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AI-powered solutions for dental clinic optimization and patient engagement – project brief

Prepared for the Network of Canadian Oral Health Research (NCOHR)

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An NCOHR-supported initiative to advance Canada's oral-health innovation ecosystem

The Network for Canadian Oral Health Research (NCOHR) is proud to highlight this multidisciplinary project as an example of the transformative impact that strategic seed oral-health research funding can achieve. Supported through NCOHR's collaborative research program administered with MEDTEQ+, this initiative brought together expertise in dentistry, health informatics, behavioral science, and artificial intelligence to explore persistent challenges in patient engagement and administrative frictions in dentistry, which is rooted in misalignments and poor mapping of the patient journey to the clinic's revenue cycle.

With NCOHR funding as primary catalyst, the project team developed *smilepass*, an innovative digital platform designed to enhance oral-health literacy, strengthen patient activation, streamline administrative workflows, and improve transparency in the payment and insurance experience. This work demonstrates how evidence-based design, grounded in patient and provider perspectives, can lead to practical tools that advance oral-health outcomes across clinical settings.

NCOHR's support enabled the team to leverage national collaborations and assemble the expertise and ecosystem necessary to secure subsequent rounds of funding, including a $150,000 Ontario Centre of Innovation grant matched by a major industry sandbox partner (dentalcorp), as well as $450,000 in angel investment. These accomplishments underscore the importance of early-stage oral-health research funding in catalyzing scalable innovations that are grounded in the reality of practice, that have the potential for significant benefit to patients, providers, and the broader healthcare system.

This project exemplifies NCOHR's commitment to advancing knowledge, supporting interdisciplinary collaboration, and fostering the conditions that can support the next generation of digital solutions to improve access to and quality of oral healthcare in Canada. Developing digital tools with academic purview – subject to Research Ethics Board oversight, peer scrutiny, and the evaluative standards of major funding agencies (like Oci and MEDTEQ+) – ensures that innovation is driven by evidence, patient welfare, and methodological rigor rather than commercial incentives alone. This grounding elevates the credibility, safety, and trustworthiness of emerging technologies.

Summary

This brief showcases an innovative, multidisciplinary translational collaboration that led to the creation of AI-powered software technology – that directly integrates with commercial patient management (PMS) and point-of sale (POS) software – and that is designed to streamline administrative touchpoints directly linked to the patient's experience of care. Through evidence synthesis, stakeholder input, and iterative software development, the startup team created a digital extension of the patient journey that approximates key steps in the administrative and revenue cycle. The goal was to enhance case acceptance by promoting health literacy, cost transparency and collaborative decision making through a digital decision-aid portal. Simultaneously, a clinic-facing, AI-powered analytics dashboard was created that organized key administrative tasks by management buckets (ie. treatment plans, payment plans, accounts receivables) and embedded workflow automation in the user experience (UX). The goal was to empower the administrative assistants to manage and track those buckets efficiently and effectively, thereby saving staff time, and ensuring accurate accounts reconciliation. The final component of the software (which is still in beta) is an AI-powered patient engagement engine, that allows clinics to obtain deep insights – through patient risk scores and treatment trajectories – and allow them to engage their patients with personalized campaigns and accessible pathways to optimal care. The final product will integrate all three components in a way that makes it one coherent and seamless experience. In conclusion, this initiative aimed to demonstrate how structured integration of clinical, behavioral, and administrative data can, conceivably, enhance access, improve care outcomes, and transform dental clinic operations.

Problem Statement

Dental clinics face persistent inefficiencies across the entire patient journey that significantly impact the experience of care inasmuch as the financial health of business operations. The most significant point of attrition remains the *case presentation* and the *disconnected experience* of reconciling benefits and payment. Patients often receive information in formats that are difficult to understand, with insufficient cost transparency and lacking decision-support structure. This results in limited comprehension and variable trust, often leading to insurance-driven decisions that may not align with clinical needs – and ultimately resulting in low treatment acceptance. On the clinic side, these challenges are compounded by production-driven scheduling, inconsistent care coordination, and manual financial workflows (eg. benefit calculations, payment discussions, and insurance reconciliation). The result is poorly configured clinic capacity, increased administrative

bottlenecks and elevated accounts receivable, collectively leading to a vicious cycle that erodes both the patient experience and the financial stability of the practice. Finally, clinics generate a vast amount of largely unstructured clinical and administrative data that present a significant, yet currently untapped, opportunity for optimization. Collectively, these system-level gaps reduce operational efficiency, compromise patient engagement, and limit equitable access to recommended care

Guiding Objectives

The core objectives of this initiative are the following:

1. Identify the clinical, behavioral, and administrative factors shaping patient engagement and treatment decisions, and translate these insights into integrated digital strategies that enhance case acceptance and care experience.
2. Rapidly prototype, iterate, and validate human-centered AI and digital tools through continuous stakeholder feedback to ensure progressive value delivery and seamless integration into clinic workflows.
3. Leverage multi-decade patient and clinic data to develop predictive models that power personalized patient engagement, forecast treatment trajectories, and support more equitable access to recommended care.

Methodology

1. Evidence Synthesis:
A scoping review, key-informant interviews, and stakeholder consultations (administrative staff, industry partner, key opinion leaders) mapped engagement barriers and facilitators against published and the interrelated theoretical frameworks of: patient activation, shared decision making, and the chronic care model, to inform the design of targeted, theory-driven digital workflows that enhance patient engagement, foster shared decision-making, and strengthen continuity of care.

2. Software Development:
In collaboration with the industry partner, the startup team adopted lean agile principles to build an integrated web-based platform supporting:

- Two-way patient engagement
- AI enabled workflow automation for insurance verification and collections
- Multi-tenant system architecture
- Secure payment gateway integration
- Interoperability across patient management systems

This development was iterative and incorporated fieldnotes and stakeholder feedback in a sandbox environment progressing from a single clinic pilot, to five, ten and soon thirty – and in a way that supports the goal of an integrated, seamless digital experience that connects treatment recommendation through administrative touchpoints and ends with a digital checkout designed to offer clear, convenient payment choices.

3. Advanced Analytics & Machine Learning:
Leveraging decades of patient-level, tooth-level, and financial data, the team conducted extensive exploratory data analysis including feature engineering, treatment co-occurrence analysis, clustering, and predictive modeling. A novel patient condition matrix enabled segmentation by age, tooth region, and procedure category, allowing for potential forecasting of treatment trajectories and patient lifetime value.

Preliminary Findings/Results

Several activities are still in progress; preliminary results will be shared and future updates will be provided as they become available.

Qualitative Insights:
Scoping review is still ongoing. Concurrently, a few final key-informant interviews and stakeholder consultations remain to reach theoretical saturation, which will be followed by final qualitative analysis consistent with Grounded Theory Methodology. Manuscripts will be prepared for publication thereafter.

- Trust is key: built through consistency, genuine care, and clear communication between the dental *team* and patients.
- Information builds confidence: patients value clear, contextualized explanations supported by visual tools.
- Cost shapes decisions: financial barriers limit access, while flexible payment options support acceptance.

Digital & Operational Outcomes:
Additional performance metrics are being assessed, and the reporting infrastructure is being created through a comprehensive analytics dashboard that will be benchmarked to a pre-implementation baseline at each site.

- 85% reduction in administrative time for insurance verification by direct comparison to traditional, manual methods
- 65% reduction in time spent on collections by direct comparison to traditional, manual methods
- 32% increase in case acceptance following deployment of patient-centered workflows.

Data Science Outcomes:

- Data Foundations & Clinical Patterns: Dataset included 12,631 patients and 339k treatments; 5,697 patients (293k treatments) had sufficient longitudinal depth for modelling. Most treatment activity occurs in ages 25–54. Preventive/diagnostic procedures dominate volume, restorative needs peak in mid-adulthood, and periodontal/prosthodontic procedures rise after 45+. The data span 30+ years, showing seasonal dips and a sharp Q2 2020 COVID shutdown.
- Treatment Relationships & Trajectories: Daily co-occurrence across 160k patient-days was dominated by exams. Six-month rolling windows revealed meaningful clusters such as crown–lab pairings (62501 ↔ 99111), restorative-to-crown escalation (49219 → crown codes), and implant–prosthodontic sequences (71201 / 72421). Sequential patterns (e.g., 43413/43414 → 49211) captured periodontal-to-restorative progression. While these pairings were statistically significant, they are largely confirmatory of known patterns and offer little additional insight though it can be viewed as a confidence test in the analytic approach. Tooth-level absence limits specificity.
- Predictive Modelling & Patient Stratification: A 3-year → 1-year rolling window predicted next-year root canals with moderate accuracy using Logistic Regression, Random Forest, and XGBoost. Key predictors were cumulative restorative burden, preventive-care frequency, and age. Longitudinal clustering identified distinct care archetypes with different future treatment probabilities. Models were constrained by missing tooth data, rare events, and off-network care.

Conclusion:

This initiative demonstrates how academically grounded, patient-centered innovation – enabled by NCOHR's strategic support and strengthened through interdisciplinary collaboration – can translate complex clinical, behavioral, and administrative insights into practical AI-powered tools that meaningfully enhance patient engagement and streamline dental clinic operations. By integrating evidence synthesis, human-centered software development, and advanced analytics, the project lays the foundation for scalable, trustworthy digital solutions that improve case acceptance, optimize workflows, and advance equitable access to oral healthcare across Canada.

Future Directions

- Patient engagement: Experimenting with various combinations of decision aid materials to evaluate patients' experiences with decision support (e.g., treatment

journey maps, pre- and post-operative instructions, and adjunctive care information).

- Enable Cross-Clinic Validation and Generalizability: Expand datasets across multiple sites to validate models, reduce bias, and establish population-level benchmarks for predictive and preventive dentistry.
- Integrate Tooth-Level and Surface-Level data: Incorporate accurate tooth numbers, restoration surfaces, and periodontal measurements to improve precision of treatment pathways and enable tooth-specific progression modelling.
- Expand to Multimodal Clinical Data: Combine structured EDRs with radiographs, periodontal charts, and clinical notes using xray vision and NLP to enrich risk prediction and capture disease severity more directly. The platform can integrate with existing solutions in those spaces
- Develop Advanced Temporal Models: Apply transformer-based sequence models and dynamic temporal networks to move beyond rolling windows and model long-range dependencies in patient trajectories.
- Improve Rare-Event and Off-Network Treatment Handling: Use specialized imbalance methods, probabilistic modelling, and external data integration to address gaps created by off-site treatments and sparse early-life histories.
- Build Clinically Embedded Decision-Support Tools: Translate predictive signals into real-time risk flags, patient segmentation dashboards, and early-warning systems integrated within practice management software.

References

Abdelrehim, M., & Singhal, S. (2024). Is private insurance enough to address barriers to accessing dental care? Findings from a Canadian population-based study. *BMC Oral Health, 24*(1), 503.

Arora, V., Moriates, C., & Shah, N. (2015). The challenge of understanding health care costs and charges. *AMA Journal of Ethics*.

Bayrakdar, I. S., Orhan, K., Akarsu, S., Çelik, Ö., Atasoy, S., Pekince, A., … Odabaş, A. (2022). Deep-learning approach for caries detection and segmentation on dental bitewing radiographs. *Oral Radiology, 38*(4), 468–479.

Büttner, M., Leser, U., Schneider, L., & Schwendicke, F. (2024). Natural language processing: Chances and challenges in dentistry. *Journal of Dentistry, 141*, 104796.

Canadian Dental Association. (n.d.). *Understanding your dental benefits: A handy guide for patients*. https://www.cda-

adc.ca/_files/oral_health/talk/For_Patients_Understanding_your_Dental_Benefits_EN_Print.pdf

Carreras-García, D., Delgado-Gómez, D., Llorente-Fernández, F., & Arribas-Gil, A. (2020). Patient no-show prediction: A systematic literature review. *Entropy, 22*(6), 675.

Chakaipa, S., Prior, S. J., Pearson, S., & van Dam, P. J. (2023). Improving patient experience through meaningful engagement: The oral health patient's journey. *Oral, 3*(4), 499–510.

Chuang, Y. S., Lee, C. T., Lin, G. H., Brandon, R., Jiang, X., Walji, M. F., & Tokede, O. (2025). Cross-institutional dental electronic health record entity extraction via generative artificial intelligence and synthetic notes. *JAMIA Open, 8*(3), ooaf061.

Desborough, J., Maskell-Knight, C., Wang, S., Parkinson, A., Butler, D., Law, H. D., ... & Donaldson, C. (2025). Lived experience of out-of-pocket costs of health care and medicines by people with chronic conditions and their families in Australia: A systematic review of the qualitative literature. *Health Policy*, 105359.

Gondro, J. V., Emode, M., Ivancevic, D., Clarke, J., Ortlieb, K., & Farmer, J. (2025). Characteristics of cost-related avoidance of oral health services among people in Canada eligible for the Canadian Dental Care Plan. *Health Reports, 36*(8), 16-28.

Grudniewicz, A., Gray, C. S., Boeckxstaens, P., De Maeseneer, J., & Mold, J. (2023). Operationalizing the chronic care model with goal-oriented care. *The Patient–Patient-Centered Outcomes Research, 16*(6), 569-578.

He, J., & Cheng, M. X. (2021). Weighting methods for rare event identification from imbalanced datasets. *Frontiers in Big Data, 4*, 715320.

Hendrickx, I., Voets, T., van Dyk, P., & Kool, R. B. (2021). Using text mining techniques to identify health care providers with patient safety problems: Exploratory study. *Journal of Medical Internet Research, 23*(7), e19064.

Hickmann, E., et al. (2022). "All together now" – patient engagement, patient empowerment and the shift to participatory health care: A systematic review. *BMC Health Services Research, 22*, 805.

Ho, J. C. Y., Chai, H. H., Luo, B. W., Lo, E. C. M., Huang, M. Z., & Chu, C. H. (2025). An overview of dentist–patient communication in quality dental care. *Dentistry Journal, 13*(1), 31.

Joda, T., Waltimo, T., Probst-Hensch, N., Pauli-Magnus, C., & Zitzmann, N. U. (2019). Health data in dentistry: An attempt to master the digital challenge. *Public Health Genomics, 22*(1–2), 1–7.

Liu, M., Li, S., Yuan, H., et al. (2023). Handling missing values in healthcare data: A systematic review of deep learning-based imputation techniques. *Artificial Intelligence in Medicine, 142*, 102587.

Moen, H., Raj, V., Vabalas, A., et al. (2025). Modeling evolving longitudinal health trajectories with a transformer-based deep learning model. *Annals of Epidemiology, 111*, 30–43.

Obermeyer, Z., & Emanuel, E. J. (2016). Predicting the future—Big data, machine learning, and clinical medicine. *New England Journal of Medicine, 375*(13), 1216–1219.

Patil, S., Albogami, S., Hosmani, J., Mujoo, S., Kamil, M. A., Mansour, M. A., ... Ahmed, S. S. S. J. (2022). Artificial intelligence in the diagnosis of oral diseases: Applications and pitfalls. *Diagnostics, 12*(5), 1029.

Pomey, M. P., Schaad, B., Lasserre-Moutet, A., Böhme, P., & Jackson, M. (2024). Towards a New Integrated Model for Taking Into Account the Experiential Knowledge of People With Chronic Diseases, Integrating Mediation, Therapeutic Education and Partnership: The Expanded Chronic Care Patient–Professional Partnership Model. *Health Expectations, 27*(5), e70054.

Poon, B. Y., Shortell, S. M., & Rodriguez, H. P. (2019). Patient activation as a pathway to shared decision-making for adults with diabetes or cardiovascular disease. *Journal of General Internal Medicine, 35*(3), 732-742.

Rajkomar, A., Oren, E., Chen, K., Dai, A. M., Hajaj, N., Hardt, M., ... Dean, J. (2018). Scalable and accurate deep learning with electronic health records. *NPJ Digital Medicine, 1*, 18.

Riggs, K. R., & Ubel, P. A. (2014). Overcoming barriers to discussing out-of-pocket costs with patients. *JAMA Internal Medicine, 174*(6), 849-850.

Royal College of Dental Surgeons of Ontario. (2015, March 1). *Ensuring patients understand and agree to the cost of treatment.* https://www.rcdso.org/en-ca/standards-guidelines-resources/rcdso-news/articles/1342

Schwendicke, F., Samek, W., & Krois, J. (2020). Artificial intelligence in dentistry: Chances and challenges. *Journal of Dental Research, 99*(7), 769–774.

Schwendicke, F., & Krois, J. (2022). Data dentistry: How data are changing clinical care and research. *Journal of Dental Research, 101*(1), 21–29.

Senguttuvan, V., & Viswapurna, T. (2024). Dental practice management—An overview. *Frontiers in Health Informatics, 13*(3).

Shahid, R., Shoker, M., Chu, L. M., Frehlick, R., Ward, H., & Pahwa, P. (2022). Impact of low health literacy on patients' health outcomes: A multicenter cohort study. *BMC Health Services Research, 22*(1), 1148.

Thomas, E. C., Ben-David, S., Treichler, E., Roth, S., Dixon, L. B., Salzer, M., & Zisman-Ilani, Y. (2021). A systematic review of shared decision–making interventions for service users with serious mental illnesses: State of the science and future directions. *Psychiatric Services, 72*(11), 1288-1300.

Wiens, J., Saria, S., Sendak, M., et al. (2019). Do no harm: A roadmap for responsible machine learning for health care. *Nature Medicine, 25*, 1337–1340.

Zhao, J., Papapetrou, P., Asker, L., & Boström, H. (2017). Learning from heterogeneous temporal data in electronic health records. *Journal of Biomedical Informatics, 65*, 105–119.

Zhao, Y., Wong, Z. S.-Y., & Tsui, K. L. (2018). A framework of rebalancing imbalanced healthcare data for rare event classification. *Journal of Healthcare Engineering, 2018*, 6275435.