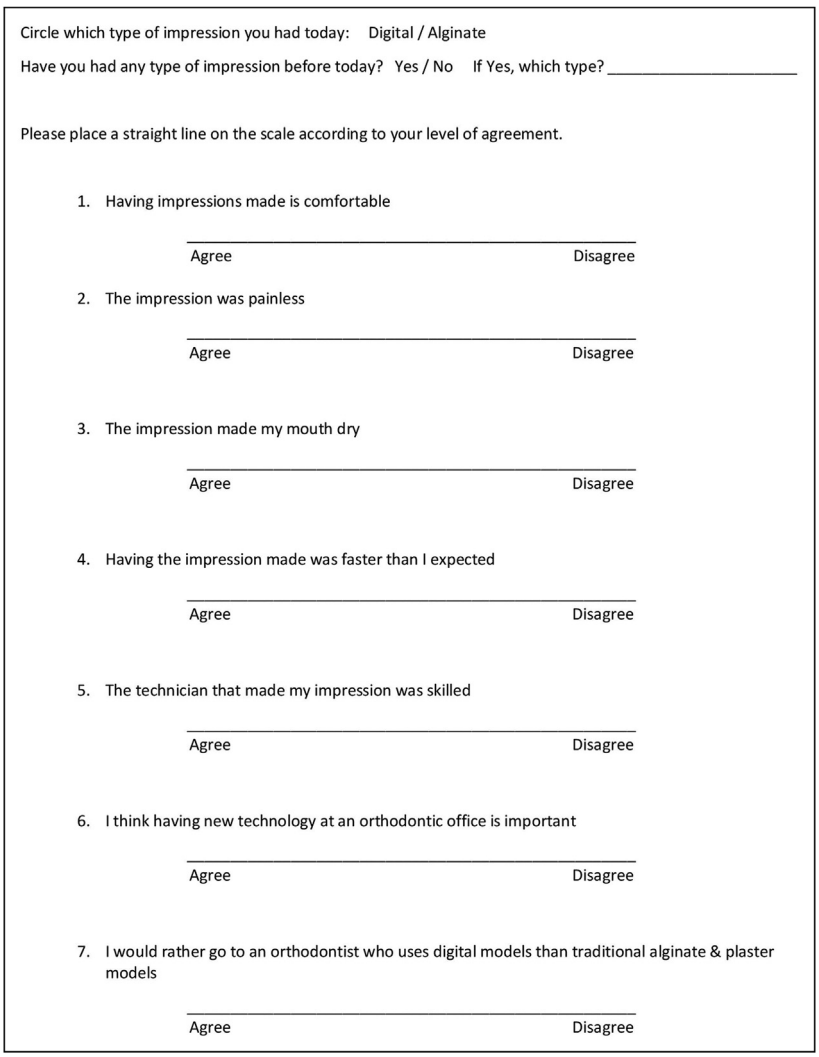
Next, a pilot study was undertaken to establish reliability of the instrument. Seventeen subjects were recruited from the graduate orthodontic clinic at Ohio State University. Each had an impression made and completed the survey. Three to 4 days after the impression, each participant completed a second survey. The surveys were measured and analyzed, and the results from the 2 time points were compared to assess the reliability of each question. After the survey instrument was determined to be both valid and reliable, the main study began.

Subjects were recruited from the graduate orthodontic clinic and a local private orthodontic practice in Columbus, OH for either an intraoral scan or an alginate impression. Inclusion criteria for participants specified that they be healthy, English-speaking subjects seeking orthodontic treatment or actively undergoing orthodontic treatment. There were no restrictions for age, sex, or race. Patients were excluded if they had a history of mental disabilities, cleft lip or palate, or other craniofacial anomalies or syndromes.

Sample size calculations were completed before data collection. With a nondirectional alpha risk of 0.05 and assuming a standard deviation of 24,[17] a sample of 50 subjects would allow detection of a difference of $\pm$14 mm on the VAS scale with power of 0.823. To account for participant dropout and the possibility of using a nonparametric data analysis, we added 20% to the number of 50, yielding a sample size of 60 per group.

A total of 180 orthodontic patients were included in the study: 60 subjects had an intraoral scan with the iTero Element (Align Technologies, San Jose, Calif), 60 had an intraoral scan with the TRIOS Color (3Shape, Copenhagen, Denmark), and 60 had alginate impressions (imprEssix Color Change; Dentsply Sirona, York, Pa). The participants included 104 female and 76 male subjects, with a median age of 15 years (interquartile range, 13-20) and an age range of 8 to 56 years.

Each subject had either a digital intraoral scan or an alginate impression completed by an operator trained



Circle which type of impression you had today: Digital / Alginate

Have you had any type of impression before today? Yes / No If Yes, which type? _____

Please place a straight line on the scale according to your level of agreement.

1. Having impressions made is comfortable

Agree Disagree

2. The impression was painless

Agree Disagree

3. The impression made my mouth dry

Agree Disagree

4. Having the impression made was faster than I expected

Agree Disagree

5. The technician that made my impression was skilled

Agree Disagree

6. I think having new technology at an orthodontic office is important

Agree Disagree

7. I would rather go to an orthodontist who uses digital models than traditional alginate & plaster models

Agree Disagree

Fig 1. Survey instrument.

and experienced in the specific impression technique used. The scanning protocol was applied according to the manufacturers' recommendations. For each intraoral scan with either the iTero Element or the TRIOS Color, the time required to complete a full mouth scan and bite registration was recorded. Any verbal explanation or isolation placement was not included in the recorded time. Alginate impressions were obtained with a fast-setting 120-hour alginate material and standard plastic impression trays. For each impression, the time required to mix the material and complete a full-mouth (maxillary and mandibular arches) impression was recorded.

Immediately after the impression procedure, each participant was asked to complete the VAS survey described above and return it before the end of the appointment. Each VAS score was measured to the nearest 0.5 mm, and medians and interquartile ranges were calculated for each response.

Statistical analyses

The reliability of the survey instrument was assessed using the data from the pilot study to measure intraclass correlation coefficients for each survey question.

Because the assumptions of parametric statistical analyses were not met, the data were analyzed using nonparametric tests. Medians and quartile ranges were calculated for subject sex, age, previous expression experience, impression time requirement, and each survey question. These data were analyzed statistically with the nonparametric Dwass, Steel, Critchlow-Flinger method multiple comparison analysis with a simultaneous P value adjustment,[18] with <0.05 as the level

Table. Median values and interquartile ranges (IQR) for survey responses and time requirements for each impression group

	iTero	*TRIOS*	*Alginate*
Comfort			
Q1: Comfortable	12* (IQR, 22.5)	26.25 (IQR, 39)	33.5 (IQR, 51.5)
Q2: Painless	4.5* (IQR, 4.75)	12.5 (IQR, 26.25)	11.75 (IQR, 35.25)
Q3: Dry mouth	82* (IQR, 27)	54 (IQR, 63.75)	64 (IQR, 65)
Time and technician skill			
Q4: Faster than expected	8.25† (IQR, 22.5)	13.5 (IQR, 31.5)	18† (IQR, 24.75)
Q5: Technician skilled	4.5* (IQR, 4.5)	8.75 (IQR, 9)	8.25 (IQR, 8.5)
Novelty and preference			
Q6: Technology importance	5* (IQR, 4.5)	6.25 (IQR, 9.25)	11 (IQR, 17.75)
Q7: Preference	5.5 (IQR, 19.25)	10.5 (IQR, 26.5)	49.5* (IQR, 55.25)
Time required			
Minutes	7 (IQR, 1)	8.6* (IQR, 3.5)	6.4 (IQR, 2.13)

*Statistical significance between other 2 groups; †Statisical significance between either iTero or Alginate.

for statistical significance. The data analysis for this study was generated using SAS/STAT software (version 9.4 of the SAS System for X64_7PRO platform; SAS, Cary, NC).

RESULTS

Analysis of data from the pilot study indicated that each of the 7 survey questions was reliable. Four questions had excellent reliability, and 3 had moderate-to-good reliability. The intraclass correlation coefficient (ICC) values and interquartile ranges for each question (Q) are as follows: Q1, 0.80 (0.55-0.92); Q2, 0.85 (0.65-0.94); Q3, 0.68 (0.33-0.86); Q4, 0.77 (0.49-0.91); Q5, 0.90 (0.76-0.96); Q6, 0.65 (0.28-0.85); and Q7, 0.71 (0.38-0.88).

For the main data acquisition study, analysis of participant demographic information showed that the 3 subject groups had no significant differences in sex: iTero, 39 female, 21 male; TRIOS, 33 female, 27 male; alginate, 32 female, 28 male. However, there were statistical differences in the ages of participants as well as their previous impression experiences. The median ages were 14 years for the iTero group, 15 years for the TRIOS group, and 17 years for the alginate group. For impression experience, 32% of subjects had never had any previous impressions, 37% had previous alginate impressions, 6% had previous digital impressions, and 25% had both digital and alginate impressions; previous impression experience was not even among the groups.

The 7 survey questions and the impression times were not normally distributed as indicated by the Shapiro-Wilk statistic ($P < 0.0001$); therefore, nonparametric analysis was completed. The analyzed data from the main survey administration study including median, interquartile range, and P value information are summarized in the Table. According to the satisfaction questionnaire, subjects had significantly more comfort and less pain with the iTero scanner than with the TRIOS scanner and alginate impressions. The iTero participants also had significantly less dry mouth related to the impressions. There was a significant difference among the subjects' time perceptions between the iTero and alginate impressions, but no significant differences among the iTero and TRIOS impressions, or alginate and TRIOS impressions, were found. Significant differences were also found in the assessment of technician skill and importance of new technology, with iTero participants rating the technicians with higher skill levels, and believing that new technology was important in an orthodontic office. When asked whether they would rather go to an orthodontist who uses digital or alginate impressions, the iTero and TRIOS participants preferred digital impressions, whereas the alginate participants had less preference toward digital impressions. Differences in the time required to complete each impression type were found, with the TRIOS digital impression requiring significantly more time than the iTero and alginate impressions.

DISCUSSION

This study was conducted to investigate patients' perceptions and opinions regarding these scanners, as well as relative chair-side time requirements for the different impression methods. Few studies evaluating the use and patient perception of intraoral scanners in the orthodontic field have been completed, with differing results.[6,13,14] Vasudavan et al[14] found that 77% of patients preferred intraoral scans over alginate impressions. Grünheid et al[6] found that 73.3% of patients preferred alginate impressions over intraoral scans. Burhardt et al[13] found that young patients

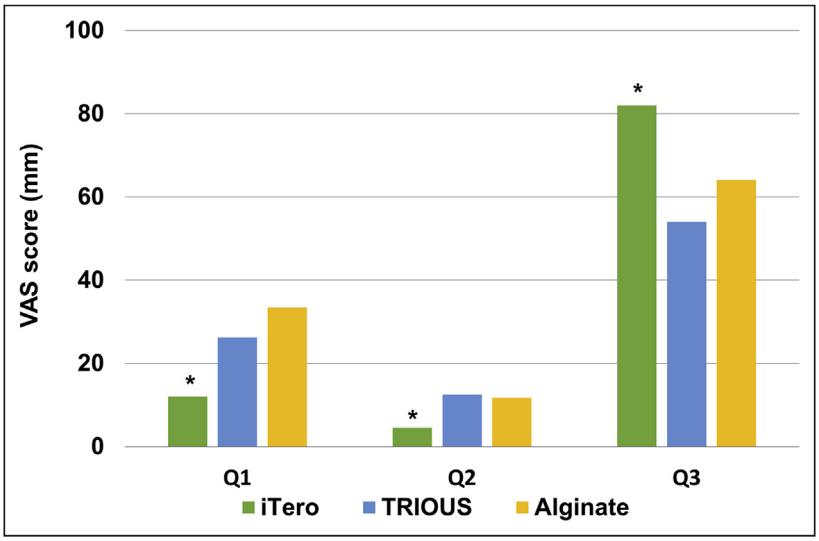


Fig 2. Data results from questions 1 through 3 regarding subjects' perceptions of comfort with varying impression methods. *Statistical significance from all other groups.

preferred digital impression techniques over alginate impressions. These studies used scanners that required the teeth to be coated with a layer of titanium dioxide powder. Generally, it has been found that powdering the dentition causes dryness and some discomfort to patients.[19] Burhardt et al investigated the impact of the titanium dioxide powder and found that 60% to 70% of the subjects reported noticing the powder. The scanners used in our study did not use titanium dioxide powder and are widely used and compatible with a variety of laboratories and orthodontic companies.

The survey instrument developed for this study used a VAS to measure participants' opinions; this allowed subjects to indicate their level of agreement without forcing them to choose a predetermined response. Low values (0) indicated agreement, midrange values (50) indicated neutrality, and high values (100) indicated disagreement. The 7 questions in the survey tested 3 areas of patient satisfaction: comfort, perceived time and technician skill, and novelty.

Questions 1 through 3 evaluated subjects' comfort during the impression (Fig 2). When questioned about comfort, the iTero group had significantly lower scores than did the TRIOS and alginate groups. The TRIOS group also had a lower median score than the alginate group, but this difference was not statistically significant. Similar results were found when the subjects were asked whether the impression was painless, with the iTero group having significantly lower values than the other 2 groups. Subjects may have experienced less pain and discomfort with the iTero scanner because of the smaller size of the intraoral camera portion and the less bulky scanner wand. A question regarding dry mouth was included since other intraoral scanners requiring titanium dioxide powder caused mouth dryness, but none of the subject groups indicated significant feelings of dry mouth.

The next 2 questions evaluated participants' perceptions of time and technician skill (Fig 3). Question 4 evaluated the subjects' opinion of time required for the impression; all 3 groups had low median values, indicating that all participants thought that their impression was faster than they expected. The iTero group had a significantly lower value than the alginate group, but there were no other significant differences among the groups. There was also not a direct correlation between subjects' perceived times and the actual times required to obtain the impression among the groups; the TRIOS scans had the longest time requirement, but the participants' time perception was not different from the other groups. Participants may have felt that the iTero impression was faster than expected because it was reported to be the most comfortable; having a less pleasant experience may increase the perceived time. Clearly, time did not translate into comfort.

Because several technicians were employed to make the impressions, a question concerning the skill level of the technician was included. All 3 groups had low median values, suggesting that all participants believed their technician was highly skilled; however, the iTero group had a significantly lower score than the TRIOS and alginate groups. This finding is interesting, since

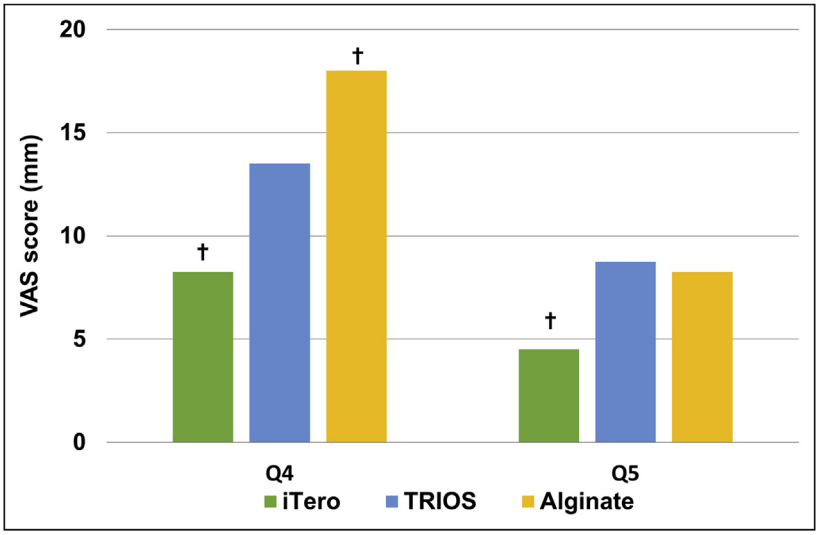


Fig 3. Data results from questions 4 and 5 regarding subjects' perceptions of time and technician skill with varying impression methods. †Statistical significance between the 2 groups indicated.

all technicians were experienced in their impression method. The iTero group was enrolled from a private orthodontic practice, whereas the TRIOS and alginate technicians were enrolled from the university setting. This may impact the responses because patients of a private practice may be more familiar with their technicians.

The final 2 questions of the survey measured the subjects' opinions of impressions regarding novelty (Fig 4). When asked about the importance of new technology in an orthodontic office, all subjects indicated that it was important, but the iTero group had a significantly lower median value. This may again be a result of the subjects' demographics, because the subjects in the iTero group were patients of a private practice, whereas the TRIOS and alginate groups were from a university practice. Patients receiving care from a private orthodontic office may have higher expectations regarding equipment and technology used, while patients of a university practice may place less emphasis on those aspects. When participants were asked whether they would rather receive treatment from an orthodontist who uses digital impressions rather than alginate, both digital groups indicated that they would prefer digital models. However, the alginate group had a significantly higher median with a lack of preference. This is an interesting finding because all groups indicated that new technology was important to them, implying that all groups would prefer the newer technology of digital impressions over alginate impressions. Although this notion holds true for the iTero and TRIOS groups, the alginate group was indifferent on the impression method used by their orthodontist. Perhaps the subjects who had alginate impressions were more neutral in their preference because they are fond of their current orthodontist, regardless of his or her impression technique. Or they simply could not evaluate the experience because they had not had it.

In comparing the chair-side times required to complete each type of impression, the TRIOS digital impression required significantly more time than the other 2 impressions (Fig 5). The alginate impressions had the shortest median time, followed by the iTero digital intraoral scan; these groups were not significantly different from one another. These measurements included only the time spent making the impression and did not consider the time required to disinfect and process any impressions. One possible explanation for the differences in impression times between the intraoral scanners is the age of the unit. The iTero Element was released in the summer of 2015, and the TRIOS Color scanner used was released in early 2014. Since this study was initiated, an updated version of the TRIOS scanner (3Shape TRIOS 3) became available to the market and may be more competitive with the iTero regarding size of intraoral tip and scanning efficiency.

Our study did not have any age, race, ethnicity, or sex exclusions for participants to obtain a study sample that represents a true orthodontic population. Additionally, the subjects had varied previous impression experiences: some participants had never had any

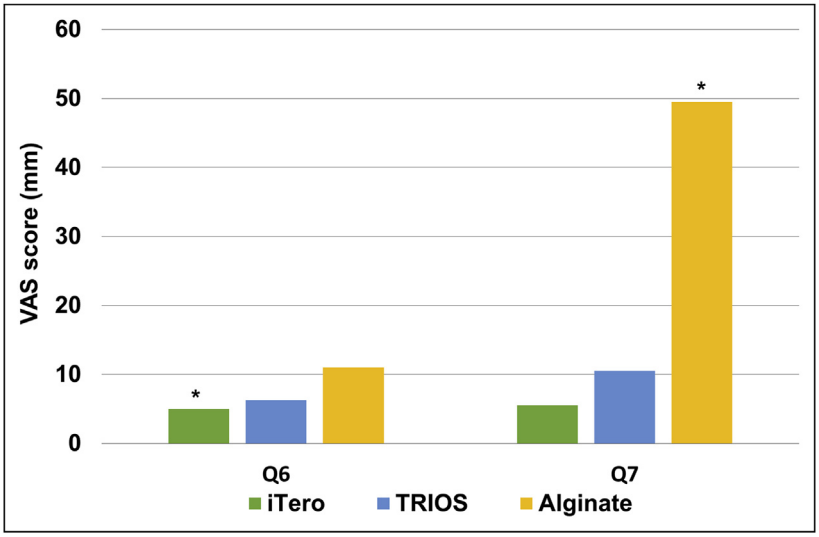


Fig 4. Data results from questions 6 and 7 regarding subjects' perceptions of novelty and preference of varying impression methods. *Statistical significance from all other groups.

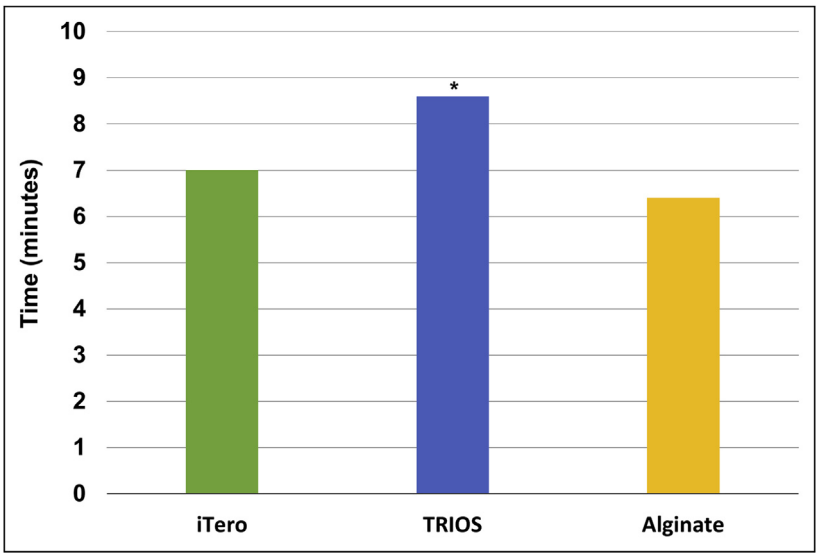


Fig 5. Median time required for each impression method. *Statistical significance from all other groups.

type of impression, and some had previously undergone alginate or digital impressions. After data analysis, there were no significant differences in sex between impression groups; however, the groups were not equally matched regarding age and previous impression experience. For all groups, median ages were similar, but the alginate group was statistically significant for increased age. This finding could be significant in terms of the subjects' responses, because age may impact the relative value of their priorities. Along with differences in subject age, previous impression experience was not equal among thegroups. Again, we cannot be sure whether the patients' previous exposure to impressions affects their responses to the questionnaires.

Although the study showed some significant differences in patient satisfaction regarding digital and alginate impressions, its limitations should be recognized. As mentioned above, the lack of even distributions for age and previous impression experience among groups are

confounding variables that could affect the subjects' responses. Second, several technicians obtained the impressions. Personal experience with the technician could affect subjects' opinions of the impression; however, it was necessary to use several technicians because we required operators with extensive experience in each impression method. Additionally, the research was conducted at different sites. This could cause population differences regarding socioeconomic status and attitudes, which could potentially influence subjects' responses. Finally, as with all research involving surveys and questionnaires, the inherent issue of response bias was present.

CONCLUSIONS

We found that orthodontic patients are satisfied with and accept contemporary intraoral digital impressions. The digital scanners required more chair-side time than do the alginate impression methods. As intraoral scanning technology continues to advance with smaller cameras and faster acquisition times, patients may show increased preference for digital impressions; this appears largely to be based on comfort when several skilled technicians are used.

Research in related areas including the impact of patient age, previous impression experience, and rapport with the operator is warranted, as well as doctor and technician satisfaction with different impression methods. When determining when to incorporate intraoral scanning into a practice or which scanner to invest in, practitioners should evaluate patient-centered and other clinician-related factors.

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REFERENCES

1. Kusnoto B, Evans C. Reliability of a 3D surface laser scanner for orthodontic applications. Am J Orthod Dentofacial Orthop 2002; 122:342-8.
2. Joffe L. Current products and practices OrthoCAD™: digital models for a digital era. J Orthod 2004;31:344-7.
3. Fleming PS, Marinho V, Johal A. Orthodontic measurements on digital study models compared with plaster models: a systematic review. Orthod Craniofac Res 2011;14:1-16.
4. Hayashi K, Sachdeva A, Saitoh A, Lee SP, Kubota T, Mizoguchi I. Assessment of the accuracy and reliability of new 3-dimensional scanning devices. Am J Orthod Dentofacial Orthop 2013;144: 619-25.
5. Flügge T, Schlager S, Nelson K, Nahles S, Metzger M. Precision of intraoral digital dental impressions with iTero and extraoral digitization with the iTero and a model scanner. Am J Orthod Dentofacial Orthop 2013;144:471-8.
6. Grünheid T, McCarthy SD, Larson BE. Clinical use of a direct chairside oral scanner: an assessment of accuracy, time, and patient acceptance. Am J Orthod Dentofacial Orthop 2014;146: 673-82.
7. Wiranto MG, Engelbrecht WP, Tutein Nolthenius HE, van der Meer WJ, Ren Y. Validity, reliability, and reproducibility of linear measurements on digital models obtained from intraoral and cone-bean computed tomography scans of alginate impressions. Am J Orthod Dentofacial Orthop 2013;143:140-7.
8. Rubel BS. Impression materials: a comparative review of impression materials most commonly used in restorative dentistry. Dent Clin North Am 2007;51:629-42.
9. Hamalian TA, Nasr E, Chidiac JJ. Impression materials in fixed prosthodontics: Influence of choice on clinical procedure. J Prosthodont 2011;20:153-60.
10. Conny DJ, Tedesco LA, Brewer JD, Albino JE. Changes of attitude in fixed prosthodontic patients. J Prosthet Dent 1985;53:451-4.
11. Hacker T, Heydecke G, Reissmann DR. Impact of procedures during prosthodontic treatment on patients' perceived burdens. J Dent 2015;43:51-7.
12. Kravitz N, Groth C, Jones P, Graham J, Redmond WR. Intraoral digital scanners. J Clin Orthod 2014;48:337-47.
13. Burhardt L, Livas C, Kerdijk W, van der Meer WJ, Ren Y. Treatment comfort, time perception, and preference for conventional and digital impression techniques: a comparative study in young patients. Am J Orthod Dentofacial Orthop 2016;150:261-7.
14. Vasudavan S, Sullivan SR, Sonis AL. Comparison of intraoral 3D scanning and conventional impressions for fabrication of orthodontic retainers. J Clin Orthod 2010;44:495-7.
15. Fleming PS, Koletsi D, O'Brien K, Tsichlaki A, Pandis N. Are dental researchers asking patient-important questions? A scoping review. J Dent 2016;49:9-13.
16. Tsichlaki A, O'Brien K. Do orthodontic research outcomes reflect patient values? A systematic review of randomized controlled trials involving children. Am J Orthod Dentofacial Orthop 2014;146: 279-85.
17. Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T. Analysis of pain level in cases treated with Invisalign aligner: comparison with fixed edgewise appliance therapy. Prog Orthod 2014;15:64.
18. Hollander M, Wolfe DA. Nonparametric statistical methods. 2nd ed. New York: John Wiley and Sons; 1999. p. 240.
19. Rangel FA, Chiu YT, Maal TJ, Bronkhorst EM, Bergé SJ, Kuijpers-Jagtman AM. Does powdering of the dentition increase the accuracy of fusing 3D stereophotographs and digital dental casts. Eur J Orthod 2016;38:440-5.