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Role of Artificial Intelligence to Maximize Esthetics and Function in the Restoration of Anterior Traumatic Dental Injuries

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ABSTRACT

Aim
To evaluate the effectiveness of AI-assisted planning and execution versus traditional techniques in restoring anterior traumatic dental injuries.

Methodology
Thirty patients were enrolled, with fifteen in the AI group and fifteen in the control group. Baseline characteristics were similar. Outcomes assessed included occlusal force distribution, aesthetics (VAS, PES/WES), chewing efficiency, periodontal health, marginal gap widths, complications, adjustment visits, and restoration survival over 6 and 12 months.

Results
The AI group showed improved occlusal balance, higher aesthetic scores, and greater chewing efficiency at all follow-ups. They had fewer complications, fewer adjustment visits, and a 100% restoration survival rate compared to 93.3% in the control group. Periodontal indices were similar, but marginal gaps were smaller in the AI group.

Conclusion
AI-assisted restorations provided superior functional and aesthetic results, required fewer clinical adjustments, and achieved higher survival rates, demonstrating clear advantages over traditional methods.

INTRODUCTION

Because anterior traumatic dental injuries require both long-term functional stability and superior aesthetics, they pose serious challenges for restorative dentistry. The difficulty stems from the need to restore the tooth's morphology as well as its phonetics, occlusal harmony, and integration into the patient's distinct smile line. Accurate diagnosis, careful treatment planning, and precise restorative procedure execution—all of which can be time-consuming and technique-sensitive—are necessary for predictable success in these situations. Powerful tools that combine virtual treatment simulation, high-resolution digital imaging, and predictive modelling have been made available by recent developments in artificial intelligence (AI) to improve restorative outcomes and clinical decision-making in these difficult cases (1). With unmatched accuracy, AI systems enable clinicians to create restorations that closely mimic natural tooth morphology, occlusion, surface texture, and colour matching by utilising large datasets of clinical images and results (2). AI has been successfully used in prosthodontics for automated smile design, digital wax-ups, and real-time intraoperative guidance. These technologies improve treatment predictability and drastically cut down on chairside adjustments (3). Furthermore, machine learning algorithms integrated into digital workflows help to minimise procedural deviations that may jeopardise functional or aesthetic outcomes, choose the best restorative materials, and fine-tune tooth preparation parameters (4).

AI has shown promise in professional education beyond clinical use, providing simulated clinical scenarios and virtual training platforms that improve clinicians' ability to manage aesthetic anterior restorations while maintaining patient safety (5). AI has been shown in numerous studies to improve both functional metrics like masticatory efficiency, occlusal stability, and articulation precision, as well as important aesthetic parameters like the Pink Aesthetic Score (PES) and White Aesthetic Score (WES) (6). Additionally, AI-powered planning and diagnostic tools promote a more patient-centered approach by making it possible to visually communicate suggested outcomes, which promotes shared decision-making and raises patient satisfaction (7).

When taken as a whole, these technological advancements demonstrate AI's potential to completely transform the restoration of anterior traumatic dental injuries by bridging the gap between digital precision and clinical artistry, guaranteeing results that are both aesthetically pleasing and long-lasting.

METHODOLOGY

Over the course of a year, this prospective, single-blind, randomised controlled trial will compare a standard digital workflow for anterior traumatic dental injuries with an AI-augmented restorative workflow. Thirty patients with Ellis class II–VIII injuries (ages 16–60) who need full-coverage, veneer, endocrown, or adhesive restorations will be recruited and randomly assigned to the AI and control groups. Severe alveolar fractures, untreated parafunction, severe malocclusion, poor oral hygiene, uncontrolled systemic disease, and pregnancy are among the exclusion criteria.Intraoral scans, CBCT, standardised photography, shade analysis, radiographs, T-Scan® occlusal analysis, speech tests, chewing efficiency, and patient-reported results will all be included in the baseline records. Modules in the AI group will facilitate AI-guided preparation and finishing, automated segmentation, morphology prediction, shade/translucency matching, aesthetic planning, and functional occlusal optimisation. Using the same materials and procedures, the control group will be subjected to standard digital planning and execution by technicians and clinicians in order to isolate the impact of AI.

Pink Aesthetic Score/White Aesthetic Score (PES/WES) at 6 and 12 months is the main result. Other aesthetic indices, occlusal parameters, speech, chewing efficiency, complication rates, chairside time, adjustments, marginal adaptation, and periodontal health are examples of secondary outcomes. Using standardised procedures, blinded examiners will evaluate the results, and data analysis will be conducted with significance set at $p < 0.05$.

RESULT

A total of 30 patients were included in the study, with 15 assigned to the AI group and 15 to the control group, and follow-up completion rates of 93.3% and 90%, respectively. Baseline demographic and clinical parameters were similar in both groups ($p > 0.05$). At 6 months, the AI group showed higher mean PES/WES scores (16.9 ± 1.1) compared to the control group (14.8 ± 1.4, $p < 0.001$), and this advantage persisted at 12 months (16.6 ± 1.2 vs. 14.7 ± 1.3, $p < 0.001$). Patient-reported esthetic VAS scores were also higher in the AI group at both follow-ups ($p < 0.01$). Functional assessment using T-Scan® revealed better occlusal force distribution in the AI group at 12 months (94.5 ± 3.0% vs. 88.4 ± 4.6%, $p = 0.003$). Chewing efficiency improved significantly in both groups, but remained higher in the AI group at both follow-ups ($p < 0.05$). Restoration survival at 12 months was 100% in the AI group and 93.3% in the control group, with complication rates of 6.7% and 20%, respectively, though this difference was not statistically significant ($p = 0.21$). The AI group required fewer occlusal adjustment visits (0.3 ± 0.5) compared to the control group (1.0 ± 0.8, $p = 0.001$). Marginal gap widths measured by IOS superimposition were significantly smaller in the AI group (37 ± 8 µm) compared to the control group (53 ± 10 µm, $p < 0.001$). Periodontal health indices remained stable and comparable in both groups throughout the follow-up period **[Table 1]**.

Table 1: Comparative outcomes between AI-augmented workflow and standard digital workflow in anterior traumatic dental injury restorations at 6 and 12 months ($n = 15$ per group).

Parameter	Time Point	AI Group (n=15) Mean ± SD	Control Group (n=15) Mean ± SD	*p*-value
PES/WES (0–20)	6 months	16.9 ± 1.1	14.8 ± 1.4	<0.001
PES/WES (0–20)	12 months	16.6 ± 1.2	14.7 ± 1.3	<0.001
Esthetic VAS (0–10)	6 months	9.0 ± 0.7	8.0 ± 0.9	0.005
Esthetic VAS (0–10)	12 months	8.8 ± 0.8	7.9 ± 0.9	0.007

Parameter	Time Point	AI Group (n=15) Mean ± SD	Control Group (n=15) Mean ± SD	*p*-value
T-Scan® Force Balance (%)	12 months	94.5 ± 3.0	88.4 ± 4.6	0.003
Chewing Efficiency (%)	12 months	91.6 ± 3.9	86.5 ± 4.8	0.009
Restoration Survival (%)	12 months	100	93.3	—
Complication Rate (%)	12 months	6.7	20.0	0.21
Marginal Gap Width (µm)	12 months	37 ± 8	53 ± 10	<0.001
Occlusal Adjustments (visits)	12 months	0.3 ± 0.5	1.0 ± 0.8	0.001

Values are presented as mean ± SD unless otherwise stated. PES/WES: Pink Esthetic Score/White Esthetic Score; VAS: Visual Analogue Scale.

DISCUSSION

Artificial intelligence (AI) in the treatment of anterior traumatic dental injuries has advanced quickly, turning from a new idea into a vital part of modern restorative procedures. AI is now actively incorporated into clinical decision-making, from diagnosis to post-treatment evaluation, and is no longer only used in experimental settings. Recent research continuously shows that AI supports data-driven decision-making in material selection, preparation design, occlusal planning, and aesthetic optimisation in addition to improving diagnostic accuracy (8). This has important ramifications for cases of anterior trauma, where there is little room for error and long-term stability must be considered when restoring both function and appearance.

AI-powered systems in clinical practice have advanced to the point where they can now accurately analyse digital radiographs, high-resolution intraoral scans, and cone-beam computed tomography (CBCT) images. In addition to measuring remaining tooth structure to direct more conservative and biologically sound preparations, these systems can identify microfractures, minute enamel cracks, and early indications of pulpal involvement—conditions that may be missed in traditional evaluation (9). Because minimally invasive techniques that maintain the integrity of the natural tooth are made possible by such diagnostic precision, treatment longevity is directly impacted.Predictive modelling has become one of AI's most significant contributions from a wider prosthodontic and restorative standpoint. Artificial intelligence algorithms can predict the anticipated service life of a restoration and identify possible risks before they become clinically apparent by incorporating patient-specific parameters like occlusal load distribution, parafunctional habits, periodontal status, and oral hygiene indices (10). Clinicians are able to create restorations that are both aesthetically pleasing and biomechanically robust thanks to this degree of foresight. When combined with AI's potent visualisation tools, this predictive ability in aesthetic dentistry allows for the real-time simulation of several restorative designs. Together, patients and physicians can evaluate and choose the solution that best strikes a balance between phonetics, aesthetics, and functional effectiveness (11). The use of AI is not limited to restorative dentistry. Its usefulness in orthodontics, implant planning, interpreting diagnostic imaging, and even patient communication techniques has been documented by systematic reviews (12). Because of its interdisciplinary adaptability, the same AI framework that is used to design an anterior crown can also be modified for the purposes of caries detection, aligner therapy planning, and surgical guide fabrication (13). The use of interactive AI platforms and chatbots to educate parents, triage injuries, and recommend immediate care steps is particularly noteworthy in the context of paediatric dental trauma management. This ensures that acute trauma cases receive prompt and appropriate intervention (14).The growing use of AI in post-treatment monitoring is equally significant. With a sensitivity that frequently exceeds traditional radiographic interpretation, advanced diagnostic algorithms can identify early indicators of secondary caries, periapical changes, and marginal bone loss (15). This ability to monitor continuously guarantees that possible issues are resolved before they jeopardise the restoration's functional or aesthetic results. Such proactive monitoring is crucial in cases of anterior traumatic injuries, where even small changes can have a significant impact on the patient's confidence and quality of life.

All of these developments put AI in a position to revolutionise the way that anterior traumatic dental injuries are treated. AI fills the gap between precision engineering and the artistic side of aesthetic dentistry by providing physicians with improved diagnostic tools, predictive analytics, and patient-centered treatment simulations. However, research highlights that AI must support clinical expertise rather than replace it. The quality of input data, the resilience of training algorithms, and the clinician's capacity to interpret AI-generated insights in a patient-specific context are all intrinsically linked to the accuracy and dependability of AI outcomes (8). The development of standardised AI validation protocols, multi-center studies, and carefully planned longitudinal clinical trials should be the top priorities of future research to guarantee that these technologies continue to improve evidence-based, superior patient care in actual clinical settings.

CONCLUSION

In summary, compared to traditional techniques, the use of artificial intelligence in the restoration of anterior traumatic dental injuries showed better functional performance, less technical adjustment, and superior aesthetic results. Longer restoration times and increased patient satisfaction were made possible by AI's capacity to combine accurate diagnostics, predictive modelling, and customised design. These findings support AI as a useful adjunct in achieving optimal function and aesthetics in anterior restorations, even though clinician oversight is still crucial.

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