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Comparison Between Measurements Taken on AI-Generated and Conventional Digital Models: A Retrospective Study

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Abstract

(1) Aim: To compare transverse dimensions measured on AI-generated intra-oral models and conventional digital intra-oral models. (2) Methods: A group of 38 patients treated with clear aligners was selected retrospectively from those whose records featured both AI-generated and conventional digital intra-oral models taken at the same timepoint. Transverse dimensions (inter-canine, inter-premolar, and inter-molar distances) on both upper and lower arches were evaluated and compared. Intra-class correlation index and paired *t*-test were applied to test the repeatability of measurements and statistically significant differences, respectively. Statistical significance was set at 0.05. (3) Results: Intra-class correlation index showed good repeatability. Paired *t*-test showed differences in measurements of the distances between the thicket area of gingiva on the palatal side of the upper first molar ($p = 0.002$), the gingival margin of the lower first molar ($p = 0.014$), and the mesio-vestibular cusps of the lower first molars ($p = 0.019$). (4) Conclusions: Transverse measurements were similar on AI-generated and conventional intra-oral .stl renderings. Statistical differences were found on posterior areas of both upper and lower dental arches, but are unlikely to be clinically significant.

Keywords: artificial intelligence; remote monitoring; transversal dimension

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1. Introduction

Artificial intelligence (AI) has recently undergone a remarkable evolution, transitioning from speculative theory to a central component of modern technology. In the medical field, and specifically in orthodontics, AI has gained attention, being used in combination with teledentistry to accelerate diagnostics, optimize therapeutic decision making, and manage large-scale health data with improved accuracy and efficiency [1–5].

In addition to these primary functions, AI has also been applied to other areas such as skeletal maturity assessment, temporomandibular joint (TMJ) evaluation, and orthognathic treatment planning. Among AI applications, remote monitoring has emerged as particularly promising, as it supports the ongoing evaluation of patient progress without the need for frequent in-office appointments [6–14]. Remote monitoring software could allow the use of smartphone-generated photographs and videos, and contact with patients, without the necessity of an immediate in-office visit. In this way, clinicians could monitor rapid maxillary expansion, inter-maxillary elastics compliance, and oral hygiene conditions, as well as manage orthodontic emergencies such as debonded brackets or tubes and problems with arch-wire ligatures. Remote monitoring could also be a helpful tool in the retention phase [7,15–18].

Within this framework, a software application that uses AI to help the clinician to remotely monitor patients during their orthodontic treatment has been developed in France; Dental Monitoring® (DM, Dental Monitoring, Paris, France) is a remote monitoring software which uses innovative AI-driven remote monitoring (AIDRM) technology to assess tooth movements during orthodontic treatment [19]. Conceptually, remote monitoring platforms such as DM can be framed within the theory of multi-agent systems (MAS), in which patients, clinicians, and software continuously interact through data exchange and feedback loops. This dynamic structure should enable adaptive treatment adjustments and promote patient-specific clinical pathways, aligning with cybernetic models of digital health systems—that is, intelligent systems based on continuous feedback loops, through which data is constantly collected, analyzed, and used to regulate and optimize clinical processes in real time [1].

At the beginning of their remotely monitored orthodontic treatment, patients are instructed to download the Dental Monitoring application on their smartphone, and to use "Scanbox" DM cheek-retractors (Dental Monitoring, Paris, France) to help them take good-quality intra-oral pictures using their smartphone. During their orthodontic treatment, patients receive notifications from the DM smartphone application prompting them to provide a DM scan; the scanning frequency depends on the clinician, who determines an initial customized protocol of remote monitoring. The DM's algorithm extracts information from the pictures taken by the patient and compares it to the initial impression [19].

Dental Monitoring was first introduced to assess orthodontic treatment with clear aligners (CA). Once the patient has taken intra-oral pictures with and without CAs, the software analyzes CA fit and informs the patient if it is time to switch to the following aligner in the series, or whether it is advisable to continue wearing the same aligner pending reassessment of repeat DM photos after few days [20,21].

Thus far, very few studies have evaluated the use of DM in orthodontic treatment. Hansa and colleagues have compared two groups of patients with similar baseline malocclusions treated via CAs, one using DM and the other not (controls). Treatment duration, number of refinements, number of refinement aligners, time to first refinement, and number of appointments were analyzed and compared between groups. The only variable found to be statistically significant was the number of appointments, which was lower in the DM group with respect to controls [20]. Although a small percentage of patients preferred conventional intra-office visits, patients were generally satisfied with the use of DM and reported that taking the intra-oral photos required by the system was easy [20]. Similar results were found by a randomized trial in which CA patients treated with the aid of DM required fewer in-office appointments than conventionally treated controls thanks to remote monitoring [22]. However, no study has yet investigated the hypothesis that DM could improve treatment quality. Marks et al. analyzed the changes in weighted peer-assessment rating (PAR) in CA patients treated with and without DM, finding no significant differences between end-of-treatment PAR scores for the two groups [23].

Another feature of DM is that the software can generate remotely reconstructed intra-oral model files, which appear to be accurate as models generated by intra-oral scans. An initial study, published in 2019, evaluated the accuracy of DM intra-oral models with respect to conventional digital intra-oral models on a group of typodonts with Class 1 malocclusion and anterior crowding. Superimpositions of intra-oral models from DM scans and the Itero intra-oral scanner (Align Technology, San Jose, CA, USA) showed that the difference between the two renderings was not statistically significant [24]. Subsequently, Homsi and colleagues demonstrated that in vivo DM photographs can successfully be used to generate intra-oral renderings, which were found to be almost as accurate intra-oral scans [25]. In clinical practice, dental models are useful not only for appliance production, but also for taking sagittal, vertical, and transverse measurements to track orthodontic treatment progress.

Transverse measurements in both the lower arch and upper arch are fundamental to the diagnostic process. Proper assessment of the transverse dimensions plays a key role not only in achieving occlusal harmony, but also in long-term treatment stability. Distinguishing between skeletal and dentoalveolar transverse discrepancies is essential, as each requires a different therapeutic approach. Moreover, untreated maxillary constriction has been associated with an increased risk of relapse, underscoring the importance of precise and early identification [26–29].

Transverse deficiency of the upper jaw is a common situation that orthodontists encounter on a daily basis [30]. It is important to assess whether the problem is related to skeletal or dentoalveolar constriction. There are different ways to assess transverse dimensions, including measurements on postero-anterior radiographs or cone-beam computed tomography scans, and clinical evaluation—i.e., for the presence of cross-bites or degree of crowding—or dental cast analysis [26]. Transverse dimensions may be analyzed on plaster casts or on digital models, which have been proven to be reliable for taking measurements [31]. Previous studies used this method to assess linear distances between dental landmarks [32].

Being able to track transverse dimensions during orthodontic treatment could help the clinician to determine whether skeletal or dentoalveolar transverse dimensions require intervention. Hence, remote monitoring could be invaluable in the assessment of transverse dimensions during orthodontic treatment. The accuracy of this approach has been previously investigated by Kuriakose et al., who assessed remote monitoring measurements during rapid palatal expander treatment in a group of children treated via hyrax expander. They reported that DM software is well capable of recognizing cross-bite correction [33]. In addition, Moylan et al. assessed the precision of DM software in evaluating transverse linear movements, as compared to measurements taken on dental models, reporting good correspondence between the two sets of measurements [15].

Within this evolving landscape, this study set out to investigate a particularly relevant aspect of AI integration in orthodontics: the reliability of AI-generated intra-oral models, as compared to conventional digital scans, for clinical measurement, specifically focusing on transverse dimensional accuracy. The null hypothesis was that there would be no statistically significant differences between measurements taken on AI-generated intra-oral models as compared to conventional digital intra-oral models.

2. Materials and Methods

This retrospective study was reviewed and approved by the University of Ferrara Postgraduate School of Orthodontics Ethics Committee and assigned number 2/25. All patients treated with clear aligners (CAs) from January 2024 to October 2024 at a private orthodontics clinic in Varese (Italy) were retrospectively selected, and provided informed consent. The following inclusion criteria were applied: (1) presence of all teeth up to the third molars; (2) availability of all initial diagnostic records (intra- and extra-oral photos, panoramic x-ray, lateral cephalogram, and conventional digital intra-oral models); and (3) conventional digital model files from intra-oral scan (C.stl) and intra-oral models AI-generated (AI.stl) by Dental Monitoring software (Dental Monitoring, Paris, France) at the same timepoint during treatment. After the application of these inclusion criteria, the sample comprised 38 patients and a total of 152 models. Of these, 38 upper and 38 lower jaw models were obtained via conventional intra-oral scanner Itero Element™ 5D (Align Technology, San Jose, CA, USA), and 38 upper and 38 lower models via Dental Monitoring.

Conventional intra-oral scans were taken by the same clinician according to the manufacturer's instructions. As such, the scan started from the occlusal area of lower teeth, from left to right, continuing lingually, with an occluso-lingual movement from lower right to the lower left molars. Scanning then proceeded buccally, with an occluso-buccal movement from the lower left to the lower right molars. Finally, if no scanning defects were observed, the same scanning procedure was applied to the upper arch and for bite registration. If scanning defects were detected, the operator repeated the scan of the area. The scans were then post-processed and downloaded in .stl format.

For Dental Monitoring® (DM, Dental Monitoring, Paris, France) scans, patients were instructed to take photographs with their smartphone according to the manufacturer's instructions and following the application's workflow. The AI.stl files were subsequently downloaded from the Dental Monitoring Dashboard.

Cast analysis consisted of comparing the transverse measurements in millimeters taken on both upper and lower arch models generated via C.stl and AI.stl files obtained during the same check-up appointment (Table 1). All measurements were made by the same orthodontist, using the software "3 Shape Ortho Viewer 2020" (3 Shape, Copenhagen, Denmark) as shown in Figures 1 and 2. Measurements were subsequently reviewed by another orthodontist, an expert in the use of such software. Ten percent of measurements were then repeated by the initial operator 30 days after the first assessment to test intra-examiner reliability.

Table 1. Description of measurements taken.

Points	Measurements taken
C3	Distance between canine cusp tips.
ZC3	Distance between the thickest area of the gingival margin at the palatal/lingual side of canines.
VC4	Distance between the vestibular cusp tip on first premolars.
CG4	Distance between the center of the central groove of the first premolars.
MVC6	Distance between the mesio-buccal cusp tips on first molars.
DPC6	Distance between the disto-palatal cusp tips on upper/lower first molars.
Z6	Distance between the thickest areas of the gingival margin on the palatal/lingual side of first molars.

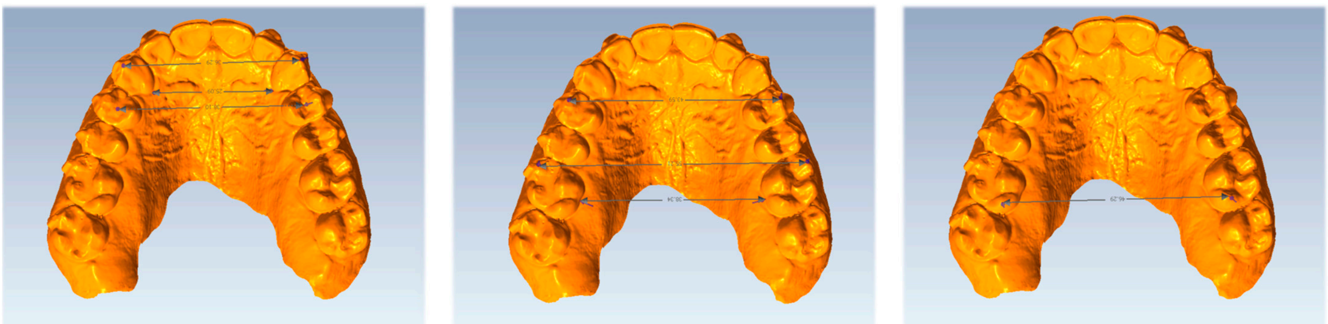

Figure 1. Example of measurement on C.stl file on Ortho Viewer Software (3 Shape, Copenhagen, Denmark).

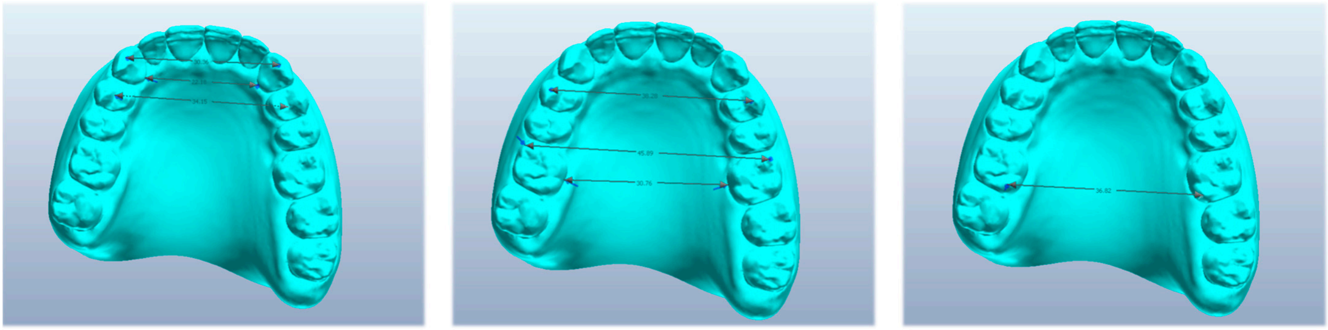

Figure 2. Example of measurement on AI.stl file on Ortho Viewer Software (3 Shape, Copenhagen, Denmark).

Statistical Analysis

The intra-class correlation coefficient (ICC) was calculated by repeating the upper C3 measurements. Due to the presence of 38 statistical units, it was possible to use the central limit theorem to assume normality of distribution. Therefore, a paired *t*-test was used to compare the transverse dimension measurements on C.stl and AI.stl renderings. The statistical significance level was set at 0.05.

3. Results

The ICC for upper C3 was 0.978, demonstrating good repeatability.

Tables 2 and 3 show descriptive analysis and the results of the paired *t*-test for both upper and lower arches.

Table 2. Descriptive statistics and paired *t*-test for upper arch measurements. SD: standard deviation; Δ: difference between means. Statistical significance*: $p < 0.05$.

	C.stl			AI.stl				
	Mean ± SD	**Median**	**25^{th}–75^{th} Percentile**	**Mean ± SD**	**Median**	**25^{th}–75^{th} Percentile**	**Δ**	***p*-Value**
ZC3	25.09 ± 2.11	25.23	23.73–25.74	25.30 ± 2.18	24.99	24.07–26.10	0.21	0.064
C3	34.60 ± 2.05	34.70	33.61–35.70	34.32 ± 1.91	34.39	32.90–35.67	0.28	0.310
CG4	36.12 ± 1.92	35.88	35.10–37.55	36.04 ± 1.89	36.10	34.81–37.70	0.08	0.557
VC4	41.97 ± 2.34	42.28	40.83–44.01	41.64 ± 2.12	42.02	40.20–42.91	0.3	0.076
Z6	34.81 ± 2.71	34.22	32.61–37.68	34.42 ± 2.62	34.05	32.39–36.76	0.39	0.002 *
MVC6	50.93 ± 3.20	50.51	49.05–53.34	50.88 ± 3.09	50.72	49.37–53.51	0.05	0.312
DPC6	41.31 ± 3.12	40.58	39.03–44.41	41.09 ± 3.18	40.49	38.81–44.10	0.22	0.258

In the upper arch, no statistically significant differences between measurements emerged. The only exception was the difference at Z6–Z6, the distance between the thickest areas of the gingiva, which was significant ($p = 0.002$). The Δ (difference between means) between C.stl and AI.stl was 0.39 mm (Figure 3).

In the lower arch, a statistically significant difference also emerged between for Z6- ($p = 0.014$) and for MVC6 ($p = 0.019$), the latter being the distance between the mesio-buccal cusp tips on the upper first molars. The Δ was 0.26 mm and 0.4 mm for Z6 and MVC6, respectively (Figures 4 and 5).

Table 3. Descriptive statistics and paired *t*-test for lower arch. SD: standard deviation; Δ: difference between means. Statistical significance *: $p < 0.05$.

	C.stl			AI.stl				
	Mean ± SD	**Median**	**25th–75th Percentile**	**Mean ± SD**	**Median**	**25th–75th Percentile**	**Δ**	***p*-Value**
ZC3	20.02 ± 1.45	20.15	18.73–21.39	20.21 ± 1.64	20.72	18.57–21.51	0.19	0.195
C3	26.49 ± 1.87	26.71	25.50–27.84	26.40 ± 1.77	26.76	25.55–27.66	0.09	0.398
CG4	30.49 ± 1.87	30.78	29.38–31.63	30.33 ± 1.78	30.70	29.07–31.43	0.16	0.106
VC4	34.48 ± 1.92	34.74	33.21–35.54	34.44 ± 1.85	34.72	32.71–36.02	0.04	0.728
Z6	33.99 ± 2.73	34.22	32.40–35.39	33.73 ± 2.77	33.94	32.43–35.15	0.26	0.014 *
MVC6	45.56 ± 2.92	45.93	44.38–47.71	45.16 ± 2.75	45.40	44.43–47.00	0.4	0.019 *
DPC6	38.13 ± 3.00	38.21	35.97–40.24	37.88 ± 2.97	38.31	35.85–39.98	0.25	0.056

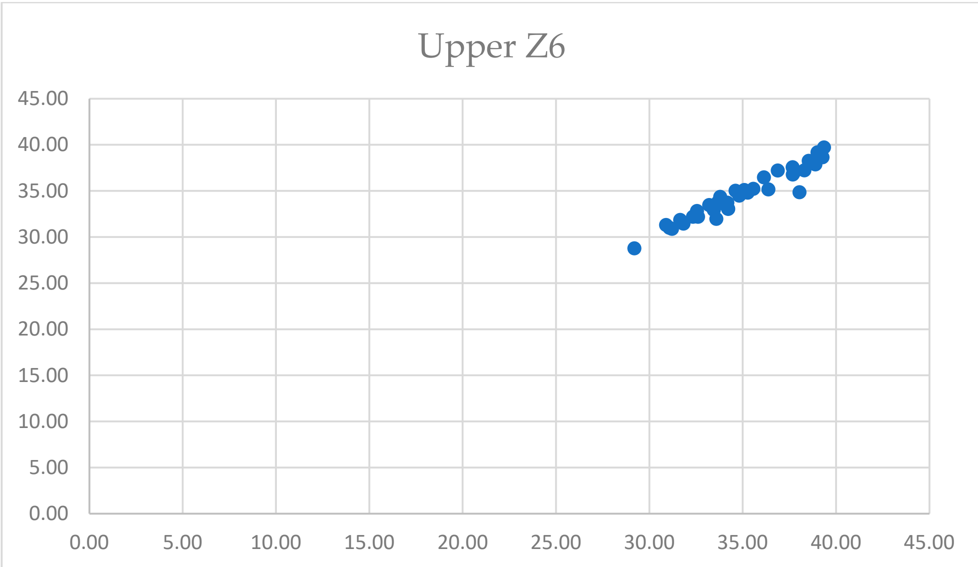

Figure 3. Scatter plot of upper Z6 measurements. X axis: C.stl data; Y axis: AI.stl data.

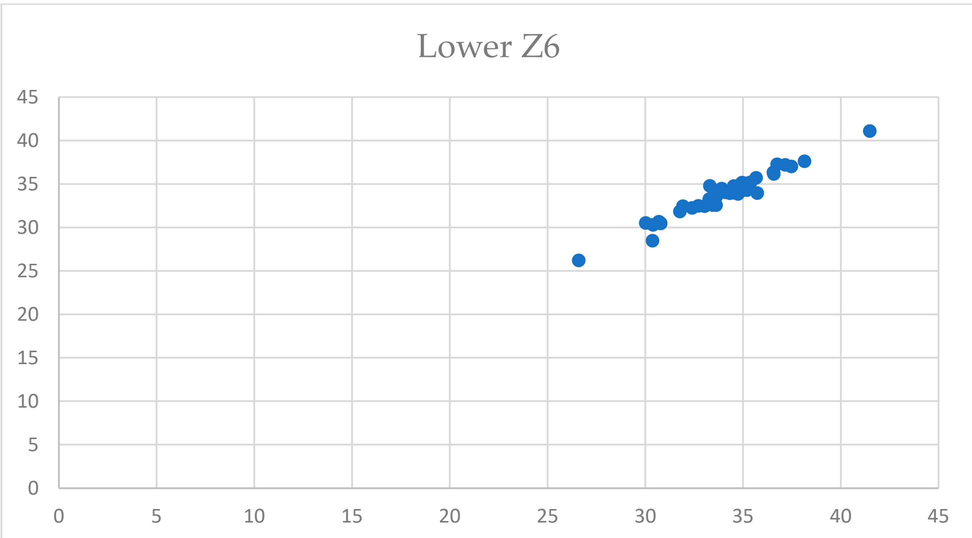

Figure 4. Scatter plot of lower Z6 measurements. X axis: C.stl data; Y axis: AI.stl data.

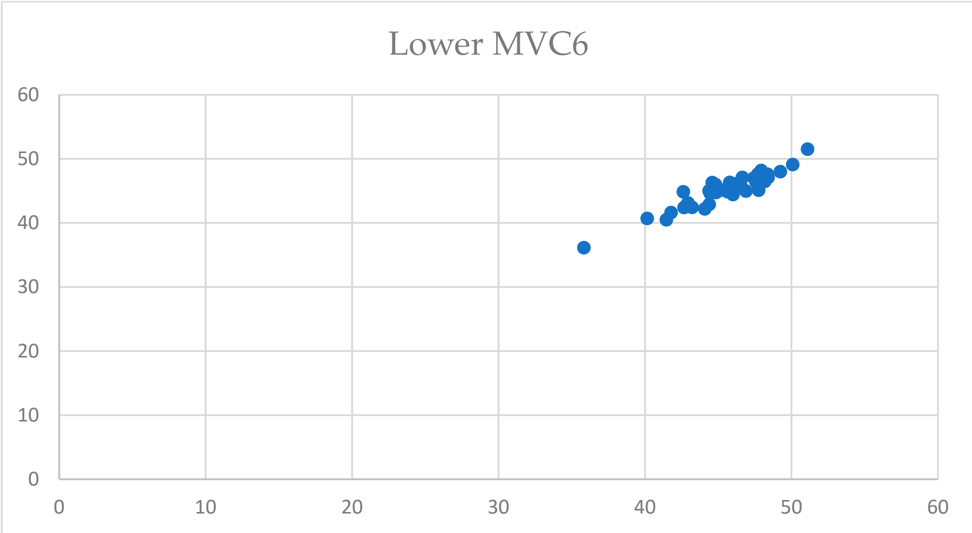

Figure 5. Scatter plot of lower MVC6 measurements. X axis: C.stl data; Y axis: AI.stl data.

4. Discussion

The introduction of AI to the fields of medicine, dentistry, and, in particular, orthodontics is now the object of scientific study due to its many potential applications which could help operators in their clinical practice. One such AI application is remote monitoring of patients during orthodontic treatment with both clear aligners and fixed multibracket appliances.

Dental Monitoring® (DM, Paris, France) is the company leading remote monitoring using ADIRM technology. DM's algorithm extracts information from intra-oral pictures and compares it to a baseline intra-oral model, thereby providing information about tooth movement during treatment [19]. This software has been proven to be able to reduce chairside appointments and to detect cross-bite, linear tooth movements, aligner fit, and patients' oral hygiene status [16,20]. Recent clinical reviews have demonstrated that Dental Monitoring® not only reduces the number of in-office visits, but also contributes to improved patient oral hygiene and post-treatment retention stability. Patients under AI-driven remote monitoring showed significantly lower plaque index levels and better retainer fit. These findings suggest that DM can enhance treatment quality without compromising clinical outcomes [34]. In addition, both the effectiveness of DM software in tracking dental movements and the precision of AI-generated intra-oral models has already been demonstrated [25].

Another advantage the software provides to clinicians is the opportunity to download intra-oral models taken by patients on their smartphones through the DM application during orthodontic treatment. These can then be used by the operator for the fabrication of orthodontic devices without the need for an in-office appointment.

In this study, the null hypothesis was that there would be no differences between measurements made on C.stl and AI.stl renderings taken at the same time point during orthodontic treatment. The results showed good correspondence between the two sets of measurements, with the exception of molar areas on both upper and lower arches, specifically on the palatal side. The differences between measurements of the distance between the thickest areas of the gingival margin (Z6) were statistically significant, being 0.39 (p = 0.002) in the upper arch and 0.26 (p = 0.014) in the lower. Therefore, the null hypothesis was refuted.

It should be noted that the generation of intra-oral models from 2D photographic inputs—such as those used by AI-driven platforms like Dental Monitoring—relies on image sequences captured by patients under uncontrolled conditions. This process, unlike intraoral scanning performed in a clinical setting, may introduce small geometric inaccuracies due to factors such as inconsistent lighting, movement, or angulation. These aspects may be particularly relevant when assessing curved anatomical regions, and those where soft tissue interference may be more pronounced [25], a likely explanation for the discrepancies noted at posterior regions in this study.

Indeed, this area has been proven to suffer a distortion during the intra-oral scanning process, resulting in slight inaccuracy of the intra-oral model [35–37]. Therefore, some inaccuracy of AI-generated intra-oral models can be expected in posterior areas. Indeed, in this study, the differences in mm between measurements taken on C.stl and AI.stl at Z6 was 0.39 (p = 0.002) in the upper arch and 0.26 (p = 0.014) in the lower. However, although these discrepancies were statistically significant, if we take into account the threshold set by the American Board of Orthodontists, 0.5 mm, they appear not to be clinically significant [38].

Previous studies have reached similar conclusions, that is, that DM-generated intra-oral models are as accurate as those taken on conventional digital ones [24,25]. For instance, Morris and colleagues [24] studied the accuracy of AI-generated intra-oral models on typodonts and found statistically, but not clinically, significant differences in both maxillary and mandibular arches; the discrepancies were <0.5 mm, and, therefore, below the threshold set by the ABO [38].

Subsequently, Homsi et al. published an in vivo study on patients undergoing orthodontic treatment with fixed multibrackets appliances. Intra-oral models generated by DM and an intra-oral scanner were compared using Geomagic Control X Software 2020 (3D Systems Inc, Rock Hill, SC, USA) [25,38]. They found statistically significant differences between conventional intra-oral models and AI-generated intra-oral ones. However, taking into account the threshold of 0.5 mm set by the ABO, no clinical discrepancies were found between the conventionally and AI-generated intra-oral models [25,38].

That being said, the methodology relied on here differed from those used in the above studies, specifically that by Homsi and colleagues [25]. Firstly, the sample differed: in the present study, models from 38 patients were included, whereas Homsi and colleagues had 24 patients in their study group, but analyzed 466 scans and 233 superimpositions [25]. As for the method, we only measured transverse dimensions on the upper and lower arches to compare conventionally and AI-generated models, whereas Homsi et al. made superimpositions of conventional and DM-generated models [25].

Another factor to consider is that in the above-cited studies [24,25], no brackets or resin grip points were present on buccal teeth surfaces. In the present study, buccal resin grip points were present when taking both DM intra-oral photos and conventional intra-oral scans. Other research has assessed the influence of orthodontic brackets and arch-wires on intra-oral scan accuracy, reporting statistical differences with minimum clinical significance [39,40]. However, no studies assessing the influence of resin grip points on intra-oral scan accuracy are reported in the literature. Nonetheless, they are usually applied on the buccal surfaces of teeth, and in the present study only the cusp tips, grooves, and palatal/lingual sides were used for measurements.

A further use for remote monitoring could be tracking palatal expansion and transverse dimension changes during the active phase of palatal expansion, and previous studies have demonstrated the reliability of DM assessment of transversal dimensions [15,33]. Kuriakose et al. showed a good correspondence between measurements from intra-oral examination, DM analysis, and digital models. In particular, DM software was able to identify posterior cross-bite correction [33]. Moylan at al. compared the software scores for linear changes and measurements made on dental models [15]. They also found a good match between the measurements taken on the intra-oral models and those made by the DM software [15].

In the present investigation, transverse measurements made by the same specialist orthodontist were evaluated on digital models derived from intra-oral scanning versus those AI-generated by Dental Monitoring software. Despite the statistical differences found, the results suggest that remote monitoring with DM, i.e., the possibility of having AI-generated intra-oral models for clinical evaluation of the progress of orthodontic treatment, is feasible, taking into account that posterior areas may present some discrepancies.

However, this study has some limitations. Specifically, the numbers of patients included and measurements taken were smaller than those reported by both Morris and colleagues and Homsi et al. [24,25]. Furthermore, as this was a retrospective study, no prior sample size analysis was performed. The inclusion and exclusion criteria were applied to consecutively treated patients but, being a retrospective study, it was not blinded. The operator who performed the measurements knew which group the models belonged to. Nonetheless, the operator who performed the statistical analysis was not informed about which group the models or measurements belonged to.

Another limitation was that inter-examiner reliability was not analyzed, but a more expert operator did review measurements before statistical analysis. In addition, only transverse measurements were assessed, and no superimpositions were performed. This decision rested on the particular importance of measuring transverse dimensions during orthodontic treatment. Making such measurements with "Ortho Viewer" 3 Shape Software (3 Shape, Copenhagen, Denmark) is immediate and easy for the clinician. In future, it would be of interest to analyze sagittal and vertical measurements on both conventional and AI-generated intra-oral models. A further avenue of research would be to analyze the fit of clear aligners made for AI-generated intra-oral models as compared to conventional digital intra-oral models taken from intra-oral scans.

In summary, while AI-generated models demonstrated overall reliability, further prospective and controlled studies are warranted to confirm their accuracy across all spatial dimensions and in various clinical scenarios, including with and without the presence of attachments or resin grip points. Such investigations will be essential to support the broader integration of AI tools into orthodontic diagnostics and appliance fabrication workflows.

5. Conclusions

Transverse measurements taken on AI-generated intra-oral models showed good correspondence with the same measurements taken on conventional digital intra-oral models. The only measurements with statistically significant differences were the distance between the thickest areas of gingiva on the palatal side of the first molars in the upper arch, and the respective distances between the mesio-buccal cusps of the first molars and the thickest gingiva on the lingual side of the first molars in the lower arch.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki, and approved by the University of Ferrara Postgraduate School of Orthodontics Ethics Committee (protocol code 2/25, 6 March 2025).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

TMJ	Temporomandibular joint
AI	Artificial intelligence
DM	Dental Monitoring
CA	Clear aligners
Stl	Standard triangulation language
C.stl	Conventional stl
AI.stl	Artificial intelligence stl
Δ	Difference between means

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