Keywords
Lifestyle Artificial intelligence; Implant dentistry; Prosthodontics; Digital rehabilitation; Implant-supported restorations

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Keywords: Alveolar ridge dimensions; Complete dentures; Edentulous residual ridge; Maximum mouth opening; Oral morphometry; Prosthodontics.

Received: 11 03 2026
Revised: 13.04.2026
Accepted: 19.05.2026

Doi:10.1922/ejprd.v34i1s.1369

Artificial Intelligence-Driven Prosthetic Rehabilitation in Partially Edentulous Patients: Long-Term Clinical Assessment of Implant-Supported Restorations

Abstract

In the fields of prosthodontics, implant dentistry, and oral surgery, artificial intelligence (AI) has become a game-changing tool that enhances digital treatment planning, diagnostic accuracy, and restorative rehabilitation results. However, evidence regarding the long-term clinical effectiveness of AI-assisted implant-supported prosthetic rehabilitation remains limited. The present investigation aimed to assess the long-term clinical outcomes, implant survival, prosthetic performance, and patient satisfaction associated with AI-assisted implant-supported prosthetic rehabilitation in partially edentulous patients. A retrospective clinical study was conducted on 80 partially edentulous patients who underwent AI-assisted implant-supported prosthetic rehabilitation. Clinical and radiographic records collected over a follow-up duration of 5–7 years were analyzed. The rehabilitation workflow incorporated AI-based CBCT analysis, digital implant planning, machine learning-assisted prosthetic design, and AI-supported occlusal adjustment. Clinical variables, prosthetic complications, peri-implant tissue conditions, and patient-centered outcomes were evaluated. The implant survival rate observed during the follow-up period was 95.0%. Mean marginal bone loss was 0.86 ± 0.35 mm, while the mean occlusal stability score was 8.64 ± 0.93. Most patients demonstrated no major prosthetic complications and reported high esthetic and functional satisfaction. The mean AI predictive accuracy score was 91.67 ± 4.49%, indicating favorable agreement between AI-assisted planning and clinical outcomes. AI-assisted implant-supported prosthetic rehabilitation demonstrated favorable long-term clinical outcomes, high restorative predictability, and satisfactory patient-centered rehabilitation, supporting the growing role of AI-driven digital workflows in modern prosthodontics.

Keywords: Artificial intelligence; Implant dentistry; Prosthodontics; Digital rehabilitation; Implant-supported restorations

1. INTRODUCTION

Partial edentulism is still a considerable oral health problem all over the world that has an impact on mastication, phonetics, facial esthetics and quality of life. One of the most predictable and reliable treatment options available for the reconstruction of oral function and esthetics for the partially dentate patient has been implanted prosthetic rehabilitation. In traditional prosthodontic rehabilitation, however, there are several clinical challenges such as inaccuracies in implant positioning, occlusal discrepancies, prosthetic misfit, peri-implant complications, esthetic limitations and long-term maintenance issues.1 As the complexity of implant-supported restorations has evolved, so too have the advanced digital and computational technologies that have been developed to increase the precision of the treatment and clinical results.

In recent years, the domain of oral surgery, implant dentistry and prosthodontics has been revolutionized with the inclusion of AI-based data-driven solutions to diagnosis, treatment planning and restorative rehabilitation.

2 AI systems can process great expanses of clinical information and detect patterns to support clinical decision making based on clinical evidence. AI has played a pivotal role in the efficiencies, predictability and reduction of operator dependent variables in the field of prosthetics.

3 Moreover, AI-powered planning software, guided surgical procedures, and digital convergence have been introduced into the field of digital implantology, which further enhances the accuracy of implant positioning and restorative precision.

4 AI has demonstrated a lot of potential in the area of implant prosthodontics, particularly in occlusal analysis and adjustment. Virtual occlusal system with artificial intelligence (AI) has been found to improve both the trueness of occlusal contact and the prostheses adaptation, reducing mechanical complications of the implant restorations.

5 Additionally, digital diagnostic imaging technologies like cone-beam computed tomography (CBCT) have also been enormously helped by the integration of AI. Automated image interpretation and radiographic assessment enables accurate image visualization of anatomic structures, implant positioning and peri-implant bone assessment.

6 These developments could help to increase implant longevity and decrease the incidence of complications following implant surgery in challenging restorative situations.

7 AI-powered tools for patient-centered communication, such as chatbots and virtual assistants, are growing more prevalent in clinical settings. In the realm of implant dentistry, patient education and engagement are greatly assisted by the use of AI-powered information platforms and intelligent chatbot systems, which are becoming more widely used in this field.

8 In the field of implant dentistry, deep learning models are used to automatically segment and analyze CBCT scans, as well as to improve the consistency of diagnosis and surgical planning, while also improving the accuracy of automated CBCT image segmentation and analysis.

9 All of these technological advances suggest that AI has the power to transform implant-supported prosthetic rehabilitation with greater precision, efficiency, and personalized care.

Although there has been significant advancement in AI in the field of dentistry, critical investigation is needed on the long-term clinical outcomes of AI-assisted prosthetic rehabilitation. Most of the current applications of digital technologies have been diagnostic, facial analysis and anthropometric studies, but not on sustained restorative outcome in partially edentulous patients.10 Furthermore, most of the existing literature focuses on demonstrations of technology or innovations presented at conferences, and there is limited evidence on clinical utility and sustainability of innovations.

11 With the increasing use of intraoral scanners, digital workflows and AI-assisted restorative systems, the efficiency of the procedures is enhanced, but thorough retrospective data analyses that relate these technologies to implant survival and long-term prosthetic success are still limited.

12 Most of the existing literature focuses on the overall application of AI in dentistry and does not specifically address the use of AI in implant supported rehabilitation in clinical practice.

13 Furthermore, although preliminary results of esthetic rehabilitation guided by AI have been encouraging, the long-term peri-implant tissue stability, prosthetic complications and patient satisfaction after the integration of AI in the restorative workflow are still not well documented or revealed.

14 AI technology in implant dentistry and prosthodontics are rapidly advancing, and there is a need to validate these technologies clinically and use evidence-based methodology to establish the practical value and reliability of these technologies. A recent narrative review noted there are major gaps in innovation and a need for clinically relevant studies looking at the performance of AI-enabled prosthetic rehabilitation systems.

15 Likewise, systematic studies of the use of AI in prosthodontics have shown significant promise in treatment planning, prosthetic fabrication, and restorative accuracy, but there is a lack of long-term clinical evidence.

16 AI in prosthodontics has also seen a significant rise in scientific and clinical research, as evidenced by the bibliometric analyses, which showed high levels of research into intelligent restorative technologies over the last 10 years.

17 This transition from the usual rehabilitation methods to smart, data-driven solutions for restoring systems is a paradigm shift in modern dentistry,

emphasizing precision, personalization and predictive care models.

18 Thus, the present retrospective study aimed to investigate the long-term clinical performance, implant survival, prosthetic outcomes, and patients satisfaction of AI-assisted implant-supported prosthetic rehabilitation in partially edentulous patients.

Research Objectives

1. To evaluate the long-term clinical performance of AI-assisted implant-supported prosthetic rehabilitation in partially edentulous patients.
2. To assess implant survival rate, prosthetic complications, and peri-implant tissue health following AI-driven rehabilitation planning.
3. To analyze patient satisfaction, esthetic outcomes, and treatment predictability associated with AI-assisted restorative workflows.

2. METHODOLOGY

2.1 Study Design

The present investigation aimed to conduct a retrospective clinical study to assess the long-term results of implant-supported prosthetic rehabilitation with AI assistance in partially edentulous patients. The clinical and radiographic records were reviewed retrospectively, evaluating implant survival, the performance of the prostheses, the health of the peri-implant tissues and the rehabilitation outcomes from the patient's perspective.

2.2 Study Setting

The study was conducted in a tertiary dental care facility's Department of Prosthodontics and Implant Dentistry, which had digital implantology and AI-assisted restorative planning systems. Patient records were retrieved from patient records over a follow-up period of 5–7 years.

2.3 Sample Size

The study included 80 partially edentulous patients who had been treated with implant-supported prosthetic rehabilitation in a digitally planned workflow supported by AI. The cases selected met all the inclusion criteria and were well documented with clinical and radiographic data.

2.4 Eligibility Criteria

The study included patients aged 25 to 70 years with an edentulous situation ranging from partial edentulism. Patients with full clinical and radiographic records and at least 3-year follow-up period were only considered for inclusion. Systemic diseases that had an impact on bone healing, severe bruxism, smoking habits, uncontrolled periodontal disease, implant failure due to trauma and non-compliance, incomplete documentation were excluded from the study.

2.5 AI-Assisted Rehabilitation Workflow

The rehabilitation workflow included AI-enabled CBCT image analysis, digital implant planning software, machine learning-driven prosthetic design, AI-driven occlusal adjustments, and predictive analysis for implant stability and prosthetic success. Digital restorative workflows were used to enhance the precision of treatment, the fitting of prosthetics and clinical predictability.

2.6 Data Collection Parameters

Demographic data and clinical data such as Prosthetic problems, occlusal stability, peri-implant tissue condition, marginal bone loss, implant survival rate, and prosthesis longevity were gathered. Other patient-centered outcomes such as esthetic satisfaction, functional satisfaction and quality of life improvement also were assessed.

2.7 Outcome Measures

Implant existence and the achievement rate of prosthetics were the main outcome measures. Secondary outcome measures were patient satisfaction, accuracy of the AI, decrease of prosthetic complications, peri-implant tissue stability and long-term functional rehabilitation results.

2.8 Statistical Analysis

Data collected were tabulated in MS Excel. Demographic and clinical data were summarized using descriptive statistics. Clinical outcome was evaluated and compared and Kaplan–Meier survival analysis was utilized to determine long-term implant survival probability. All analyses were performed, and a p-value <0.05 was deemed statistically substantial.

3. 3. RESULTS

3.1 Demographic Profile of the Study Population

Of the 80 partially edentulous patient who received an implant-supported prosthetic rehabilitation, 80 were selected for this retrospective study using AI assistance. The study population consisted of 51.3% male and 48.7% female patients. Most participants were in the 56-70 years age group, tailed by the 25-40 years age group (31.2%). The 5-6 year follow-up duration (43.8%) showed that most patients were clinically well evaluated over a long time with adequate implant-supported restorations (Table 1).

Table 1. Demographic Features (n = 80)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	41	51.3
	Female	39	48.7
Age Group (Years)	25-40	25	31.2
	41-55	23	28.7
	56-70	32	40.0
Follow-Up Duration (Years)	3-4	31	38.8
	5-6	35	43.8
	7	14	17.5

3.2 Long-Term Implant and Peri-Implant Outcomes

During the follow-up period, there were 4 implant failures and 76 implant-supported restoration successes, resulting in an overall implant survival rate of 95.0%. The peri-implant tissue evaluation showed that 25.0% of patients had healthy peri-implant tissue, 40.0% had mild peri-implant inflammation and 35.0% had moderate peri-implant inflammation. The results suggest good long-term survival rates and satisfactory stability of the peri-implant tissues after AI-based rehabilitation (Table 2).

Table 2. Implant Survival and Peri-Implant Tissue Outcomes of AI-Assisted Implant Rehabilitation

Clinical Outcome	Category	Frequency (n)	Percentage (%)
Implant Survival Outcome	Successful implants	76	95.0
	Implant failures	4	5.0
Peri-Implant Tissue Condition	Healthy	20	25.0
	Mild inflammation	32	40.0
	Moderate inflammation	28	35.0

The results of the implant survival and peri-implant tissue conditions are shown in Figure 1 over the follow-up period after AI-assisted implant-supported rehabilitation.

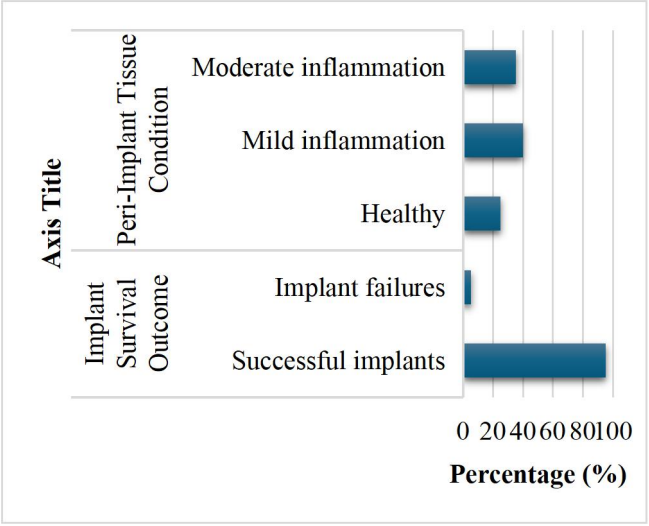

Figure 1. Implant Survival and Peri-Implant Tissue Outcomes

At long term clinical follow-up, as shown in Figure 1, the clinical outcome of the implants was found to be good, with the peri-implant tissue health being maintained.

3.2 Quantitative Clinical Performance Indicators

The quantitative clinical results showed a mean marginal bone loss of 0.86 ± 0.35 mm. Mean occlusal stability score was 8.64 ± 0.93, and the mean prosthesis longevity was 5.25 ± 1.09 years (Table 3). The results showed that the long-term function of the prosthesis was preserved and the performance of the restorations was satisfactory after the implant rehabilitation with the aid of AI.

Table 3. Quantitative Clinical Outcomes of AI-Assisted Implant Rehabilitation

Clinical Parameter	Mean ± SD
Marginal bone loss (mm)	0.86 ± 0.35
Occlusal stability score	8.64 ± 0.93
Prosthesis longevity (years)	5.25 ± 1.09

3.3 Distribution of Prosthetic Complications

The assessment of the prosthetic complications showed that most of the patients (75.0%) had no complications during the follow-up period. Screw loosening and prosthetic chipping occurred in 10.0% and 5.0% of the patients, respectively, while occlusal problems were diagnosed in 5.0% of the subjects (Table 4). The low complication rate is due to the success of the AI-aided restorative planning process and occlusal optimization.

Table 4. Distribution of Prosthetic Complications

Prosthetic Complication	Frequency (n)	Percentage (%)
No complication	60	75.0
Screw loosening	8	10.0
Chipping	8	10.0
Occlusal issue	4	5.0

Figure 2 displays the distribution of complications of the prosthesis during follow-up. Most of the patients achieved complication-free implant-supported restorations after the AI-assisted prosthetic rehabilitation

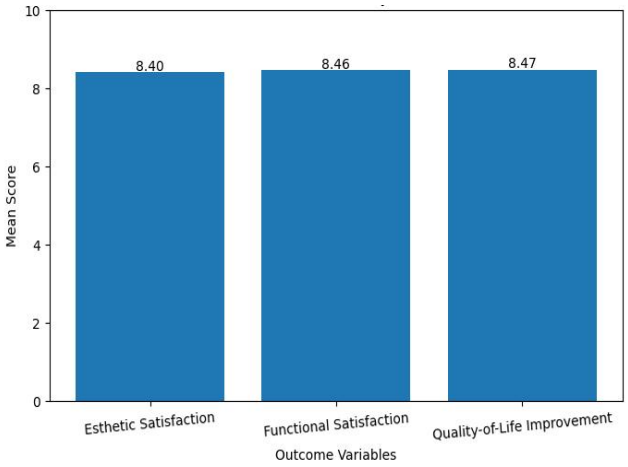

Figure 3. Patient Satisfaction and Quality-of-Life Outcomes

The figure shows positive patient-reported outcomes: There is satisfactory esthetic appearance, functional efficiency, and overall improvement in the quality of life associated with oral health during dental rehabilitation.

3.6 Predictive Performance of AI-Assisted Rehabilitation

The implant planning and restorative rehabilitation process with the aid of the AI assisted digital workflow showed excellent predictive performance. The mean AI predictive accuracy score was 91.67 ± 4.49%, which represents a strong agreement between AI treatment planning and clinical outcomes. The results validate the clinical validity and accuracy of AI-powered restorative workflows in implant prosthodontics.

3.7 Comparative Outcome Assessment Across Clinical Variables

The clinical outcome of the implants was not significantly different between the genders (p = 1.000) (Table 6). Likewise, there was no statistically substantial alteration in marginal bone loss between males and females, and male and female patients had similar treatment outcomes.

Table 6. Comparative Evaluation of Clinical Outcomes

Variables Compared	p-value	Interpretation
Gender vs Implant survival	1.000	Not significant
Gender vs Marginal bone loss	0.186	Not significant

3.8 Survival Probability During Follow-Up Period

The Kaplan–Meier survival analysis showed good long-term implant survival during the follow-up period. After the observational period, the probability of implant survival was always high, confirming the long-term efficacy and reliability of implant-supported prosthetic rehabilitation with the use of AI in the handling of partially edentulous patients.

4. DISCUSSION

The present retrospective clinical study aimed to measure the long-term results of implant-supported prosthetic rehabilitation for partially edentulous patients, assisted by AI. The results showed promising results for implant survival, peri-implant tissue health, minimal prosthetic complications, and high patient satisfaction after using AI-driven restorative workflows. The high implant survival rate of 95.0% in this study implies that the incorporation of AI into implant planning and prosthetic rehabilitation has the potential to enhance the precision of treatment and its lasting results. Further, the mean marginal bone loss was small and the mean occlusal stability score was high, suggesting a satisfactory functional adaptation and peri-implant maintenance during follow-up period.

The findings also revealed that most of the patients did not have any significant complications with the prostheses during the long term follow up. One of the reasons for the relatively low incidence of screw loosening, prosthetic chipping, and occlusal problems might be explained by the accuracy of the implant positioning techniques combined with the optimization of prosthetics and occlusal adjustments techniques, made possible by AI. The high patient-reported satisfaction scores indicate that AI-supported restorative rehabilitation can positively impact patient-focused treatment outcomes with respect to esthetics, functionality, and quality of life improvements. The high AI predictive accuracy found in the present study is further evidence of the reliability of AI-driven digital workflows in implant prosthodontics.

The results of the present study are in line with previous articles which have emphasized the increasing importance of AI in prosthodontics and rehabilitative dentistry. According to Koul et al., treatment planning accuracy, predictability of the restorative treatment and workflow efficiency are enhanced with the use of AI-based prosthodontic systems in the treatment of implant rehabilitation.19 Likewise, Nulty showed that using AI for esthetic rehabilitation technologies can help enhance the smile symmetry, precision of restorations, and digital treatment customization in edentulous patients.20 These observations corroborate the good esthetic and functional results achieved in the present investigation.

Biomechanical studies focusing on the importance of digital computation in the field of restorative rehabilitation have also been included in the current findings. Zhu et al. concluded that using advanced biomechanical modeling and finite element analysis can enhance the long-term prosthesis stability and load distribution in the removable partial denture rehabilitation process.21 The results of the current study, however, were based on implant-supported restorations, but the increase in longevity of the restorations and the lower problem rates could be similar for restorations that were planned with the help of AI to obtain optimum biomechanical conditions.

Moreover, the current results are congruent with recent studies that have shown the clinical effectiveness of AI decision support tools in implant dentistry. Gönüldaş et al. showed that AI systems can make decisions in implant planning similar to the clinical human

experience, which could lead to better consistency in treatment and minimize the operator-dependent differences in it.22 The ability of AI to predict with high accuracy like in the present study validates the increasing trustworthiness of AI-assisted restorative workflows in clinical implantology.

In the literature, there are also other examples of integration of AI systems into patient communication platforms. AI-powered chatbot systems showed great potential for providing implant dentistry information and enhancing patient interaction, Akpınar said.23 This study did not directly investigate patient communication, but the positive patient satisfaction scores identified may be linked to improved understanding of treatment and/or an AI-assisted patient treatment workflow.

The current research has tremendous implications for today's prosthodontics and implant dentistry. These rehabilitation workflows can foster improved diagnostic accuracy, treatment outcomes, prosthetics fitting, and long term rehabilitation results, with less complications along the way. As AI continues to evolve and advance in digital implantology, it holds the potential to further revolutionize restorative care and support individualized treatment planning, as well as improve interdisciplinary collaboration. In the future, these technologies could help to create more effective, data-driven, less invasive rehabilitation approaches in restorative dentistry.

While the results were promising, there were some limitations that need to be taken into account. The retrospective design might also suffer from selection bias and have restricted causal inference capabilities regarding the relationship of workflows supported by AI and clinical outcomes. The study's single-center design and rather small sample size may potentially restrict how far the results may be applied. Furthermore, the outcomes and predictive ability of AI software systems, the experience of the clinicians, and the protocols for restoring the treatment may also affect treatment outcomes and predictive ability. There is no conventional (non-AI) control group, which further restricts the ability to compare against it directly.

Future research is recommended to conduct prospective multicenter studies on a large scale to monitor long-term clinical outcomes of the use of AI support in implant rehabilitation versus traditional methods for implant rehabilitation. Continued efforts in other areas such as prognostic systems leveraging deep learning, robotic implant surgery, augmented reality rehabilitation, and AI-integrated digital twins could yield other perspectives on the future of intelligent prosthodontic treatment. Standardized protocols for using AI and the incorporation of real-time predictive analytics can further improve precision, efficiency and personalisation in implant-supported prosthetic rehabilitation.

5. CONCLUSION

The current retrospective clinical study showed that long-term clinical and functional results of implant-supported prosthetic rehabilitation are favorable using the aid of AI. The results showed excellent implant survival rates, good peri-implant tissue conditions, no significant prosthetic complications and satisfactory restorative performance during the study period. Qualitative clinical data like marginal bone loss, occlusal stability, implant prosthesis longevity, and quantitative clinical parameters were also used to validate the effectiveness and reliability of using AI in implant restorative workflows. Esthetic satisfaction was also high as were functional improvement and oral health-related quality of life following rehabilitation, as shown by patient-centered outcomes. AI's ability to accurately predict treatment outcomes showed high interagreement between AI-driven treatment plans and clinical outcomes, indicating the potential of AI to improve the accuracy of treatment and restoration results. Using AI technologies in implant dentistry could revolutionize the treatment planning process, the design and adaptation of prostheses, and the patient's rehabilitation over time; it would also reduce operator-dependent variability and risks of procedure-related complications. The findings highlight the clinical importance of AI-driven smartly designed restorative systems in today's prosthodontics and restorative dentistry. While a few caveats are present because of the retrospective study design and small sample size, the present study is a great prospect for a paradigm shift in implant supported prosthetic rehabilitation by precision, patient-centred and digitally optimised approaches. Future prospective multicenter studies are recommended to confirm these results and create standard clinical practices of using AI in restorative practice in the future.

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