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Dimensional accuracy of digital dental casts compared with conventional plaster casts: A cross-sectional study

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Abstract

Introduction: Orthodontic diagnosis requires accurate analysis of dental morphology and occlusion. While plaster casts were the standard, several drawbacks such as breakages, storage requirements and retrieval challenges have led to a digital shift, exemplified by intraoral scanning, which is more efficient and comfortable. To justify clinical adoption, the diagnostic accuracy of intraoral scanners must be validated.

Aim and Objectives: This study aimed to compare the accuracy and reliability of intraoral orthodontic assessments performed using conventional plaster casts versus digital dental casts generated by the AlliedStar AS 260 scanner.

Materials and Methods: This comparative cross-sectional study assessed 14 orthodontic variables on conventional dental casts and corresponding digital models in 34 subjects. Variables included arch lengths, mesiodistal widths of teeth 11, 41, 13, 43, 14, 44, 16, and 46, overjet, overbite, and upper and lower space analyses. Measurements were performed using digital calipers on conventional casts and AS Connect software for digital models. Data analysis employed Paired Samples T-tests to assess validity, and Intraclass Correlation Coefficients (ICC) to evaluate reliability.

Results: Data normality was confirmed (Shapiro-Wilk, $p > 0.05$). Paired t-tests revealed no statistically significant differences between conventional and digital measurements for any of the 14 variables ($p > 0.05$). Mean differences ranged from −0.08 mm to 0.17 mm, all within the clinically acceptable threshold of 0.5 mm. Reliability analysis demonstrated excellent agreement (ICC > 0.9)

Conclusion: Digital casts produced by the AlliedStar AS260 are statistically equivalent to conventional plaster casts and offer a reliable, clinically accurate alternative for routine orthodontic assessment.

Keywords: Orthodontics; Intraoral Scanner; Digital Dental Cast; Accuracy; Alliedstar AS 260

1. Introduction

Orthodontic treatment planning is fundamentally dependent on the accurate analysis of patient records. Among these, the dental study model is indispensable for evaluating occlusal relationships, arch dimensions, and tooth size discrepancies (mesiodistal widths). Historically, the gold standard for these assessments has been the conventional plaster cast, fabricated from alginate impressions and dental stone (Abduo, 2019). While accurate, this analogue

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workflow presents significant logistical challenges: models are prone to breakage, degradation over time, and require substantial physical storage space (Akdeniz et al., 2022).

The advent of digital dentistry has introduced intraoral scanners (IOS) as a transformative alternative. Digital models offer inherent advantages such as indestructibility, instant retrieval, and the ability to perform virtual diagnostic setups (Baxi et al., 2022). Furthermore, digital workflows align with modern expectations for efficiency and patient comfort, eliminating the gag reflex often associated with impression materials (Bosio et al., 2017).

However, the clinical adoption of any diagnostic tool fundamentally rests on its metric properties: trueness and precision. According to the International Organization for Standardization (ISO), trueness refers to the closeness of agreement between the scanner's digital representation and the actual, true reference value of the dental arch. Precision, on the other hand, describes the repeatability and consistency of these digital measurements when acquired through consecutive scanning under identical conditions. While high-end scanners such as the 3Shape TRIOS or iTero series have been extensively validated, a clear technological divergence exists within the market (Baresel and Baresel, 2025). Premium systems predominantly utilize confocal laser scanning microscopy, a technology that captures sharply focused images at specific depths while physically filtering out scattered light, rendering them highly accurate in complex, moisture-rich intraoral environments (Mangano et al., 2017). In contrast, the market has seen a rapid influx of cost-effective devices utilizing structured-light projection (SLP). This alternative technology calculates spatial coordinates by actively triangulating the geometric deformation of a projected light pattern as it drapes over the dental topography (Baresel and Baresel, 2025). One such device is the AlliedStar AS 260. While early-generation structured-light scanners historically struggled with optical scatter and resolution loss in deep undercuts, the AS 260 claims to overcome these limitations via an optimized 18 mm depth of field and advanced AI-driven artifact removal (AlliedStar, 2024). Despite these manufacturer specifications, independent scientific validation is urgently required to ascertain whether this specific, budget-tier structured-light architecture can match the diagnostic fidelity of established standard benchmarks.

This validation must focus on the parameters most vulnerable to scanning inaccuracies. Current literature highlights significant brand-dependent inconsistencies in IOS performance, particularly in full-arch scans where frame-to-frame "stitching errors" progressively accumulate (Zhang et al., 2020). These cumulative errors frequently distort transverse dimensions, such as arch width (Baresel and Baresel, 2025). Additionally, some SLP systems systematically underestimate individual mesiodistal tooth sizes due to limited light penetration or aggressive algorithmic smoothing (Vág et al., 2020). Even minor localized errors can compound exponentially during total space analysis, altering arch length discrepancy calculations and potentially jeopardizing extraction decisions in crowded dentitions (Akdeniz et al., 2022). Therefore, to bridge this specific research gap, this study aimed to conduct a comprehensive evaluation of orthodontic measurements, specifically arch width, mesiodistal tooth, and space analysis using the AlliedStar AS 260 against conventional gold-standard plaster casts. The null hypothesis tested was that there is no statistically significant difference between the measurements obtained from the two methods.

2. Materials and Methods

2.1. Ethical Approval

Ethical approval for this study was obtained from the IIUM Research Ethics Committee (IREC-2025-106). All participants provided written informed consent prior to enrolment. The study was conducted in accordance with the Declaration of Helsinki.

2.2. Sample Size

The required sample size was determined through a power analysis, which indicated that a minimum of 34 participants was needed. This calculation utilized a significance threshold of 0.05 and a power value of 80%. The study population comprised orthodontic patients aged 15 to 45 years old who presented to the Orthodontic Specialist Clinic, Kulliyyah of Dentistry, International Islamic University Malaysia (IIUM), Kuantan, seeking orthodontic treatment. Patients who required study models as part of their diagnostic records were screened and selected according to predefined inclusion and exclusion criteria. The inclusion criteria required participants to be willing to participate and to have a complete permanent dentition from the left second molar to the right second molar. The exclusion criteria included patients with severe craniofacial anomalies or syndromes, those currently undergoing fixed orthodontic treatment, and those with extensive restorations or prosthetic rehabilitations, including crowns and veneers.

2.3. Intraoral Scanning Procedure

A total of 34 patients who met the study inclusion and exclusion criteria were scanned intraorally using a 3D intraoral scanner (AS260; AlliedStar Medical Equipment Co., Ltd., China) to record digital cast of the dentition by the orthodontic specialist (S.H.N) according to the manufacturer's instructions. Prior to intraoral scanning, the intraoral scanner was calibrated using the Medit Calibration Wizard in MeditLink (v3.1.0, Medit, Seoul, South Korea) to ensure consistent and accurate 3D data acquisition. For standardization and subsequent digital processing, datasets from each scan were exported in stereolithography file format (.STL) into the AS Connect software (AlliedStar Medical Equipment Co., Ltd., China) for analysis.

2.4. Conventional Dental Cast Fabrication

Following the completion of intraoral scanning, conventional dental casts were fabricated. Alginate impressions (Kromopan; Lascod S.p.A., Florence, Italy) were taken using a standard orthodontic impression tray by the same orthodontic specialist (S.H.N) who performed the intraoral scanning. The alginate was mixed following the manufacturer's instructions and handled by a single operator. Each impression recorded all teeth and the attached gingiva. Impressions were sent to the dental laboratory, where they were poured using Type IV dental stone (Whip Mix Corp., Louisville, KY, USA). The plaster-to-water ratio, water temperature, and room temperature were standardised for all models following the manufacturer's recommendations, to eliminate any risk of dimensional changes during reproduction. All conventional dental casts were carefully stored in labelled boxes to prevent distortion or damage.

2.5. Measurement Variables

Intraoral orthodontic assessment was performed on all conventional and digital dental casts. Fourteen variables were measured and the details of each measurement are described in Table 1. Measurements were conducted by two investigators (M.I.D and M.D.H). A calibration session with an orthodontic specialist (C.J.M) was conducted whereby the two investigators measured both conventional and digital dental casts. This process ensured that data collection was accurate, consistent, and reliable, minimising inter- and intra-examiner errors.

Table 1 Dental cast measurement and definition

Measurements	Definition
Upper Arch	Distance measured along the upper arch from the mesial surface of one second permanent molar to the mesial surface of the opposite second permanent molar, passing through the contact points of the teeth.
Lower Arch	Distance measured along the lower arch from the mesial surface of one second permanent molar to the mesial surface of the opposite second permanent molar, passing through the contact points of the teeth.
Incisor Width (Teeth 11 and 41)	Linear measurement between the mesial interproximal contact point and the distal interproximal contact point of the maxillary right central incisor (11) and mandibular right central incisor (41), respectively.
Canine Width (Teeth 13 and 43)	Linear measurement between the mesial interproximal contact point and the distal interproximal contact point of the maxillary right canine (13) and mandibular right canine (43), respectively.
Premolar Width (Teeth 14 and 44)	Linear measurement between the mesial interproximal contact point and the distal interproximal contact point of the maxillary right first premolar (14) and mandibular right first premolar (44), respectively.
Molar Width (Teeth 16 and 46)	Linear measurement between the mesial interproximal contact point and the distal interproximal contact point of the maxillary right first molar (16) and mandibular right first molar (46), respectively.
Overjet	Greatest horizontal distance between the incisal edge of the upper central incisor and the corresponding labial surface of the lower central incisor, measured parallel to the occlusal plane. Recorded as a negative value in cases of anterior crossbite.

Overbite	Greatest vertical distance between the incisal edge of the most prominent upper central incisor and the most-overlapped lower central incisor. Recorded as a negative value in cases of anterior open bite.
Upper Arch Space Analysis	Assessment of the space relationship in the maxillary arch by comparing the sum of mesiodistal tooth widths with the available arch space. Crowding is expressed as a positive value (combined tooth widths exceed available space); spacing as a negative value.
Lower Arch Space Analysis	Assessment of the space relationship in the mandibular arch using the same method applied for the upper arch space analysis. Crowding is expressed as a positive value; spacing as a negative value.

2.6. Measurement Methodology

All measurement landmarks and the procedures were conducted in strict adherence to the definitions described in Table 1. Assessment of conventional casts was carried out using a digital caliper (Absolute Digimatic 500-196-30, Mitutoyo, Japan) and a standard metal orthodontic ruler. All measurements were recorded in millimetres (mm) to two decimal places. Assessment of digital casts was performed using the measurement utility within the AS Connect software (AlliedStar Medical Equipment Co., Ltd., China).

2.7. Statistical Analysis

All data were analysed using SPSS® Statistics (version 27, IBM, Armonk, NY, USA), with Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) used for data handling. The normality of the data distribution was assessed using both the Shapiro-Wilk test and the Kolmogorov-Smirnov test, with the Shapiro-Wilk test serving as the primary normality test given the sample size (n = 34). The mean, standard deviation, and standard error of the differences between repeated measurements for each method and between the two methods were computed. A Paired Samples T-test was used to compare measurements between the conventional and digital methods across all 14 variables. A p-value of < 0.05 was designated as the threshold for statistical significance. To determine inter- and intra-observer reliability of manual landmark identification, Intraclass Correlation Coefficients (ICC) were computed.

3. Results and Discussion

3.1. Examiner Reliability

The Intraclass Correlation Coefficient (ICC) was used to evaluate inter- and intra-examiner reliability. ICC values exceeded 0.9 for all repeated cast measurements, indicating an excellent degree of intra- and inter-observer reliability (Table 2).

Table 2 Intraclass Correlation Coefficient (ICC) for examiner reliability

	Intraclass Correlation	**95% Confidence Interval Upper Bound**	**95% Confidence Interval Lower Bound**	**F Value**	**df1**	**df2**
Single Measures	0.997	0.893	0.998	190,412	4	4
Average Measures	0.999	0.918	0.999	282.030	4	4

3.2. Normality of Data

Data normality was assessed using both the Shapiro-Wilk test and the One-Sample Kolmogorov-Smirnov test. The p-values across the entire 14-variable matrix exceeded the 0.05 threshold for both tests (p > 0.05), confirming that the data were normally distributed and that the assumptions of the Paired Samples T-test were satisfied.

Table 3 presents the means and standard deviations from the analysis of 34 pairs of conventional and digital dental casts across all 14 variables. The mean values derived from the digital casts were highly comparable, and in most cases nearly identical, to those obtained from conventional plaster casts. For example, the mean upper arch length was 112.41 mm (SD ±8.23) for the conventional method and 112.49 mm (SD ±8.50) for the digital method. Individual tooth widths and occlusal measurements (overjet and overbite) similarly demonstrated consistent mean values and variability (SD) across both methods.

3.3. Measurement Analysis

The Paired Samples T-test revealed no statistically significant differences ($p > 0.05$) between the two modalities across all 14 analysed variables (Table 3). Detailed examination of arch dimension measurements revealed that the maximum observed mean difference was for lower space analysis, which recorded a deviation of 0.17 mm ($p = 0.054$). Conversely, the smallest mean differences were observed for the mandibular central incisor mesiodistal width (tooth 41) and overbite, both of which showed a negligible discrepancy of just −0.01 mm ($p = 0.687$ and $p = 0.704$, respectively).

Table 3 Paired Samples T-test: Comparison of conventional and digital dental cast measurements

Category	Variable	Conventional Cast Mean (mm)	SD	Digital Cast Mean (mm)	SD	Mean Difference (mm)	p-Value
Dental Arch Measurement (Arch Length)	Upper Arch	112.41	8.23	112.49	8.50	−0.08	0.624
	Lower Arch	101.94	8.51	101.91	8.40	0.03	0.807
Tooth Measurement (Mesiodistal Width)	Incisor 11	8.65	0.56	8.61	0.61	0.04	0.207
	Incisor 41	5.47	0.40	5.48	0.40	−0.01	0.687
	Canine 13	7.90	0.56	7.92	0.94	−0.02	0.507
	Canine 43	7.11	0.55	7.09	0.52	0.02	0.636
	Premolar 14	7.43	0.42	7.44	0.37	−0.01	0.784
	Premolar 44	7.40	0.53	7.39	0.54	0.01	0.831
	Molar 16	10.68	0.65	10.73	0.62	−0.05	0.214
	Molar 46	11.11	0.68	11.10	0.69	0.01	0.812
Occlusion Assessment	Overjet	3.63	2.58	3.71	2.59	−0.08	0.074
	Overbite	3.17	1.36	3.18	1.35	−0.01	0.704
Space Analysis	Upper	−0.62	4.51	−0.74	4.62	0.12	0.136
	Lower	−0.61	4.38	−0.78	4.57	0.17	0.054

The primary objective of this study was to validate the diagnostic accuracy of the AlliedStar AS260 intraoral scanner against the established gold standard of conventional plaster models. The comparative analysis of 14 orthodontic variables revealed no statistically significant differences ($p > 0.05$) between the two methods, providing compelling evidence to accept the null hypothesis that digital dental casts are as accurate as conventional plaster casts for intraoral orthodontic assessments. Crucially, statistical non-significance was corroborated by clinical equivalence: in orthodontics, a linear measurement difference of less than 0.5 mm is universally accepted as clinically insignificant, as it does not influence diagnostic decisions (e.g., extraction versus non-extraction) or appliance fit (Naidu and Freer, 2013). In the present study, the mean differences for all 14 variables fell well within this threshold, with the maximum discrepancy being only 0.17 mm (lower space analysis). This finding is consistent with the systematic review by Akdeniz et al. (2022) and the study by Murugesan and Sivakumar (2020), which confirmed that modern IOS devices have reached a level of fidelity that matches or exceeds that of plaster models. Specifically, for the AlliedStar AS260, these results confirm that the device is a precise alternative for routine clinical use.

While the differences were clinically negligible, a noteworthy trend was observed in the space analysis and overjet variables. The lower space analysis showed the largest mean difference (0.17 mm), with a borderline p-value ($p = 0.054$). The digital measurements tended to indicate slightly more crowding than the plaster models. This discrepancy can likely be attributed to the “caliper access” phenomenon described by Zhang et al. (2020). In crowded mandibular arches, the physical tips of a digital caliper are often too bulky to reach the true interproximal contact points, forcing the operator to measure slightly buccal or lingual to the contact, which overestimates the available arch space. In contrast, software-based measurement allows the operator to zoom, rotate, and section the three-dimensional mesh to view the contact point in cross-section. This suggests that, in cases of severe crowding, digital measurements may be geometrically more accurate than their physical counterparts, as they eliminate the physical limitations inherent to manual instruments.

To contextualise the accuracy observed in this study, it is important to understand the underlying mechanics of the AlliedStar AS260. This scanner operates using advanced structured-light technology, whereby a structured pattern of light is continuously projected onto the dental arches. As these light contacts the complex topography of the teeth and gingiva, the pattern distorts; the scanner's sensors capture this distortion to mathematically calculate the precise three-dimensional spatial coordinates of the surface. Crucially, the AS260 incorporates an optimised optical structure with an 18 mm depth of field, enabling accurate data capture within deep interproximal spaces, steep palatal vaults, and complex subgingival margins without loss of resolution (AlliedStar Medical Equipment Co., Ltd., 2023).

Furthermore, modern intraoral scanning relies on artificial intelligence (AI)-powered image processing for dynamic soft-tissue removal. During scanning, AI algorithms actively identify and filter out moving artefacts such as the tongue, buccal mucosa, and pooling saliva, which are primary hindrances to optical data capture. By removing these artefacts, the AI ensures uninterrupted mesh generation, contributing to the exceptional dimensional accuracy observed in this dataset (Lione et al., 2024).

A fundamental vulnerability inherent to all optical intraoral scanning technologies is the phenomenon known as "stitching error" (Abduo, 2019). Because the wand's camera possesses a restricted field of view, it cannot capture an entire dental arch simultaneously. Instead, the device captures thousands of individuals, overlapping optical frames as it is swept across the dentition. The scanner's internal software must then continuously "stitch" or digitally register these frames together by identifying matching geometric and textural features. Digital stitching which pieces together thousands of independent photographic frames to reconstruct the jaw and captures sweeping, continuous anatomical curves without introducing cumulative expansion or contraction scaling errors.

Historically, earlier generations of intraoral scanners struggled with full-arch scans because microscopic frame-to-frame misalignments would rapidly accumulate over the long span of the arch, a phenomenon documented as cumulative stitching error (Ender and Mehl, 2013). This global distortion frequently resulted in the digital model being artificially warped, often manifesting as severe transverse expansion or contraction at the contralateral molars, rendering the digital casts unsafe for complex space analysis or appliance fabrication (Abduo, 2019).

Beyond diagnostic precision, the transition from analog plaster to digital meshes introduces profound logistical advantages, particularly concerning the legal and physical burdens of record retention. Under established clinical guidelines, such as those adapted by the Ministry of Health Malaysia (2023), dental records and orthodontic study models must typically be securely retained for a minimum of seven years following a patient's last visit, and frequently indefinitely in the event of ongoing medico-legal cases. Storing hundreds or thousands of bulky gypsum casts requires dedicated, climate-controlled physical archiving space. Furthermore, plaster models are inherently brittle and carry a perpetual risk of catastrophic breakage or surface degradation over their mandated lifespan (Baxi et al., 2022).

Digital models, generated as Standard Tessellation Language (STL) or Polygon File Format (PLY) files, completely eradicate these physical storage constraints. Digital casts occupy zero physical footprint and can be securely backed up on encrypted cloud servers or local hard drives, ensuring absolute compliance with data protection and patient retention laws. This digital architecture not only eliminates the risk of physical model degradation but also facilitates instantaneous data retrieval, seamless global interdisciplinary communication, and direct integration into modern CAD/CAM appliance fabrication workflows.

Despite the strong statistical agreement observed, there were several limitations that warrant acknowledgement. The findings from this study are specific to the AlliedStar AS260 and cannot be extrapolated to other intraoral scanning systems, as trueness and precision vary considerably across devices and proprietary scanning algorithms. Also, this study design excluded patients with extensive prosthodontic restorations, which means the results reflected relatively idealised optical conditions that may not fully represent the complexity encountered in routine adult clinical practice. Future research should involve multiple intraoral scanning systems evaluated under standardised conditions to determine whether the accuracy extends across the broader digital dentistry market. Additionally, subsequent studies should actively recruit patients with diverse restorative profiles, including metallic crowns, composite resins, and translucent ceramic restorations, to assess scanner performance under non-idealised conditions and validate the technology for use in multidisciplinary treatment contexts.

4. Conclusion

In conclusion, this study demonstrates that there is no statistically significant difference between orthodontic measurements obtained from the AlliedStar AS260 digital casts and conventional plaster casts ($p > 0.05$). Furthermore, the dimensional differences between the two methods are clinically negligible (< 0.2 mm), falling well within the universally accepted 0.5 mm tolerance required for accurate orthodontic diagnosis. Beyond dimensional accuracy, the digital workflow exhibited excellent inter-rater (ICC > 0.9) and intra-rater reliability, proving to be a highly consistent alternative to traditional manual measurements. Based on these findings, the AlliedStar AS260 intraoral scanner is highly recommended as a reliable and valid alternative to conventional methods for routine orthodontic diagnosis and comprehensive treatment planning

Compliance with ethical standards

Disclosure of conflict of interest

All authors declare no conflict of interest.

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