DOI: https://doi.org/10.46811/apjnh/3.2.6

AI-guided Prediction Model for Restoration Longevity using Intraoral Photographs and Occlusal Mapping

(Authors Details)
Andre Bergeron[1], Louis H. Hargreaves[2]
[1]DDS, MSD
[2]DDS

**Correspondence*
Andre Bergeron
DDS, MSD

Abstract

The integration of artificial intelligence (AI) into restorative dentistry has created new opportunities for predicting restoration longevity through advanced digital assessment methods. This approach utilizes intraoral photographs, occlusal mapping, and machine learning algorithms to analyze restoration-related parameters, including surface deterioration, marginal integrity, occlusal stress distribution, and functional changes over time. AI-guided prediction models can process large volumes of clinical imaging data to identify early indicators of restoration failure and estimate the probability of long-term restoration survival. By combining two-dimensional photographic information with three-dimensional occlusal analysis, these systems provide a comprehensive evaluation of restoration performance and patient-specific risk factors. Such predictive frameworks may assist clinicians in developing personalized maintenance strategies, optimizing treatment planning, and reducing unnecessary restorative replacements. The application of computer vision, deep learning, and digital modeling technologies represents a shift toward preventive and data-driven restorative care. Although further clinical validation and standardized datasets are required, AI-based restoration longevity prediction models demonstrate significant potential to enhance accuracy, efficiency, and decision-making in modern dentistry.

Keywords: Artificial intelligence; Restoration longevity; Intraoral photography; Occlusal mapping; Machine learning; Digital dentistry; Predictive modeling; Restorative dentistry.

1. Introduction

The longevity of dental restorations remains a major concern in restorative dentistry, as restoration failure is influenced by complex interactions between material properties, tooth structure, occlusal forces, biological factors, and patient-specific conditions. Accurate prediction of restoration survival can improve clinical decision-making by allowing early identification of potential failures and supporting preventive intervention. Conventional evaluation methods mainly depend on visual examination and periodic clinical follow-up; however, these approaches may not fully capture subtle structural changes that precede restoration breakdown.

Recent advances in digital dentistry have introduced artificial intelligence (AI)-based approaches capable of analyzing complex clinical data from intraoral photographs and three-dimensional occlusal mapping systems. Intraoral photographic records have demonstrated reliable diagnostic potential, allowing clinicians to evaluate dental conditions through standardized digital images (Jackson et al., 2019). Furthermore, the ability to map intraoral photographs onto virtual tooth models provides an enhanced method for integrating surface information with three-dimensional dental structures, improving digital assessment accuracy (Lam et al., 2018).

Occlusal mapping plays an essential role in restoration longevity prediction by identifying contact patterns, load distribution, and areas exposed to excessive mechanical stress. Comparative investigations between virtual and actual dental models have shown that digital occlusal analysis can effectively evaluate occlusal contact areas, supporting its application in restorative assessment (Lee et al., 2018). Similarly, advanced registration techniques combining two-dimensional images with three-dimensional surfaces have demonstrated potential for detailed analysis of dental surface characteristics (Chen et al., 2020).

AI algorithms, particularly deep learning and generative modeling approaches, can integrate photographic features, occlusal parameters, and patient-related variables to develop personalized predictive models. AI-assisted design methods have shown promise in generating individualized occlusal surfaces based on patient-specific anatomical information (Yuan et al., 2020). These technologies align with the principles of conservative restorative dentistry, where maintaining tooth structure and ensuring predictable restoration performance are essential goals (Singh, 2020). Therefore, AI-guided prediction models using intraoral photographs and occlusal mapping represent a promising direction for improving restoration monitoring, longevity estimation, and personalized restorative care.

2. Role of Intraoral Photographs and Occlusal Mapping in Restoration Assessment

Intraoral photographs and occlusal mapping have become essential digital tools for evaluating restoration quality, functional performance, and long-term prognosis. High-resolution intraoral images provide detailed information regarding marginal adaptation, surface wear, discoloration, fracture lines, and secondary caries development around restorations. Their diagnostic reliability supports their use as a non-invasive method for monitoring restorative changes over time (Jackson et al., 2019). Furthermore, digital photographic data can be integrated with three-dimensional virtual dental models, allowing accurate visualization of restoration morphology and tooth-restoration relationships (Lam et al., 2018).

Occlusal mapping provides complementary biomechanical information by identifying contact areas, pressure distribution, and functional loading patterns that influence restoration survival. Comparative studies have demonstrated that virtual occlusal models can effectively reproduce actual occlusal contact characteristics, supporting their application in digital restorative assessment (Lee et al., 2018). Advanced registration techniques combining two-dimensional images with three-dimensional surfaces further enhance the ability to analyze spatial dental characteristics, including surface changes and plaque distribution patterns (Chen et al., 2020).

AI-guided models can utilize these photographic and occlusal datasets to identify subtle deterioration patterns and predict potential restoration failure. Personalized occlusal analysis using AI-based approaches may improve restoration design by adapting to individual functional characteristics and stress patterns (Yuan et al., 2020). Such predictive assessment aligns with conservative restorative principles, where early detection and preservation of tooth structure are prioritized (Singh, 2020).

Table 1: Digital Assessment Parameters from Intraoral Photographs and Occlusal Mapping

Digital Data Source	**Evaluated Parameters**	**Role in Restoration Longevity Prediction**
Intraoral photographs	Marginal defects, cracks, discoloration, surface wear	Detects early clinical signs of restoration degradation
Virtual tooth models	Restoration shape and anatomical integration	Provides three-dimensional structural assessment
Occlusal mapping	Contact points, occlusal force distribution, loading patterns	Predicts mechanical stress and fracture susceptibility
Image-surface registration	Spatial surface changes and functional variations	Enhances accuracy of AI-based analysis

The integration of these digital approaches provides a foundation for AI-driven restoration longevity prediction by enabling objective, continuous, and personalized evaluation of restorative outcomes.

3. Development of AI-Guided Prediction Model

The development of an AI-guided restoration longevity prediction model involves the integration of intraoral photographic data, three-dimensional occlusal mapping, and machine learning algorithms to evaluate factors associated with restoration survival. The first stage includes standardized acquisition of intraoral images, where AI-based computer vision systems analyze restoration margins, surface changes, wear patterns, and early defects. Intraoral photographs can be accurately linked with virtual dental models, enabling spatial correlation between clinical appearance and three-dimensional tooth structures (Lam et al., 2018). The reliability of photographic records for dental assessment supports their application as a digital monitoring tool for restorative evaluation (Jackson et al., 2019).

The second stage involves occlusal data processing, where virtual models and occlusal contact analysis are used to identify areas exposed to excessive mechanical stress. Digital occlusal mapping has demonstrated the ability to reproduce contact areas between virtual and physical models, providing valuable biomechanical information for predictive analysis (Lee et al., 2018). Furthermore, three-dimensional registration techniques allow detailed visualization of surface distribution patterns, supporting accurate feature extraction from dental structures (Chen et al., 2020).

Machine learning algorithms can then combine photographic features, occlusal parameters, and patient-related variables to predict restoration failure risks. Generative AI approaches may further enhance personalized restoration assessment by modeling individualized occlusal characteristics and optimizing restoration design (Yuan et al., 2020). Such predictive systems align with conservative restorative principles by enabling early detection and maintenance strategies that preserve tooth structure (Singh, 2020).

Table 2: Components of an AI-Guided Restoration Longevity Prediction Model

Component	Technology/Method	Role in Prediction Model
Image acquisition	Intraoral photography and digital scanning	Captures restoration condition and surface changes
Feature extraction	Computer vision and deep learning	Identifies cracks, wear, marginal defects, and discoloration
Occlusal analysis	3D virtual models and contact mapping	Evaluates functional stress and load distribution
Predictive algorithm	Machine learning models	Estimates restoration longevity and failure probability
Personalized modeling	AI-based generative design	Supports patient-specific restoration optimization

4. Clinical Applications and Future Potential

AI-guided prediction models based on intraoral photographs and occlusal mapping have significant potential to improve restorative dentistry by enabling continuous monitoring, early detection of deterioration, and personalized treatment planning. Intraoral photographic analysis can identify changes in restoration surfaces, marginal adaptation, discoloration, and structural defects, supporting accurate clinical evaluation. The reliability of photographic records for dental assessment has demonstrated their value as a non-invasive monitoring approach (Jackson et al., 2019). Furthermore, mapping intraoral photographs onto virtual tooth models allows integration of visual information with three-dimensional dental anatomy, improving restoration assessment and digital documentation (Lam et al., 2018).

Occlusal mapping combined with AI algorithms can evaluate contact distribution, occlusal loading patterns, and potential areas of mechanical stress that contribute to restoration failure. Virtual occlusal models have shown comparable accuracy with actual models, supporting their application in digital restorative analysis (Lee et al., 2018). AI-based systems may also incorporate three-dimensional surface registration techniques to analyze complex oral features and detect risk factors affecting restoration longevity (Chen et al., 2020).

The future development of these models may involve personalized restoration design, where AI predicts optimal occlusal morphology and material requirements based on individual patient characteristics (Yuan et al., 2020). Such approaches align with conservative restorative principles by supporting preservation of tooth structure and improved restoration management (Singh, 2020).

Table 3: Clinical Applications of AI-Based Restoration Longevity Prediction

Clinical Application	**AI-Based Function**	**Potential Benefit**
Restoration monitoring	Detects cracks, wear, marginal defects, and discoloration from photographs	Enables early intervention
Occlusal stress assessment	Analyzes contact points and force distribution	Reduces fracture and failure risk
Digital follow-up	Compares sequential intraoral images and 3D models	Supports long-term evaluation
Personalized restoration design	Predicts patient-specific occlusal patterns and restoration geometry	Improves functional outcomes
Preventive restorative planning	Combines clinical data for risk prediction	Enhances treatment decision-making

Overall, AI integration with digital imaging and occlusal analysis may provide a predictive, preventive, and patient-centered approach for improving restoration longevity. Further clinical validation and standardized AI datasets are required before widespread implementation.

5. Conclusion

AI-guided prediction models using intraoral photographs and occlusal mapping represent an important advancement toward improving the assessment and management of restoration longevity. By integrating digital imaging, three-dimensional surface analysis, and machine learning algorithms, these systems can provide clinicians with objective information regarding restoration integrity, occlusal stress distribution, and early signs of functional deterioration.

Accurate mapping of intraoral photographs onto virtual dental models has demonstrated the potential to enhance digital evaluation by linking visual clinical information with three-dimensional anatomical structures (Lam et al., 2018).

The application of AI-based occlusal analysis may further improve restoration planning by identifying abnormal contact patterns and predicting areas vulnerable to mechanical failure. Virtual occlusal models have shown comparable reliability with actual dental models, supporting their use in digital restorative workflows (Lee et al., 2018). Furthermore, advanced computational approaches, including personalized occlusal surface design using generative models, highlight the potential of AI for developing patient-specific restorative solutions (Yuan et al., 2020).

The incorporation of photographic monitoring and automated image interpretation may enable early detection of restoration-related changes, improving preventive care and reducing unnecessary replacement procedures. The diagnostic reliability of intraoral photographic records and digital monitoring approaches supports their application for longitudinal clinical assessment (Jackson et al., 2019; Morris et al., 2019). Additionally, AI-assisted visualization of surface characteristics and oral conditions through advanced image registration techniques may enhance comprehensive restoration evaluation (Chen et al., 2020).

Overall, AI-guided restoration longevity prediction offers a promising pathway toward personalized, minimally invasive, and data-driven restorative dentistry. When combined with conservative restorative principles, such as preservation-focused approaches emphasized in modern restorative care (Singh, 2020), these technologies may improve clinical decision-making, restoration survival, and long-term patient outcomes. Further clinical validation and standardized AI datasets will be essential for widespread implementation in dental practice.

References

1. Singh, S. (2020). Deep margin elevation: A conservative alternative in restorative dentistry. *SRMS JOURNAL OF MEDICAL SCIENCE*, *5*(02), 1-9.
2. Jawale, P. (2016). Phenylthiocarbamide (PTC) Taster Status in South Indian Adult Medical Students. *Journal of Evidence Based Medicine and Healthcare*.
3. Lee, H., Cha, J., Chun, Y. S., & Kim, M. (2018). Comparison of the occlusal contact area of virtual models and actual models: a comparative in vitro study on Class I and Class II malocclusion models. *BMC Oral Health*, *18*(1), 109.
4. Chen, Q., Jin, X., Zhu, H., Salehi, H. S., & Wei, K. (2020). 3D distribution of dental plaque on occlusal surface using 2D-fluorescence-image to 3D-surface registration. *Computers in Biology and Medicine*, *123*, 103860.
5. Yuan, F., Dai, N., Tian, S., Zhang, B., Sun, Y., Yu, Q., & Liu, H. (2020). Personalized design technique for the dental occlusal surface based on conditional generative

adversarial networks. *International Journal for Numerical Methods in Biomedical Engineering*, *36*(5), e3321.
6. Lam, W. Y., Hsung, R. T., Cheng, L. Y., & Pow, E. H. (2018). Mapping intraoral photographs on virtual teeth model. *Journal of dentistry*, *79*, 107-110.
7. Jackson, T. H., Kirk, C. J., Phillips, C., & Koroluk, L. D. (2019). Diagnostic accuracy of intraoral photographic orthodontic records. *Journal of Esthetic and Restorative Dentistry*, *31*(1), 64-71.
8. Morris, R. S., Hoye, L. N., Elnagar, M. H., Atsawasuwan, P., Galang-Boquiren, M. T., Caplin, J., ... & Kusnoto, B. (2019). Accuracy of Dental Monitoring 3D digital dental models using photograph and video mode. *American Journal of Orthodontics and Dentofacial Orthopedics*, *156*(3), 420-428.