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Evaluating Computer Dependence in IV Sedation Bone Graft Procedures to Assess Mixed Reality Implementation: A Retrospective Analysis

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Abstract

Virtual and augmented reality are key components of mixed reality, enabling users to interact seamlessly with real or simulated environments based on clinical needs. Integrating mixed reality into dental loupes holds promise for enhancing clinical efficiency by reducing treatment times and minimizing the need for practitioners to divert their attention from patients to external computer monitors. This study evaluates the impact of mixed reality adoption by analyzing digital screen usage during oral surgical procedures and examining whether its necessity varies by treatment type. The retrospective analysis involves two oral surgeons performing procedures on their regularly scheduled patients in a clinical setting. To assess the feasibility of incorporating mixed reality into dental loupes, data was collected on the frequency and duration of digital computer interactions, categorized by procedure type. For bone graft procedures, statistical analysis focused on the influence of intravenous (IV) sedation on computer usage and treatment duration, given the additional monitoring required for vital signs. A two-sample t-test showed a statistically significant 95.9% increase in computer usage with IV sedation compared to local anesthesia, though no significant difference in treatment duration was observed. An ANOVA test revealed significant differences in computer usage across various oral surgery procedures, indicating that the potential benefits of mixed reality integration may vary by procedure. These findings suggest that incorporating mixed reality into dental loupes could enhance workflow efficiency and reduce reliance on external screens in oral surgery practices.

Keywords: Bone graft, intravenous sedation, computers, smart glasses, virtual reality, augmented reality.

INTRODUCTION

Mixed reality (MR), a technology conceptualized by Ivan Sutherland at Harvard University in 1968, merges elements of virtual reality (VR) and augmented reality (AR) to create interactive environments that blend real and simulated components. MR allows users to engage either with entirely virtual spaces via VR or with enhanced real-world surroundings through AR features (Barteit, S. *et al.,* 2021). The global adoption of VR and AR technologies within healthcare has seen rapid growth rising by 33.97% between 2023 and 2024 positioning healthcare as the third-largest sector for VR/AR usage after gaming and automotive industries (*Virtual Reality in Healthcare Market: Revenue Statistics [2032], 2024*).

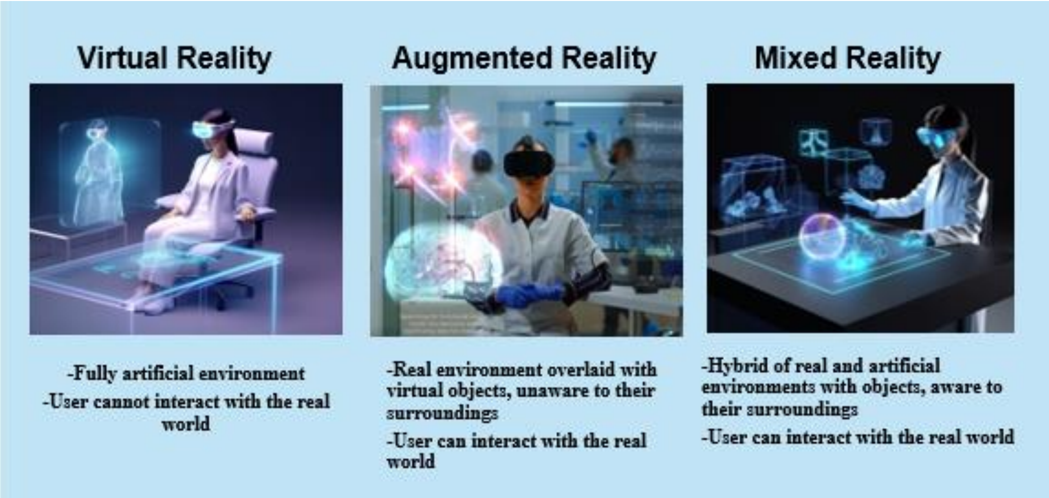

Figure 1: Comparing Different Types of Reality. The figure summarizes VR (a), AR (b), and MR (c), using images (designed by Freepik) and text noting the type of environment and user interaction

Recent advancements have driven MR technologies into high-precision medical disciplines, particularly neurosurgery and cardiovascular procedures. These applications often involve complex surgeries such as brain and spinal operations or heart valve replacements, where MR tools, like AR head-mounted displays (HMDs), enhance visualization. Surgeons can overlay real-time 3D reconstructions of patient anatomy and interact with these images to improve spatial awareness and surgical accuracy (Bhugaonkar, K. *et al.,* 2022; Bouraghi, H. *et al.,* 2023). This capability reduces the need for surgeons to divert their attention to external monitors, thereby minimizing distraction and streamlining intraoperative decision-making.

However, integrating MR into dentistry faces specific technical and ergonomic challenges. One critical limitation is the absence of loupe magnification a standard visual aid used extensively in dental procedures. According to survey data, 64.3% of general dentists, 60% of oral surgeons, and 80.38% of dental hygienists rely on loupes for enhanced visibility (Kharouba, J. *et al.,* 2022; Wei, C. 2018; Brancheau, K. 2020). Without this functionality built into medical-grade HMDs, MR remains impractical for many dental applications. Solving this would be a pivotal step toward broader MR integration across dental specialties.

A related yet simpler technology is assisted reality (aR), which differs from AR by providing basic digital overlays without full spatial interaction. aR can mirror digital content such as computer displays onto an HMD, offering passive but useful information delivery during clinical procedures. While it lacks features like hand tracking or 3D interaction, its simplicity makes it beneficial in settings where hands-free access to data is vital, such as during surgery (Worlikar, H. *et al.,* 2023).

In oral surgery, aR technologies are beginning to influence workflows, particularly in implant procedures supported by dynamic navigation systems like *X-Guide* by X-Nav Technologies. This platform projects real-time 3D guidance on implant angulation, depth, and positioning, dynamically adapting to changes during surgery. While X-Guide eliminates the need for static surgical guides, clinicians must frequently shift their gaze between the surgical site and external screens for feedback. Integrating aR-enabled HMDs could streamline this process, keeping visual data within the surgeon's line of sight and enhancing efficiency (Engelschalk, M. *et al.,* 2024; Fahim, S. *et al.,* 2022; Nagata, K. *et al.,* 2024).

Despite these advancements, the literature presents mixed findings regarding the clinical benefits of AR-assisted procedures. A 2022 meta-analysis of 425 studies found significantly higher accuracy in AR-assisted, computer-navigated implant surgeries compared to freehand and non-AR-guided methods ($p < 0.001$). Conversely, a 2024 systematic review of 45 studies reported no significant differences in accuracy among robot-assisted, AR-guided, and traditional approaches, while noting that digital systems generally led to longer procedure times (Mai, H. *et al.,* 2023; Miura, T. *et al.,* 2024).

Another area where MR could make a significant impact is during procedures involving intravenous (IV) sedation. IV sedation is common in dental surgeries, including implant placement, bone grafting, and complex extractions. It typically involves drugs such as midazolam, propofol, and fentanyl, administered using titration methods like intermittent bolus or target-controlled infusion. While safe when performed correctly, IV sedation demands continuous monitoring of vital signs—oxygen saturation, temperature, blood pressure, heart rate, and respiratory rate—which are displayed on monitors often placed outside the surgeon's line of sight (Areia, C. *et al.,* 2021; Lobb, D. *et al.,* 2023).

Monitoring becomes more challenging during procedures where the clinician must move frequently around the operatory, potentially blocking their view of the monitor and delaying response to changes in vital signs. HMDs with integrated MR or aR capabilities could provide a solution by displaying real-time vital signs directly in the clinician's field of view, reducing screen-checking time and enhancing patient safety. This technology is already gaining traction in hospital settings and is being explored for its physical and cognitive effects on practitioners (Areia, C. *et al.,* 2021).

Bone grafting, a foundational procedure in implant dentistry, exemplifies the potential benefit of MR in dental settings. It is used in ridge augmentation, sinus lifts, socket preservation, and periodontal surgery. The procedure employs graft materials that support bone regeneration and must demonstrate osteogenesis, osteoconduction, and osteoinduction properties. Bone grafting can be performed under local anesthesia, IV sedation, or general anesthesia, with IV sedation often used in conjunction with local anesthesia to improve patient comfort and compliance. However, it necessitates continuous vital sign monitoring, increasing computer usage during the procedure (Ciszyński, M. *et al.,* 2023; Ferraz, M. *et al.,* 2023).

The current study investigates whether the need for IV sedation in bone grafting procedures significantly affects treatment duration and digital screen interactions due to vital sign monitoring requirements. Patients were divided into two groups: one receiving only local anesthesia and another receiving both local anesthesia and IV sedation. The results aim to inform the feasibility and utility of MR integration in surgical workflows.

Ultimately, MR's widespread adoption in dentistry depends on overcoming several hardware and software limitations. These include the integration of loupe magnification into HMDs and the ability to simultaneously display multiple information streams—such as navigation data and patient vitals—within a single interface. Addressing these challenges could allow MR to revolutionize preoperative planning, intraoperative accuracy, and time efficiency in both general dentistry.

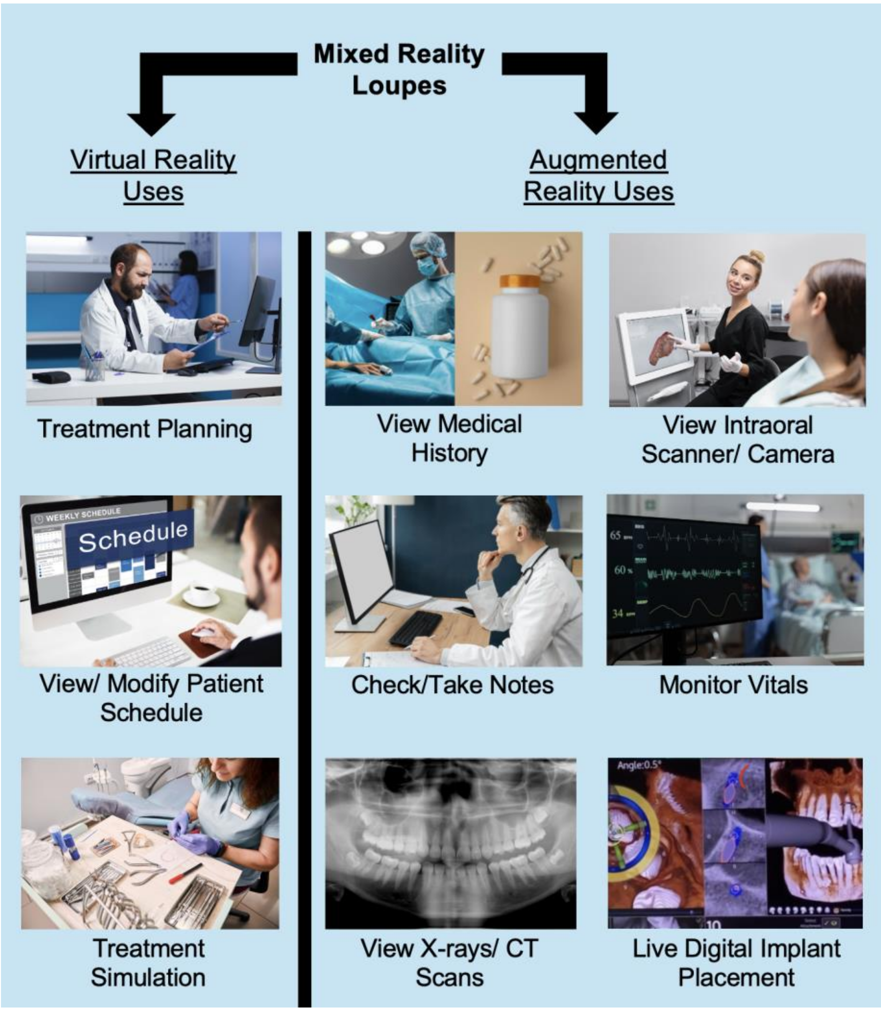

Figure 2: Examples of Mixed Reality Loupes Usage. The figure shows the Virtual Reality Uses (a) and Augmented Reality Uses (b), through images (designed by Freepik) and captions

Experimental Section/Materials and Methods

This retrospective analysis was conducted at a private dental office. The study included two oral surgeons practicing at the office, both of whom participated in the data collection involving a total of 50 patients they treated. Informed consent from the two oral surgeons, patient consent, and permission was granted to conduct the study.

2.1 Treatment Selection and Data Categorization

2.1.1 Treatment Types

The types of treatment recorded included: Surgical Extraction(s) with IV Sedation, Implant without Assisted Reality Glasses, Implant with Assisted Reality Glasses, Bone Graft with IV Sedation, Bone Graft with Local Anesthesia, and Biopsy. Data from ten patients were collected for each treatment type, except for the two implant treatment groups, which involved five patients each. Treatments marked with "(s)" refer to instances where patients received one or multiple procedures (e.g., Surgical Extraction(s) with IV Sedation could include one or several extractions per patient). Treatment duration was recorded for each procedure to account for any variability in time, as longer treatments were expected to involve more frequent computer usage.

2.1.2 Minimizing Data Collection Bias

To minimize potential biases due to surgeon experience and variation in treatment time, five patients from each non-implant treatment type were treated by each oral surgeon, totaling ten patients per treatment. For the Implant treatments, data for "Implant without Assisted Reality Glasses" was collected from only one surgeon, while data for "Implant with Assisted Reality Glasses" was collected exclusively by the other. This allocation reflects each surgeon's preference, with one surgeon favoring assisted reality glasses and the other preferring the X-Guide machine's external computer. Rare or minor dental procedures and dental exams/consultations were excluded from this study.

2.1.3 Patient Care Protocol

The study was designed to be non-intrusive, with data collected as part of routine patient care. The oral surgeons treated their regularly scheduled patients, and treatment types aligning with the study's focus were selected. The surgeon performing Implant treatments with assisted reality glasses was already using this technology before the study, ensuring no modifications in patient care were necessary. As a result, the study did not interfere with patient treatment; data was collected solely through observation as the oral surgeons performed dental procedures on their patients.

2.2 Recording Data on Computer Usage in Oral Surgery Treatments

2.2.1 Treatment Time Calculation

Treatment time was defined as the duration the oral surgeon actively treated each patient. To optimize data accuracy, patient exams were conducted on separate dates to minimize time spent discussing procedures on the day of treatment. Once patients were prepped by registered dental assistants, treatment time began as the surgeon entered the operatory. Timing was managed using an Apple Watch, recording down to milliseconds. Any pauses in patient care (e.g., for x-rays taken or if the surgeon temporarily exited) were noted, with the stopwatch paused and resumed accordingly until patient treatment was completed.

2.2.2 Recording Computer Usage

Throughout each patient's treatment time, data was gathered on the number of interactions with digital devices by the treating surgeon only, excluding interactions by dental assistants. Devices tracked included computer screens, intraoral digital imaging systems, vital signs monitors, and the X-Guide monitor (for implant surgeries). For treatments using assisted reality glasses, interactions with the glasses themselves were not counted; however, if the surgeon looked away from the glasses, interactions with external screens were tallied.

2.2.3 Quantifying Computer Usage

Computer usage per patient was calculated by dividing treatment time (in seconds, converted from minutes and milliseconds) by the number of device interactions recorded.

2.3 Data Analysis and Statistical Tests

2.3.1 Graphical Representation of Data

In Figure 3, data on computer usage for each patient was categorized by treatment type in Excel, and box-and-whisker plots were generated to illustrate the distribution of seconds per interaction. Key values such as the minimum, Q1, Q2, Q3, and maximum were identified for each treatment group. Table 1 was created to show the collected data on treatment time and computer usage in the bone graft procedures with and without IV sedation. In Figure 4, a conceptual design of a future, improved alternative to assisted reality in oral surgery was created using an artificial intelligence software, showcasing mixed reality dental loupes and their applications in oral surgery and other dental professions.

2.3.2 ANOVA for Comparing Computer Usage Across Treatment

An ANOVA test was conducted to assess whether computer usage (treatment time in seconds divided by number of interactions with digital devices) varied significantly among various oral surgery procedures. Data from all treatment types, excluding Implant with Assisted Reality Glasses, were included. The F-value from the test was used to calculate a corresponding p-value, with a significance level of 0.05, to determine whether significant differences in computer usage existed across treatment types.

2.3.3 Statistical Analysis of Bone Graft Procedures

Two two-sample t-tests were conducted to compare bone graft procedures with and without IV sedation. The first test assessed whether the use of IV sedation in bone graft procedures leads to an increased treatment time by comparing treatment times in minutes and seconds for both bone graft treatment groups. The second t-test examined whether the use of IV sedation increases the number of device interactions due to the continuous monitoring of vital signs required on an additional external computer during procedures. For both tests, the p-value was recorded to determine the statistical significance of the results.

RESULTS AND DISCUSSION

The collected data on computer usage during oral surgery procedures revealed that the use of digital devices varies significantly by treatment type. Differences in computer usage appear to be influenced by both the complexity of the procedure and the patient's oral health status. For instance, in Surgical Extraction(s) with IV Sedation, a patient with impacted third molars may require more frequent reference to external digital resources, such as radiographs, compared to a patient with non-impacted molars.

3.1 Data Analysis Results

3.1.1 Comparison Across Oral Surgery Treatments

An ANOVA test was conducted to assess the variance in computer usage across oral surgery treatments without aR, excluding the Implant with Assisted Reality Glasses category (*F-value = 50.244 and* $p < 0.001$).

The p-value was well below the significance level of 0.05, indicating a statistically significant difference between the group means. This suggests that the observed differences are unlikely to be due to chance, and the null hypothesis (no difference in group means) was rejected. These findings demonstrate significant variance in computer usage across oral surgery procedures, indicating that certain procedures may benefit more from MR technology than others.

3.1.2 Computer Usage for Treatment Types

Computer usage for each treatment type was calculated by dividing treatment time (in seconds) by the number of computer interactions. Figure 3 shows that lower values correspond to higher computer usage, as interactions with digital devices are more frequent relative to the total treatment time. The median of computer usage for each treatment type was as follows: 230.5 for Surgical Extraction(s) with IV Sedation, 102 for Implant without Assisted Reality Glasses, 340 for Implant with Assisted Reality Glasses, 255.5 for Bone Graft with IV Sedation, 520.5 for Bone Graft with Local Anesthesia, and 559 for Biopsy.

These results highlight considerable variation in computer usage across procedures and underscore the potential benefit of aR in implant surgeries. Ranking the treatments from lowest to highest computer usage, the order is as follows: Biopsy, Bone Graft with Local Anesthesia, Implant with Assisted Reality Glasses, Bone Graft with IV Sedation, Surgical Extraction(s) with IV Sedation, and Implant without Assisted Reality Glasses.

3.1.3 Impact of Anesthesia Type on Computer Usage in Bone Graft Procedures

Bone graft procedures were categorized by anesthesia type: Bone Graft with IV Sedation and Bone Graft with Local Anesthesia. Due to the need for continuous vital signs monitoring, IV sedation resulted in higher computer usage than local anesthesia.

Two independent two-sample t-tests were conducted to evaluate the impact of IV sedation on treatment time and computer interactions. Results showed a non-statistically significant increase in treatment time by 5.9% in bone graft procedures utilizing IV sedation in comparison to those without IV sedation ($p = >0.05$). However, results showed a statistically significant increase in computer usage of 95.9% for bone graft treatments utilizing IV sedation compared to bone graft procedures without IV sedation ($p = <0.0001$).

3.1.4 Figures Created to Represent Gathered Data

Two figures, Figures 3 and 4, and Table 1 were created to illustrate the findings. Figure 3 represents a box-and-whisker plot, which combines data from all oral surgery procedures, highlighting differences in computer usage and identifying procedures that may benefit more from mixed reality integration. Table 1 illustrates the difference in treatment time and computer usage between bone graft procedures with and without IV sedation, emphasizing that choice of anesthesia impacts computer dependence. Figure 4 involves a conceptual illustration, showing a potential application of mixed reality loupes in the dental profession and demonstrating the convenience of integrated mixed reality technology in enhancing workflow.

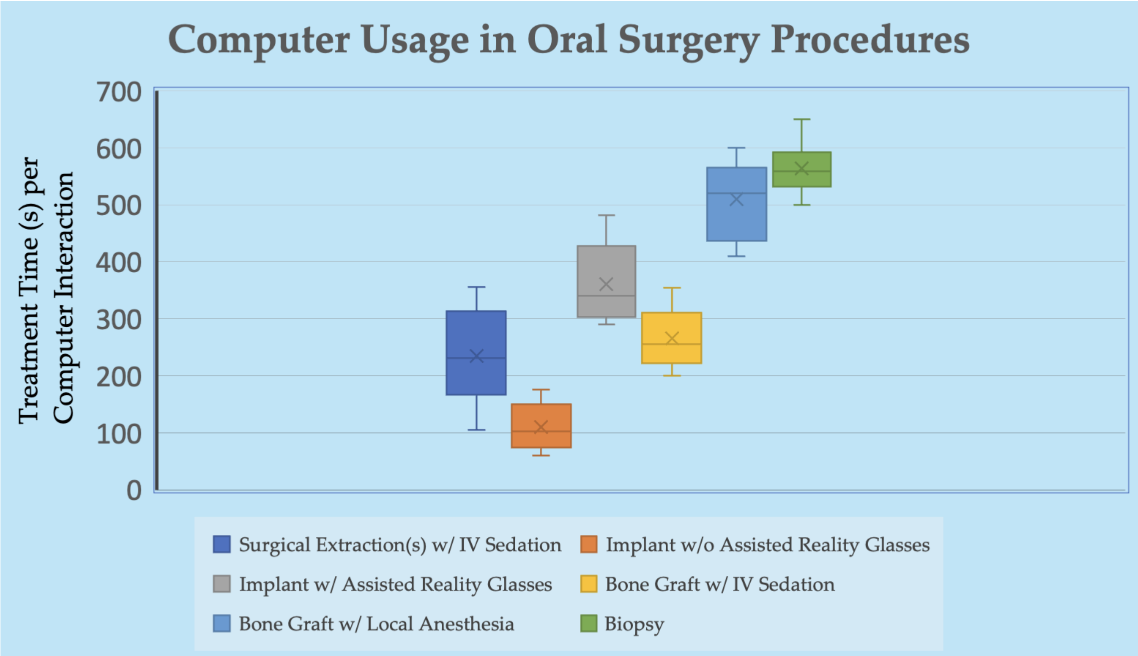

Figure 3: Box-and-Whisker Plot of Oral Surgical Procedures

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.

Table 1: Comparison of Treatment Time and Computer Usage in Bone Graft Procedures

Bone Graft w/ IV Sedation			
	Procedure Number	Treatment Time (min)	Computer Usage
	1	34.74	298
	2	16.32	230
	3	19.14	227
	4	28.14	276
	5	34.49	354
	6	34.14	349
	7	29.11	205
	8	28.98	200
	9	30.23	278
	10	19.62	235
	Average	27.49	265.2
Bone Graft w/ Local Anesthesia			
	1	34.85	600
	2	28.5	520
	3	23.98	521
	4	16.04	409
	5	27.56	570
	6	20.01	422
	7	26.1	481
	8	28.51	551
	9	34.08	600
	10	20.01	522
	Average	25.96	519.6

The table shows data for bone graft procedures performed with and without IV sedation. The column labeled "Treatment Time (min)" displays treatment time in minutes for each procedure, while the column labelled "Computer Usage" shows computer usage, measured as treatment time (in seconds) per computer interaction. Averages for each category are provided in the row below the individual data points, offering a comparative view of the impact of anesthesia type on both treatment duration and digital interaction frequency.

Figure 4: 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).

CONCLUSION

The data collected from oral surgery procedures, excluding Implant with Assisted Reality Glasses, aimed to determine whether computer usage varies based on the type of dental treatment. Results from the ANOVA test revealed a statistically significant difference in computer usage across the various treatments, suggesting that mixed reality technology may be more beneficial for certain procedures. Given the high reliance on digital devices in the dental field, implementing mixed reality in loupes or glasses could offer significant advantages.

4.1 Discussion on Current Gaps and Future Potential of Mixed Reality in Dentistry

4.1.1 Computer Usage Across Dental Treatments and the Implications for Mixed Reality

Data collected from various oral surgery procedures—excluding those involving implant placement with Assisted Reality (aR) glasses—were analyzed to determine whether computer usage varied based on treatment type. An ANOVA test revealed statistically significant differences in computer interaction across procedures, suggesting that certain dental treatments demand more frequent reference to digital systems than others. These findings imply that the benefits of mixed reality (MR) technology may not be uniform across all dental procedures. Instead, MR may offer the greatest advantages in procedures where frequent digital reference is necessary, highlighting a potential for targeted implementation. Given the growing reliance on digital tools in modern dental practice, incorporating MR into dental loupes or head-mounted displays (HMDs) could offer significant workflow improvements.

4.1.2 Barriers to the Implementation of Mixed Reality in Dentistry

Despite its success in other medical fields, MR adoption in dentistry remains limited. One of the primary barriers is the absence of MR-compatible head-mounted displays that include integrated loupe magnification—a critical visual aid for most dental procedures. In specialties like neurosurgery and cardiovascular surgery, MR systems are effective even without magnification, as the level of detail required is typically viewed on larger, external monitors. However, in dentistry, practitioners work at very close proximity to the operative site and depend heavily on magnified, high-resolution visualization.

Additionally, many existing dental software platforms, including practice management and imaging systems, are not designed to integrate with MR hardware. This lack of interoperability creates a technical barrier to seamless integration of MR into the clinical workflow. These limitations, both hardware and software related, have so far hindered widespread adoption in general and surgical dentistry.

4.1.3 Enhancing Patient Monitoring During IV Sedation with Mixed Reality

IV sedation is commonly used in various oral surgical procedures—including extractions, implant placements, and bone grafts—to increase patient comfort and compliance. However, it also introduces the need for constant monitoring of patient vital signs to ensure safety and prevent adverse events. Currently, this monitoring is performed using external digital monitors that clinicians or their assistants must check periodically during procedures.

Mixed reality headsets could offer a compelling solution by displaying real-time vital signs directly within the clinician's field of view. This integration would reduce the need to look away from the surgical site, minimizing workflow disruptions and potentially improving patient safety by enabling faster response to any changes in vital signs.

4.1.4 Mixed Reality in Bone Grafting with IV Sedation

Bone graft procedures are especially well-suited to benefit from MR integration. Data from this study showed that computer usage was 95.9% higher during bone graft procedures performed with IV sedation compared to those using only local anesthesia. This increase was primarily due to the continuous monitoring required during sedation. Interestingly, the increased computer use did not correlate with a longer treatment time, suggesting that the heightened need for digital interaction is related more to patient monitoring than to procedural complexity.

The use of MR glasses that can display vital signs in real-time may significantly enhance both efficiency and safety in these procedures. By minimizing the need to shift attention away from the patient, MR technology could help streamline workflow while supporting critical decision-making throughout treatment.

4.1.5 Study Limitations

Several limitations must be acknowledged. First, the potential influence of the Hawthorne effect—where individuals change their behavior in response to being observed—may have impacted the results. Although the researcher took steps to minimize social interaction and avoid disrupting the clinicians' natural workflow, the mere presence of an observer may have altered their treatment speed or level of computer interaction (Berkhout, C. *et al.,* 2022).

Second, the study involved only two oral surgeons, limiting the generalizability of the findings. A small sample size increases variability and reduces the statistical power of the results. Additionally, the two practitioners had a considerable difference in clinical experience—approximately ten years post-residency—which could have affected treatment duration, clinical decision-making, and the frequency of computer use. Previous studies, such as one published in the *Journal of Oral Implantology*, have shown that surgical experience correlates strongly with procedural accuracy and may indirectly impact efficiency (Hinckfuss, S. *et al.,* 2012). Future studies should aim to include a larger, more experience-balanced sample to improve the reliability and applicability of the findings.

4.1.6 Advancing Mixed Reality Technology for Dental Applications

To unlock MR's full potential in dentistry, further technological developments are needed. Specifically, MR HMDs should be optimized to include loupe magnification, higher-resolution displays, ergonomic designs suited for long procedures, and software compatibility with dental imaging and navigation systems. The ability to display multiple data sources—such as vital signs and 3D implant navigation—simultaneously will be essential for broader adoption.

Beyond convenience, MR may also improve clinical outcomes by enhancing accuracy, enabling better spatial awareness, and reducing the likelihood of iatrogenic errors. However, more clinical research is needed to confirm whether MR can tangibly reduce complication rates or improve long-term treatment success.

4.1.7 Recommendations for Future Research

Future investigations should explore MR applications across a wider range of dental specialties. For example, studying MR's effectiveness in endodontics, orthodontics, or periodontics could help determine its versatility and scope. In oral surgery, research can be conducted involving aR implementation into procedures other than implant surgeries to see whether that results in a reduction in treatment time and/or computer usage. Another potential study could involve integrating vital signs monitoring into current HMDs to see whether that can result in a reduced treatment time and improved treatment outcomes.

Comparative studies analyzing complication rates and procedural errors in surgeries performed with and without MR or aR integration would provide valuable insights into the impact of this technology on patient outcomes. Additionally, research into the ergonomic and psychological effects of prolonged HMD use in dental settings may help determine best practices for implementation.

As technological innovation accelerates in healthcare, MR is expected to play a more prominent role in dental practice—especially among oral surgeons, who are more likely to adopt advanced procedural technologies. This study's findings indicate that IV sedation significantly increases dependence on external digital monitoring systems, even though it does not extend treatment time. This supports the hypothesis that MR HMDs could help reduce screen reliance and enhance efficiency, particularly in bone graft surgeries. Although not addressed in this study, future research should also explore whether similar benefits could be realized in non-bone graft procedures involving IV sedation.

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Patient consent statement: Informed consent was obtained from the two oral surgeons and one general dentist as well as patient consent for those involved in the data collection.

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