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**DEVELOPMENT OF A DIGITAL FORENSIC ODONTOLOGY
 WORKFLOW INTEGRATING SMARTPHONE-BASED 3D DENTAL
 DOCUMENTATION AND TELEGRAM-BASED DENTAL RECORDS.**

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ABSTRACT

Background: The availability of complete and accessible antemortem dental records is essential for forensic odontology identification. Conventional dental records have limitations in data storage, retrieval, and documentation standardization. Integration of three-dimensional (3D) dental documentation and electronic dental records may improve forensic dental data management. **Purpose:** This study aimed to develop and evaluate an integrated digital forensic odontology workflow combining Boxphone-assisted smartphone image acquisition, Blender-based 3D dental model construction, and Telegram-based electronic dental records for individual identification simulation. **Methods:** This research employed a research and development design followed by system evaluation. Dimensional agreement was evaluated using 44 dental casts, while electronic dental record workflow efficiency was evaluated using 43 simulated patient datasets across manual, Telegram-based, and web-based systems. Parameters included mesiodistal first-molar measurement, data-entry time, and data-retrieval time. **Results:** The overall mean mesiodistal measurement was 10.83 mm for the reference dental casts and 10.84 mm for the reconstructed 3D models; the difference between the two overall means was 0.01 mm. The Telegram-based system showed a mean data-entry time of 149.41 seconds, compared with 225.27 seconds for the manual record and 259.00 seconds for the web-based system. Mean retrieval time was 6.72 seconds for the Telegram-based system, 21.72 seconds for the manual record, and 8.00 seconds for the web-based system. **Conclusion:** The integrated workflow showed close group-level dimensional agreement between reference and reconstructed measurements and shorter descriptive task-completion times for the Telegram-based record system in this controlled evaluation.

Keywords: Digital health technology; Electronic dental records; Forensic odontology; Three-dimensional dental documentation.

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INTRODUCTION

Forensic odontology plays an important role in human identification, particularly in situations where visual recognition, fingerprint analysis, or DNA examination cannot be readily performed. Dental structures are among the most durable components of the human body and can withstand environmental conditions that may compromise other biological tissues. Consequently, dental records are widely utilized as an antemortem data source in disaster victim identification (DVI), criminal investigations, and unidentified human remains cases. The accuracy of forensic dental identification largely depends on the availability, completeness, and accessibility of antemortem dental records for comparison with postmortem findings.¹⁻³

Despite their importance, dental records in many healthcare facilities remain inadequately documented and predominantly maintained in conventional paper-based formats. Manual records are susceptible to physical deterioration, data loss, incomplete documentation, and prolonged retrieval processes. Furthermore, variations in recording practices among clinicians may result in inconsistencies that complicate forensic comparison procedures. In mass disaster scenarios and forensic investigations requiring rapid identification, difficulties in accessing accurate dental information may delay reconciliation processes and reduce the effectiveness of forensic identification efforts.⁴⁻⁶

Recent advances in digital health technologies have encouraged the transformation of conventional dental records into electronic dental record (EDR) systems. Electronic records facilitate data storage, retrieval, sharing, and long-term preservation while reducing the risk of physical damage or information loss. Simultaneously, smartphone-based technologies and three-dimensional (3D) imaging methods have emerged as affordable alternatives for dental documentation. Three-dimensional dental models provide detailed morphological information and may enhance the quality of antemortem records used in forensic identification. Previous studies have demonstrated the feasibility of digital dental documentation and electronic record systems; however, these technologies are commonly developed and evaluated as separate components.⁷⁻¹¹

To date, previous studies have primarily investigated smartphone-based 3D imaging approaches, including photogrammetric methods, and electronic dental record systems as separate technological approaches. Smartphone-based 3D imaging has been evaluated for acquisition and reconstruction of dental data, whereas electronic dental record systems have mainly focused on storage, management, and retrieval of dental information. However, limited attention has been given to combining these functions within a unified forensic odontology workflow. In the present system, multi-view smartphone images acquired under controlled lighting in the Boxphone are used as visual references for Blender-based 3D model construction. The resulting 3D documentation is linked to the corresponding individual dental record managed through the Telegram-based system, allowing the digital model and associated dental information to be accessed within the same identification workflow. Thus, the novelty of this study lies not in the independent use of smartphone-based 3D imaging or electronic dental records, but in their operational integration as complementary components for acquisition, 3D documentation, record management, and subsequent retrieval for forensic identification.¹²⁻¹⁴

This study aimed to develop and evaluate an integrated digital forensic odontology workflow combining Boxphone-assisted smartphone image acquisition, Blender-based three-dimensional dental model construction, and Telegram-based electronic dental records for forensic identification simulation. The workflow was evaluated based on dimensional agreement between reference and reconstructed dental measurements and descriptive data-entry and retrieval times across the recording systems.

MATERIALS AND METHODS

Material

This research employed a research and development (R&D) design followed by system performance evaluation at Institut Ilmu Kesehatan Bhakti Wiyata, Kediri, Indonesia. The developed workflow integrated Boxphone-assisted smartphone image acquisition, Blender-based three-dimensional (3D) dental documentation, and a Telegram Bot-based electronic dental record system. Dimensional agreement was evaluated using 44 maxillary and mandibular dental casts with identifiable dental morphology and no fractures or surface defects affecting measurement. Electronic record efficiency was evaluated using 43 simulated patient datasets containing identity

information, odontograms, dental conditions, and odontogram codes, without actual patient-identifying information.

Methods

The study comprised four stages: Boxphone-assisted multi-view image acquisition, 3D model construction and dimensional assessment, evaluation of the Telegram-based electronic dental record against manual and web-based systems, and linkage of 3D documentation with the corresponding electronic dental record.

Boxphone-Based Image Acquisition

The Boxphone was a 40 × 40 × 40 cm controlled image-acquisition chamber equipped with internal LED lighting and a central turntable. Illuminance in lux was not measured, and external light was minimized. Dental casts were photographed using a smartphone camera with a minimum resolution of 2 megapixels, with digital zoom and flash disabled. The camera was positioned approximately 30 cm from the cast. Approximately 40 images were acquired over a complete 360° rotation at approximately 9° intervals, covering the entire dental arch. Object position, camera distance, and lighting conditions were maintained consistently throughout acquisition.

Three-Dimensional Model Construction and Dimensional Assessment

Multi-view images were processed using Blender version 4.2 LTS (Blender Foundation, Amsterdam, The Netherlands). Processing included image referencing, geometric adjustment, mesh editing, artifact removal, surface refinement, orientation, and scale calibration using a reference object of known dimensions. The unit system was set to Metric (mm); procedures that could alter morphology or dimensions were avoided, and final models were exported in STL format. Dimensional agreement was assessed using the mesiodistal width of an identifiable first molar, defined as the greatest distance between the most mesial and distal points of the crown. The same landmarks were used on reference and 3D models without predetermined side or arch. Reference casts were measured using a Mitutoyo Series 500 digital caliper (0–150 mm; resolution 0.01 mm; Mitutoyo Corporation, Japan), whereas 3D models were measured in Blender 4.2 LTS. Two standardized examiners independently performed each measurement three times, and the mean was used for analysis. Discrepant measurements were re-evaluated and repeated.

Telegram-Based Electronic Dental Record and Efficiency Evaluation

The electronic dental record followed the architecture Telegram Bot → Google Apps Script → Google Sheets → Google Drive. Google Apps Script processed commands, Google Sheets stored structured dental data, and Google Drive stored associated digital documentation. Each dataset and its corresponding 3D documentation were linked using a unique identification code, enabling retrieval through the Telegram Bot. Efficiency was evaluated using the same 43 simulated datasets across manual, Telegram-based, and web-based records. A single operator familiar with all three systems performed all procedures to minimize inter-operator variability. System order was randomized for each dataset, with a 10-minute interval between trials, and identical data fields were used across systems. Data-entry time was measured from entry of the first field until the complete dataset was saved, whereas retrieval time was measured from entry of the identification code until the corresponding record was fully displayed. Timing was recorded manually using a digital stopwatch and expressed in seconds.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics (IBM Corp., Armonk, NY, USA). Descriptive statistics summarized dimensional measurements and task-completion times. For dimensional assessment, the overall means of 44 reference casts and corresponding 3D models were calculated, and their difference was reported descriptively as a group-level difference rather than individual measurement error. Data-entry and retrieval times from 43 simulated datasets were summarized as mean task-completion times for each recording system; therefore, comparisons were interpreted descriptively.

RESULTS

The developed digital forensic odontology workflow consisted of a Boxphone-assisted image-acquisition and Blender-based 3D dental documentation component integrated with a Telegram-based electronic dental record component. Performance was evaluated through dimensional agreement and descriptive task-completion times.

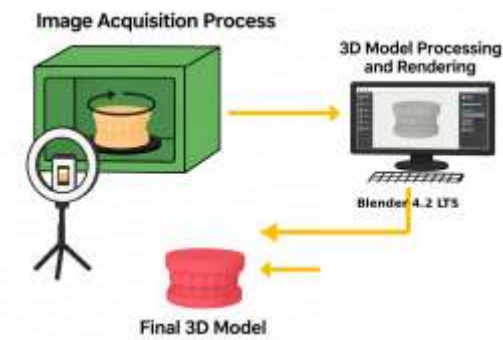


Figure 1. Workflow of Boxphone-assisted image acquisition and Blender-based three-dimensional dental model construction.

Figure 1 illustrates the workflow of the Boxphone system for three-dimensional dental documentation. Dental casts are photographed using a smartphone camera under controlled lighting within the Boxphone. The acquired multi-view images are then used as visual references for image-based 3D model construction in Blender version 4.2 LTS. After scale calibration and mesh refinement, the final digital model is exported in STL format for measurement, documentation, and linkage with the electronic dental record workflow.



Figure 2. Image acquisition process using the Boxphone system.

Figure 2 illustrates the image acquisition stage of the Boxphone system, where a dental model is photographed using a smartphone camera under controlled lighting conditions. Multiple images are captured from various perspectives to provide sufficient data for three-dimensional reconstruction. The resulting digital model may be utilized for dental documentation, morphological analysis, and forensic odontology applications.

Table 1. Comparison of overall mean mesiodistal measurements between reference dental casts and Boxphone-generated three-dimensional models.

Parameter	Reference Model (mm)	3D Model (mm)	Difference between overall means (mm)
Overall mean	10.83	10.84	0.01

Table 1 shows that 44 dental casts were evaluated. The overall mean mesiodistal measurement was 10.83 mm for the reference dental casts and 10.84 mm for the Boxphone-generated 3D models. The 0.01-mm value represents the difference between these two overall mean values and should not be interpreted as the mean individual dimensional deviation or per-cast measurement error.

Table 2. Comparison of mean data-entry and retrieval times among Telegram-based, manual, and web-based dental record systems.

Parameter	Telegram-Based EDR	Manual Record	Web-Based EDR
Data entry time (seconds)	149.41	225.27	259.00
Data retrieval time (seconds)	6.72	21.72	8.00

Table 2 summarizes mean task-completion times for the same 43 simulated datasets. The Telegram-based system had a mean data-entry time of 149.41 seconds, compared with 225.27 seconds for the manual record and

259.00 seconds for the web-based system. Mean retrieval time was 6.72 seconds for the Telegram-based system, 21.72 seconds for the manual record, and 8.00 seconds for the web-based system. These results are descriptive and indicate shorter task-completion times for the Telegram-based workflow in this controlled single-operator evaluation.

DISCUSSION

This study developed and evaluated an integrated digital forensic odontology workflow combining Boxphone-assisted smartphone image acquisition, Blender-based three-dimensional dental documentation, and Telegram-based electronic dental records. The findings showed close group-level dimensional agreement between the reference and reconstructed measurements and shorter descriptive data-entry and retrieval times for the Telegram-based workflow than for the manual and web-based systems in the controlled evaluation. These findings support the growing role of digital technologies in forensic odontology, particularly in improving the availability and accessibility of antemortem dental documentation for human identification processes.^{14–16}

The dimensional evaluation showed closely similar overall mean mesiodistal measurements for the reference dental casts (10.83 mm) and reconstructed 3D models (10.84 mm), corresponding to a 0.01-mm difference between the two overall means. This value reflects group-level agreement and should not be interpreted as the mean individual dimensional deviation or per-cast measurement error. Accordingly, the present findings support minimal systematic difference at the aggregate level rather than proving individual-model accuracy from the mean difference alone. Accuracy remains important in forensic odontology because dental morphology, restorations, missing teeth, and other individual characteristics are commonly used for antemortem and postmortem comparison. Previous studies have reported that digital dental models can provide reliable measurements and documentation quality comparable to conventional models, supporting their use in clinical and forensic applications^{17–21}. The findings of the present study therefore support the feasibility of controlled smartphone-based image acquisition and Blender-based 3D documentation as a practical approach, while individual-level agreement should be characterized more comprehensively in future validation studies.

For the electronic dental record component, the Telegram-based system showed shorter mean data-entry and retrieval times than the manual and web-based systems in the same 43 simulated datasets. Similar advantages of electronic record platforms have been reported in previous studies, including improved information accessibility and reduced administrative burden^{22–24}. In forensic investigations, rapid access to antemortem dental information is important because delays in retrieval may prolong identification procedures. In the present evaluation, use of the same datasets and data fields, randomized system order, and a 10-minute interval between trials reduced several procedural sources of bias. Nevertheless, because all timing trials were performed by a single operator who was already familiar with the systems, the observed differences should be interpreted as within-operator workflow performance rather than generalized superiority across different users.

An important contribution of this study is the operational integration of three-dimensional dental documentation and electronic dental records within a single forensic odontology workflow. Most previous studies have evaluated digital dental documentation or electronic record systems independently^{24,25}. However, forensic identification requires both adequate dental documentation and efficient mechanisms for data storage and retrieval. In the developed workflow, the 3D dental documentation is linked to the corresponding electronic record through a unique identification code, with structured data stored in Google Sheets and associated digital documentation stored in Google Drive and accessed through the Telegram Bot. This integration may support the development of more continuous digital forensic dental data-management workflows and future disaster victim identification preparedness.

Several limitations should be acknowledged. The system was evaluated using dental casts and simulated patient datasets rather than actual forensic case records. The electronic dental record timing assessment was performed by a single operator who was already familiar with the three recording systems; therefore, the observed task-completion times may not represent users with different levels of experience. Reuse of the same simulated datasets across systems may also permit residual recall despite randomized order and the 10-minute interval. For the imaging component, smartphone brand and model were not restricted beyond the minimum camera-resolution requirement, and illuminance was not quantified in lux; these factors limit characterization of device- and lighting-related variability. In addition, Blender-based model construction and landmark placement remain operator-dependent procedures. The study did not assess user acceptance, interoperability, information-security

performance, or long-term implementation outcomes. Future studies should include multiple operators, quantify inter- and intra-examiner reliability, report individual-level dimensional agreement metrics, test standardized camera and lighting configurations, and evaluate the workflow in clinical and forensic settings^{26–28}

The integrated digital forensic odontology workflow combining Boxphone-assisted image acquisition, Blender-based three-dimensional dental documentation, and Telegram-based electronic dental records demonstrated close group-level dimensional agreement and shorter descriptive task-completion times for the Telegram-based record workflow in this evaluation. The integration of 3D documentation with structured dental records through a common identification code provides a practical framework for digital forensic dental data management and warrants further validation in multi-operator, clinical, and forensic environments.^{29–31}

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