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Original Research Article

Evaluating Computer Dependence in General Dentistry to Assess Mixed Reality Integration: A Retrospective Analysis

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Abstract

Mixed reality (MR), encompassing augmented reality (AR) and virtual reality (VR), is an emerging technology in dentistry that allows real-time integration of digital information into the clinician's visual field. Contemporary dental workflows require frequent interaction with electronic health records, radiographs, and diagnostic tools, leading to workflow interruptions and increased cognitive load. This study aimed to quantify computer dependence across common dental procedures and identify those that may benefit most from MR integration. A retrospective observational study was conducted on 50 patients treated by a single general dentist. Patients were equally distributed among five procedure categories ($n = 10$ each): Extractions, Root Canal Treatments, Crowns, Fillings, and Prophylaxes. Computer dependence was quantified as active treatment time (seconds) divided by the number of clinician interactions with digital devices, expressed as seconds per interaction. A one-way ANOVA was used to evaluate differences among procedure types, and Welch's t-tests compared Extractions with each of the remaining groups. Significant differences in computer dependence were observed among procedures. Extractions and Root Canal Treatments showed no statistically significant difference ($p = 0.341$), indicating similarly high reliance on digital interaction. In contrast, Crowns, Fillings, and Prophylaxes demonstrated significantly lower computer dependence than Extractions (all $p < 0.001$). Surgical and endodontic procedures exhibit the highest levels of computer dependence, suggesting they may benefit most from MR integration. Targeted implementation of MR could reduce screen shifts, decrease cognitive load, and improve procedural efficiency, supporting its prioritization in these workflows.

Keywords: Virtual reality; Augmented reality; Dental informatics.

INTRODUCTION

Advances in digital technologies are transforming the landscape of general dentistry, creating opportunities to improve workflow efficiency and clinical precision. Among these technologies, mixed reality (MR), which blends virtual reality (VR) and augmented reality (AR), allows clinicians to interact with both real and digitally enhanced environments simultaneously (Barteit *et al.,* 2021). Unlike VR, which immerses users in a fully virtual setting, MR enables overlaying digital information onto the real-world operative field, while assisted reality (aR) provides simpler overlays of critical data without full spatial interaction (Worlikar *et al.,* 2023). The rapid growth of VR and AR adoption in healthcare, increasing by nearly 34% between 2023 and 2024, reflects the rising need for technologies that streamline clinical workflows and reduce reliance on external monitors (Virtual Reality in Healthcare Market: Revenue Statistics [2032], 2024).

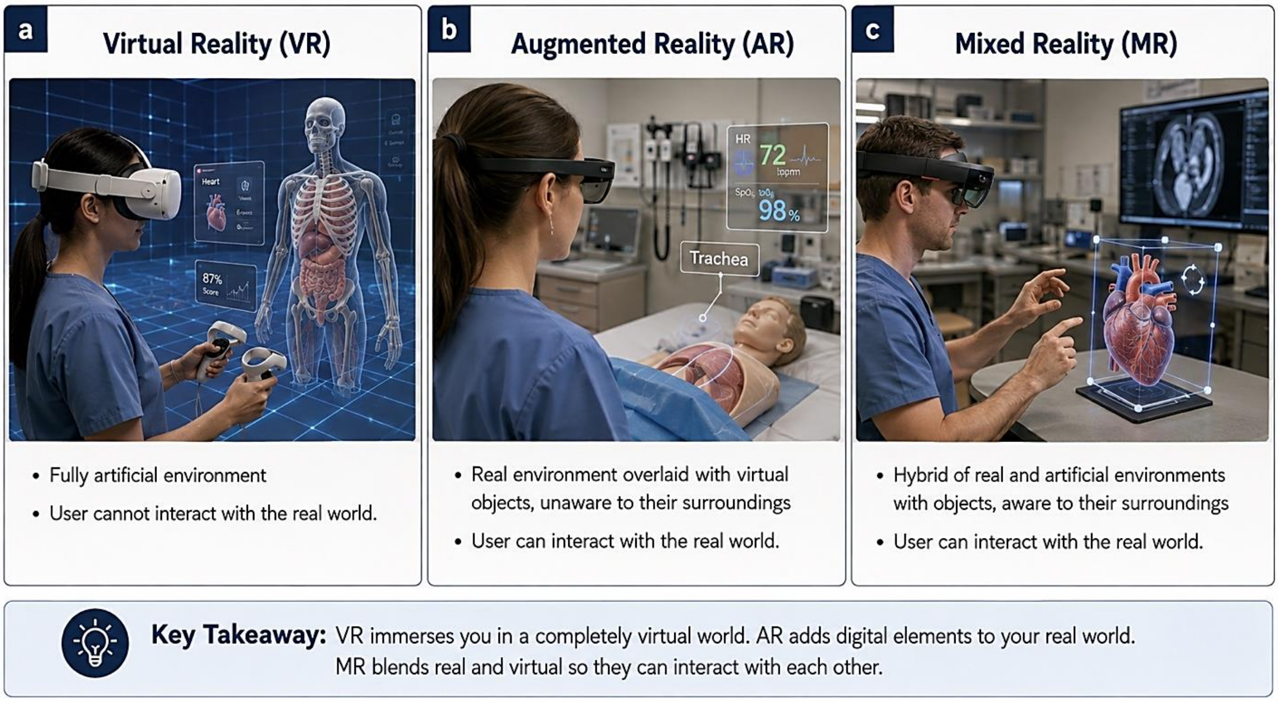

Figure 1: Comparing Different Types of Reality. The figure summarizes VR (a), AR (b), and MR (c), using images (designed by Freepik) and text noting the type of environment and user interaction

In general dentistry, procedures such as surgical extractions and root canal treatments require frequent consultation of radiographs, electronic health records, and diagnostic devices during active treatment. These repeated gaze shifts away from the operative field can disrupt workflow and increase cognitive load, potentially affecting efficiency and patient safety (Bhugaonkar *et al.,* 2022; Bouraghi *et al.,* 2023). Despite the potential of MR to address these challenges, adoption remains limited, largely due to the lack of integrated loupe magnification, which is essential for clinical visualization. Surveys show that 64.3% of general dentists, 60% of oral surgeons, and over 80% of dental hygienists rely on loupes in daily practice (Kharouba *et al.,* 2022; Wei, 2018; Brancheau, 2020). However, recent developments such as AR-loupes demonstrate the feasibility of combining magnification with digital overlays to provide real-time guidance (Qian *et al.,* 2022).

Assisted reality and MR systems can project imaging, treatment plans, and other data directly into the clinician's field of view, reducing the need to look away from the operative site. Early applications in oral surgery, including dynamic navigation-assisted implant placement, suggest that such overlays can improve efficiency and reduce cognitive interruptions (Engelschalk *et al.,* 2024; Nagata *et al.,* 2024; Fahim *et al.,* 2022). These tools are particularly valuable in high-dependence procedures like extractions and endodontic treatments, where frequent digital consultation is required and maintaining continuous focus may reduce operator fatigue.

This study aims to quantify computer dependence across common dental procedures, emphasizing surgical and endodontic care. By measuring digital interaction frequency, it seeks to identify procedures that may benefit most from MR or assisted reality integration, potentially improving efficiency and accuracy in general dental practice (Monterubbianesi *et al.,* 2022).

EXPERIMENTAL SECTION / MATERIALS AND METHODS

Treatment Selection and Data Collection

This retrospective analysis was conducted at a private dental office. The study involved one general dentist with 50 treated patients. Five common dental procedure categories were included: Extraction(s), Root Canal Treatment(s), Crown(s), Filling(s), and Prophylaxes, with ten patients per group. The designation "(s)" indicates that patients may have received one or multiple procedures within a category. Minor procedures and routine examinations were excluded. Treatment duration was recorded for each case to account for variability, as longer procedures were expected to involve more frequent digital interactions.

To reduce bias within the Crown(s) group, five cases involved crown preparations and five involved crown seatings. Data collection was non-intrusive and conducted during routine patient care, with the general dentist treating regularly scheduled patients. All data were obtained through direct observation without interfering with clinical workflow.

Treatment time was defined as the period during which the dentist actively provided care, beginning once the patient was prepared and the dentist entered the operatory. Timing was recorded using an Apple Watch, with pauses during interruptions such as radiographs or temporary absence.

Computer usage was measured as the number of interactions with digital devices performed by the dentist, excluding actions by dental assistants. Devices included computer monitors, intraoral imaging systems, and apex locators. Computer usage per patient was calculated as total treatment time (in seconds) divided by the number of recorded interactions, yielding a standardized measure of seconds per interaction.

Data Analysis and Statistical Methods

Data were organized in Microsoft Excel and categorized by treatment type. Box-and-whisker plots (Figure 2) were generated to illustrate the distribution of seconds per interaction, including minimum, quartiles, median, and maximum values. Table 1 summarizes treatment duration and computer usage across all groups, while Figure 3 presents a conceptual design of mixed reality dental loupes and their potential applications.

Inferential statistical analyses were performed to evaluate differences in computer usage across treatment categories. A one-way analysis of variance (ANOVA) was used to determine whether mean computer usage differed significantly among the five groups. Assumptions of normality and homogeneity of variance were assessed using visual inspection and Levene's test.

Following a significant ANOVA result, post hoc comparisons were conducted using independent two-sample Welch's t-tests to compare Extraction(s) with each of the other treatment categories. This method was selected due to its robustness to unequal variances and small sample sizes. All tests were two-tailed with a significance level of $\alpha = 0.05$. P-values, t-statistics, and degrees of freedom were reported where appropriate, and all analyses were performed using Microsoft Excel.

RESULTS AND DISCUSSION

The collected data on computer usage during general dentistry procedures revealed notable variation across treatment groups. Differences in digital interaction appear to be influenced by both procedural complexity and patient-specific factors. For example, in Extraction(s), patients requiring third molar extractions often necessitated more frequent consultation of digital resources, such as radiographs, compared to patients undergoing simpler anterior tooth extractions.

Data Analysis Results

Overall Differences Across Procedures

A one-way ANOVA was conducted to examine the effect of treatment type on computer usage across five categories: Extraction(s), Root Canal Treatment(s), Crown(s), Filling(s), and Prophylaxes. The analysis indicated a statistically significant difference in mean computer usage among the groups ($F(4, 45) = 13.68$, $p < .001$). Given the significant omnibus result, post-hoc comparisons using Welch's two-sample t-tests were warranted to identify specific differences between the Extraction(s) group and the other treatment modalities, as reported in subsequent sections.

Comparison of Extractions with other General Dentistry Procedures

Independent-samples Welch's t-tests were conducted to compare the mean computer usage of the Extraction(s) group, designated as the baseline, against each of the other treatment modalities (Table 1). These analyses provided insight into procedure-specific reliance on digital resources during active dental care.

For Root Canal Treatment(s), Welch's t-test indicated no statistically significant difference in mean computer usage compared with Extraction(s) (Extraction(s): $M = 122.0$ s/interaction, $SD = 54.14$; Root Canal Treatment(s): $M = 142.0$ s/interaction, $SD = 34.77$; $t(15.34) = -0.98$, $p = 0.341$). This finding suggests that both extractions and root canal procedures share a high degree of dependence on real-time digital guidance, reflecting frequent radiographic review, apex locator verification, and procedural planning throughout treatment.

In contrast, Crown procedures demonstrated significantly higher seconds per interaction ($M = 271.0$, $SD = 77.99$) than Extraction(s), $t(16.04) = -4.96$, $p < 0.001$. The longer intervals per digital interaction indicate that crowns require less frequent consultation of computer-based resources during treatment, likely due to the repetitive and visually guided nature of crown preparation and seating once initial planning is complete.

Similarly, Filling procedures exhibited significantly greater seconds per interaction ($M = 320.0$, $SD = 94.18$) compared with Extraction(s), $t(14.36) = -5.76$, $p < 0.001$. This reflects lower computer dependence during routine restorative care, where digital resources such as radiographs or charting systems are referenced less frequently once treatment begins.

Prophylaxis procedures also showed higher seconds per interaction ($M = 332.0$, $SD = 129.73$) relative to Extraction(s), $t(12.04) = -4.72$, $p < 0.001$. This pattern is consistent with the minimal reliance on digital devices during preventive care, which is largely manual and guided by direct visual and tactile assessment.

Surgical and endodontic procedures like extractions and root canals demand the most frequent digital interactions. Integrating mixed reality into these workflows would provide real-time clinical data, preventing disruptive attention shifts from the operative field.

Computer Usage for Treatment Types

Computer usage was quantified by dividing total treatment time (seconds) by the number of digital interactions, where lower values indicate higher dependence. As shown in Figure 2, median seconds per interaction ranked from highest to lowest dependence: Extractions (112), Root Canal Treatments (147), Crowns (257), Prophylaxes (303.5), and Fillings (312.5). This demonstrates that surgical and endodontic procedures require the most frequent digital consultation. Consequently, these high-dependence workflows stand to benefit most from mixed reality (MR) technologies, which can streamline operations and reduce attention shifts compared to restorative or preventive treatments.

Figures Created to Represent Gathered Data

Figure 2 and Table 1 summarize the study findings. Figure 2, a box plot of computer usage in general dentistry, identifies treatments that could benefit most from mixed reality (MR) integration. Table 1 compares treatment durations and computer usage across five procedures to highlight MR's efficiency advantages. Finally, Figure 3 illustrates how conceptual MR-enabled dental loupes can streamline workflows, reduce attention shifts, and improve clinical efficiency.

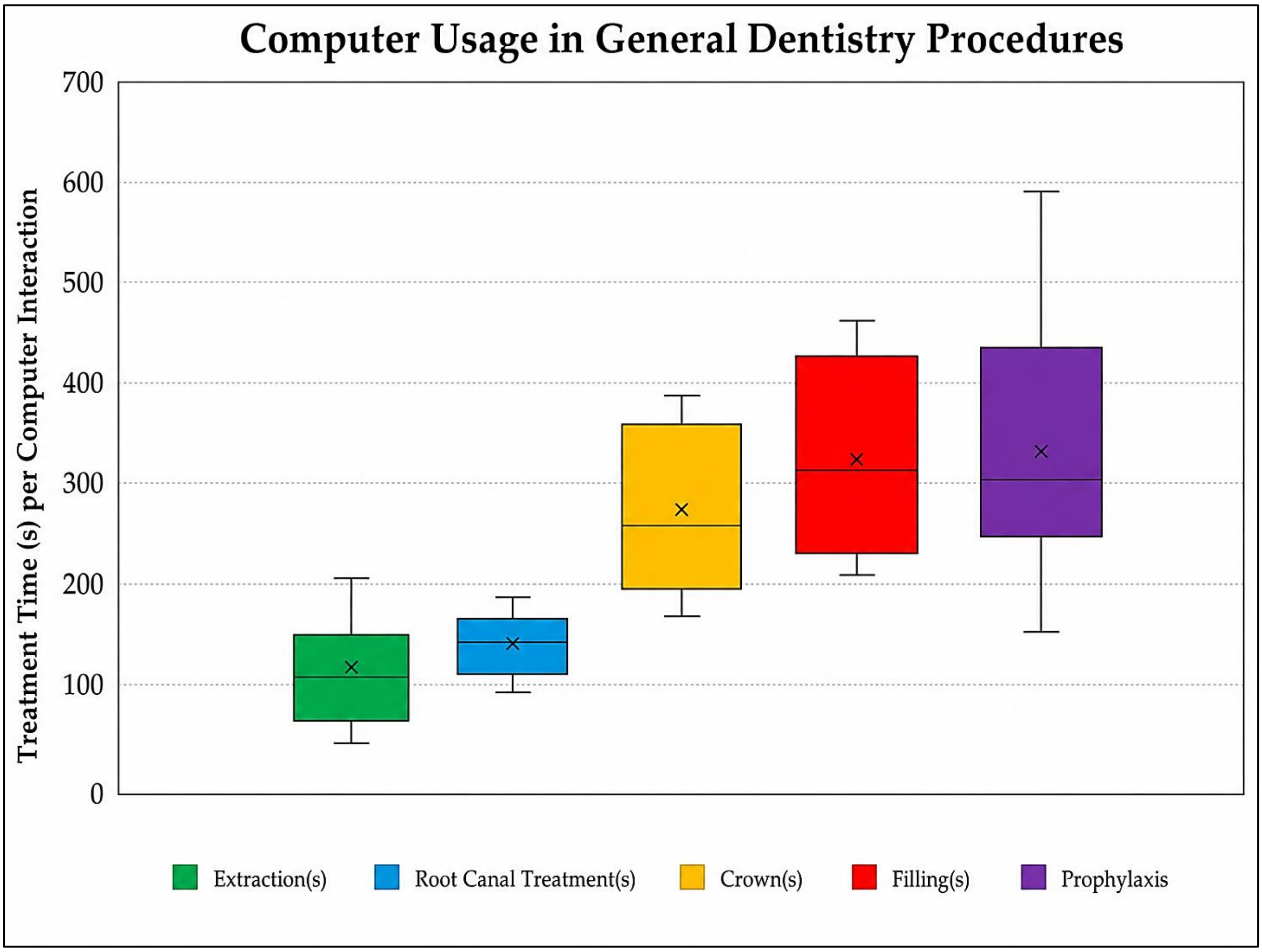

Figure 2: Box-and-Whisker Plot of General Dentistry Procedures. Each data point represents an individual patient undergoing treatment

The median fence represents the median number of seconds per interaction with digital devices, while the lower and upper boundaries are the 25th and 75th percentiles. The whiskers, extending from the box, indicate the 10th and 90th percentiles. Procedures with lower median values indicate a higher dependence on digital technology, as interactions with digital devices occur more frequently during these treatments. Procedures with lower median values indicate a higher dependence on digital technology, as interactions with digital devices occur more frequently during these treatments.

Table 1: Comparison of Treatment Time and Computer Usage

Treatment Types	Average Treatment Time(min)	Average Computer Usage	Sample Size(n)
Extraction(s)	8.73	122	10
Root Canal Treatment(s)	28.24	142	10
Crown(s)	29.5	271	10
Filling(s)	19.1	320	10
Prophylaxes	19	332	10
Average/ Total	**20.91**	**237.4**	**50**

The table shows data for the five treatment groups analyzed. The column labeled "Average Treatment Time (min)" displays treatment time in minutes for all procedures performed within the treatment groups, while the column labelled "Average Computer Usage" shows computer usage, measured as treatment time (in seconds) for all procedures performed within the treatment groups. The sample size from each treatment group was ten. Averages for each category are provided in the last row, offering a comparative view.

Figure 3: Proposed Mixed Reality HMD and Applications in Dentistry

The figure illustrates a conceptual design (developed using OpenArt) for Mixed Reality Loupes (a) and potential applications of mixed reality technology in third molar extractions (b), crown seat procedures (c), and root canal treatments (d).

Data Evaluation

Analysis of computer usage showed that Extraction(s) and Root Canal Treatment(s) had the highest frequency of digital interactions, reflecting reliance on radiographic evaluation, procedural verification, and treatment planning software. These procedures require frequent reference to digital resources to confirm anatomical landmarks and ensure accuracy, making them more computer-dependent than restorative or preventive treatments, which rely primarily on visual and tactile feedback.

The lack of a statistically significant difference between Extraction(s) and Root Canal Treatment(s) ($p = 0.341$) suggests that MR technology could provide similar efficiency gains in both surgical and endodontic workflows. Head-mounted MR systems integrated with dental loupes can overlay radiographs, treatment plans, and real-time data directly into the clinician's field of view, reducing attention shifts, improving focus, and minimizing errors associated with frequent screen checking (Barteit *et al.,* 2021; Qian *et al.,* 2022).

Frequent disengagement from the patient to interact with digital devices increases cognitive load and the risk of procedural errors. MR-enabled loupes could centralize access to key data streams—such as radiographs, apex locator readings, and charting software—improving ergonomics, reducing fatigue, and maintaining workflow continuity. These benefits are especially relevant in complex procedures like extractions and endodontic therapy, where interruptions may compromise accuracy (Bhugaonkar *et al.,* 2022; Worlikar *et al.,* 2023).

Despite its potential, MR integration faces limitations. Systems must effectively integrate multiple digital platforms without introducing workflow disruptions. Additionally, the single-practitioner design limits generalizability, as operator habits and procedural variability may influence results. However, MR adoption in dentistry aligns with trends in other surgical fields, where head-mounted displays improve information access, reduce cognitive load, and enhance procedural efficiency (Monterubbianesi *et al.,* 2022; Fahim *et al.,* 2022).

CONCLUSION

The study analyzed computer usage across general dentistry procedures and found significant variation by treatment type, with ANOVA confirming differences in digital interaction. Surgical extractions and root canal treatments demonstrated the highest computer dependence due to frequent reliance on radiographs, apex locator readings, and treatment planning software, whereas restorative and preventive procedures showed lower dependence. These findings suggest that mixed reality (MR) integration would be most beneficial in workflows requiring frequent digital consultation, supporting its ability to overlay critical information directly into the clinician's field of view (Barteit *et al.,* 2021; Qian *et al.,* 2022).

Despite its potential, MR adoption in dentistry faces technical and ergonomic challenges. A key limitation is the lack of integrated loupe magnification in current head-mounted displays, which remains essential in clinical practice (Kharouba *et al.,* 2022; Wei, 2018; Brancheau, 2020). MR systems must also integrate multiple digital streams—such as radiographs and device outputs—without disrupting workflow. Additionally, operator habits and procedural complexity, as reflected in this single-practitioner study, may influence computer usage patterns.

Integration of MR with dental loupes or head-mounted displays may reduce cognitive load, minimize attention shifts, and maintain procedural continuity, particularly in high-precision procedures such as extractions and endodontic therapy (Bhugaonkar *et al.,* 2022; Worlikar *et al.,* 2023). By centralizing digital data within the clinician's field of view, MR could improve efficiency and reduce errors from frequent disengagement. These benefits align with trends in other surgical fields, where MR enhances access to critical information while maintaining focus (Monterubbianesi *et al.,* 2022; Fahim *et al.,* 2022).

Future implementation should prioritize high-dependence procedures, particularly surgical and endodontic treatments. Further research across multiple practitioners and clinical settings is needed to evaluate the impact of MR on efficiency, accuracy, and patient outcomes. Overall, MR technology has strong potential to improve workflow and enhance the standard of care in modern dentistry.

Author Contributions:

Conceptualization, H.R.; methodology, H.R.; validation, L.M., K.R., and D.L.; formal analysis, H.R.; investigation, H.R.; resources, L.M., K.R., and D.L.; data curation, H.R.; writing original draft preparation, H.R.; writing review and editing, H.R. and K.R.; visualization, H.R.; supervision, H.R. and K.R.; project administration, H.R. All authors have read and agreed to the published version of the manuscript.

Patient Consent Statement: Informed consent was obtained from the participating general dentist and all patients involved in data collection.

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