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Promoting the Importance of Recall Visits Among Dental Patients in India Using a Semi-Autonomous AI System

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Abstract. In many developing countries like India, there is a widespread lack of general awareness about the importance of good oral health, which causes dental patients to neglect their oral hygiene, thus precipitating many long-term ailments. We developed an application that promotes the significance of regular dental checkups and oral health care by explaining to patients how these are intrinsic to overall health. Our application, in essence, extracts relevant health information from published scientific studies according to a patient's medical history and shares it with the patient at the discretion of the supervising dentist, thereby empowering patients to make more informed decisions. We present a detailed overview of our semi-autonomous machine learning-based solution, along with the complex challenges involved in the design, development, and real-world deployment of our application. Finally, we conducted a randomized parallel-group study in India with 224 dental patients over two years to assess the utility of our proposed solution. Results show our application improved the patient recall rate from 21.1% to 37.8% (p-value = 0.024).

Keywords. evidence-driven dentistry, health information systems, public health informatics, artificial intelligence (AI), machine learning, preventive dentistry

1. Introduction

In 2016, FDI World Dental Federation affirmed that oral health constitutes an essential component of overall health [1], and it plays a significant role in individuals' physical, social, and emotional well-being [2-5]. Furthermore, recent studies have shown that poor dental health can lead to an increased risk of various diseases and morbidities like birth complications [7], cardiovascular diseases [6,8], pneumonia [9], and other systemic manifestations. Fortunately, regular dental checkups and preventive care can avert many oral diseases like dental caries (cavities), periodontal (gum) disease, oral and facial pain, etc., which adversely impact health-related quality of life [3]. In addition, routine oral examinations can be instrumental in the early detection of oral and pharyngeal (mouth and throat) cancers [10]. Therefore, dental clinics typically request patients for "recall visits" [11] to perform routine diagnostic [12] and preventive procedures [13,14] like tooth cleaning [15] to ensure the continued care of their patient's oral health.

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1.1. Challenges with dental recall

Despite growing evidence [16-18] indicating the importance of dental recall in retaining good oral health, poor recall practice is widely prevalent in many countries [19]. The problem is more acute in many developing countries like India because: (1) a significant portion of the population exhibit limited health literacy [22], and (2) subsidized insurance options are not available to cover recall visits [20,21], resulting in patients incurring significant out-of-pocket expenses. Consequently, an overwhelming fraction of dental patients in India ignore scheduled recall appointments and instead visit dental clinics only for curative and mitigative care, which is financially more taxing [26] and has a punitive effect on their overall health in the long run.

1.2. Motivation

Dentists and health professionals should educate people without medical background about the importance of dental recall and the crucial life-saving care they can receive at each checkup. In this work, we propose a simple strategy to promote such awareness among dental patients by sharing medical insights that are relevant to them, given their medical history. To illustrate this, consider the following situation. Medical research has shown that diabetes increases the risk of periodontitis (gum infection), and bacteria from untreated periodontal disease can further lead to higher blood sugar levels [23,24]. Our objective is to communicate this information in layman's terms to patients who have diabetes and help them understand that regular dental checkups can control gum infection and help maintain healthy blood sugar levels [25]. Consider another example. There is a common perception that elderly patients largely neglect oral health [27], assuming it has no direct link to mortality. However, recent studies [17,18] have shown that oral frailty (decrease in oral function) can lead to adverse health outcomes like physical frailty, sarcopenia (loss of skeletal muscle mass), and even mortality. Therefore, it is imperative to encourage elderly patients to seek preventive dental care by explaining how maintaining a good oral status can ensure longevity and healthy aging [17].

1.3. Contributions

Typically, patients are reminded of their recall visits via standard automated text messages or emails from dental clinics. To educate patients in a timely and meaningful manner, we aimed to send appropriate medical insights to them along with their recall reminders. Thus, this paper discusses our experience of designing, developing, and deploying such a prototype in dental practice. In addition, we also investigate through an experimental study if our strategy of promoting dental recall can indeed lead to a better patient response or not. To the best of our knowledge, this is the first work that conceptualizes and implements a personalized patient recall system in dentistry and evaluates its efficacy through extensive experimentation. Therefore, this paper formally makes the following contributions: (1) We built an artificial intelligence (AI) driven application that can generate relevant medical insights for a patient from published scientific literature according to one’s past medical history. We also discuss several critical considerations, which led to a semi-autonomous design and also ensured the overall system's fairness. (2) We integrated our developed AI model into an existing patient recall software system and deployed it in regular practice in India. (3) Finally, a quantitative study was conducted to measure the utility of our application.

2. Methods

2.1. Prototype design considerations

We designed our prototype following the general guidelines for health research prescribed by the Indian Council of Medical Research (ICMR) [28] (in consultation with the World Health Organization) in accordance to the Declaration of Helsinki [37] and the Belmont report [38]. We discuss these essential principles in the context of our prototype design:

- *Principle of beneficence*: Our application should attempt to achieve maximum possible public good and societal benefit instead of bringing maximum individual gain to a health practitioner, patient, or clinic.
- *Principle of non-maleficence and justice*: We should ensure our system does not harm patients in the form of discrimination due to their economic conditions, educational qualifications, and other social prejudices.
- *Principle of voluntariness*: We imposed a two-step informed consent process. In the first step, patients can exercise their right to allow or deny our application to access their medical history. Patients agreeing to the first step can then decide if they want to receive relevant medical insights about them electronically via text messages or email. The patients reserve the right to withdraw from the study at any time.
- *Ensuring privacy and confidentiality*: We adopted safeguards to ensure that our system handled patients' health records discreetly under strict authorization. For example, whenever possible, sensitive health records (e.g., HIV positive status, history of mental illnesses, STD, etc.) were anonymized to hide patient identity. Furthermore, our application sent medical insights to patients over secure end-to-end encrypted channels.
- *Principle of non-exploitation*: Our primary objective is to educate patients about the importance of dental recall. Hence, our application should never use "scare tactics" to increase recall visits by sending alarming medical information that may not be pertinent to a patient.
- *Principle of risk minimization*: Care must be taken to minimize the risk of causing inconvenience to patients. For example, more than one medical insight may be relevant to an individual. However, receiving every piece of applicable medical information can be overwhelming for a patient. Therefore, our prototype should send only the most beneficial medical insight to the patient.
- *Principle of totality of responsibility*: The dentists and health practitioners involved in this research are responsible for the overall actions. Thus, even though an AI can generate valuable medical insights for patients, a dentist must always verify them before sending them out. Therefore, our designed system should be semi-autonomous since it requires the presence of an expert to approve the final action.

2.2. Prototype implementation and deployment

Figure 1 presents a high-level working overview of our prototype. The entire workflow can be broadly divided into the following stages: (1) data collection and preprocessing, (2) text mining, and (3) integration with patient recall.

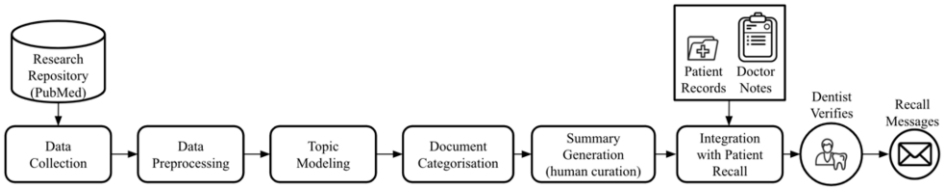


Figure 1. A high-level implementation design of our method.

Data collection and preprocessing: We downloaded around 250 scientific papers about oral health and dentistry from a research repository (PubMed) using various keywords related to common medical conditions, diseases, and living habits. We then performed standard text preprocessing techniques like lower casing and stop word removal [29] on this dataset.

Text mining: In this step, we first performed *topic modeling* using Labeled LDA (Latent Dirichlet Allocation) [29] on the preprocessed corpus containing around 250 research articles. The former method is a well-known unsupervised machine learning technique to extract topics (word distribution) from multi-labeled document corpora, where each document has multiple tags. We apply it here to generate topics from research manuscripts having several author-specified keywords (used as tags in this context). Then we categorized each research paper (*document categorization*) by the appropriate topic using its posterior probability (conditioned over topics) computed during the learning process of Labeled LDA. This step narrows down the list of articles under a topic. For example, studies [2,17,18] can be clustered under one topic related to 'oral health and aging.' Once the research papers have been categorized into different topics, we ran the popular Textrank algorithm [30] using Gensim to perform extractive text summarization (*summary generation*) on the abstract of all the papers under a given topic. This extractive summary for each topic is then manually edited, shortened, and simplified (*human curation*) to make it easily understandable.

Integration with patient recall: Our AI system should essentially retrieve relevant medical insights (summaries generated previously) for patients according to their medical records when their recall is due. Patients visiting a dental clinic for the first time often provide information about their medical history by answering a detailed questionnaire about their age, gender, smoking habits, drug addiction, alcohol use, history of ailments, and existing medical conditions. Our application integrated these health records of patients who consented to participate in the study and any available doctor notes from their earlier dental visits. It is important to reiterate that our AI system should not discriminate between two patients based on non-medical attributes (e.g., educational qualification, occupation, residential address, etc.). Therefore, we removed all references to non-medical patient information (except details like age and gender) from our application database. Thus, if two patients share identical medical histories and demographics, they would receive the same medical insight from our system.

When a patient is due for a recall, our system first converts the patient's medical record into a normalized query vector [39] based on the patient's attributes, prevalent chronic diseases, and conditions. Our application then computes cosine similarity [39] between the query vector and the topic vectors (each topic computed from Labeled LDA in the previous step is a vector of probabilities defined over the words in the medical corpus) to find likely topics that match the patient's history. Both the query and topic vector have the same dimension as the vocabulary size of the preprocessed corpus. A

higher cosine similarity would indicate higher relevancy. Finally, our system retrieves the top three relevant topics for a patient. It then populates the corresponding summary messages (one for each topic) in a dashboard in ranked order (according to cosine similarity). A dentist eventually verifies the correctness and relevance of these messages from the dashboard and decides which is the most useful one given the patient's medical history. If deemed appropriate and risk-averse, the dentist can then send this medical insight to the patient along with the recall reminder. Additionally, the dentist also has the option to overwrite a message if needed. Figure 2 shows an example of medical insights generated and ranked for a cardiovascular disease [8] patient with a family history of pancreatic cancer [31,32]. It is important to note that our system remains oblivious about which recall reminders eventually worked. This ensures our application is never incentivized for just patient recall as that would compromise the principle of non-exploitation.

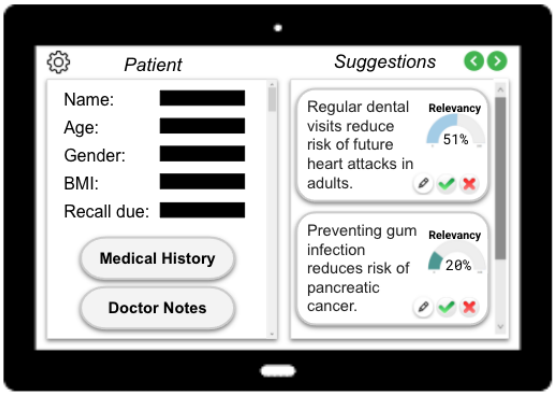


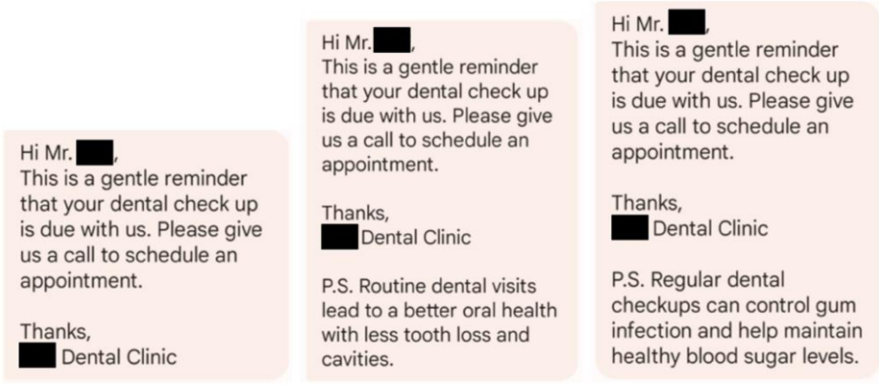
Figure 2. A semi-autonomous system: dentists eventually decide on the most relevant insight for a patient.

2.3. Quantitative study

We conducted a controlled experiment to evaluate the effectiveness of our method. The study was conducted at two primary care dental practices in India over 24 months. Patients with severe oral diseases that required frequent monitoring were excluded from the study. These patients were a high priority for recall at an interval of 3 months [35] and were personally contacted by the dental clinic over the phone. Patients recommended for a traditional 6/12-month recall period [11,34,36] by dentists were considered for the experiment. Total 224 participants agreed to be part of the study. We ran a three-arm parallel-group study, where each participant was *randomized* to one of the following:

(a) *Control*: Participants (N = 76) receive a standard recall reminder message without any medical insight (Figure 3a).
(b) *Group 1*: Participants (N = 73) receive a recall reminder with a broad general medical statement like "routine dental visits lead to a better oral health with less tooth loss and cavities" [16]. Every participant in this group receives the same general medical insight (Figure 3b). Recall messages for control and group 1 were sent using standard patient recall software system.
(c) *Group 2*: Participants (N = 75) would receive a recall reminder with a particular medical insight generated according to the patient's past medical history. Participants in

this group receive different medical insights. Figure 3c cites an example of a recall reminder received by a diabetic patient. An anonymized electronic poll was conducted among patients in group 2. They were asked to score their recall message on a scale of one to five (with a score of one indicating 'annoyed,' two meaning 'somewhat uncomfortable,' three implying 'neutral,' four suggesting 'somewhat useful/interesting,' and five representing 'very useful').



(a) Control (b) Group 1 (c) Group 2

Figure 3. An example of different recall messages sent in a three-arm parallel randomized study.

3. Results

3.1. Recall rate evaluation and patients' response

We observed that 21.1% of the participants in the control group, who received a recall reminder, returned for a visit (control recall rate). The recall rate among group 1 participants was 26.0%, and the change was statistically insignificant (p-value = 0.47). However, the recall rate among group 2 participants was 37.8% and the improvement was statistically significant (p-value = 0.024). Figure 4 shows the patients' survey response, where more than two-thirds of the respondents found the medical insights helpful, while only 5.3% found it 'somewhat uncomfortable.'

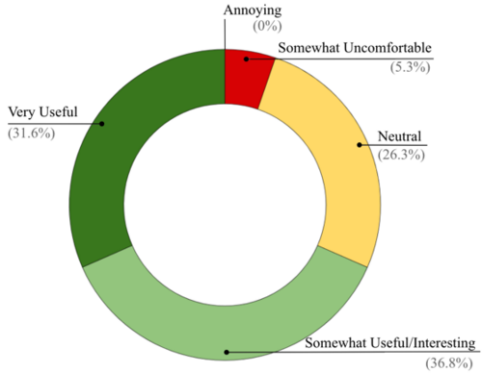


Figure 4. Survey response about the quality of personalized patient recall messages.

3.2. Evaluation by dentists

Dentists used our application to send personalized, medically relevant recall messages to all patients in group 2 except one. Among 74 recall messages sent, 68 were directly selected from the top relevant messages suggested by our system (91.9%). In the remaining 6 cases, the supervising dentist customized the recall reminder by incorporating a more appropriate and timely insight than the ones recommended by our application. For example, in the case of a patient suffering from the rare Sjögren's syndrome [40] characterized by a frequent dry mouth, the supervising dentist consulted the doctor's notes and patient history and then overwrote the system suggestion. The new recall reminder for the patient explained how dry mouth leads to an increased risk of dental cavities and tooth loss, which can be prevented through regular dental checkups. This leads to an interesting direction for future work, where our AI system could try to improve its recommendations further by learning from these revised messages drafted by the specialists.

4. Discussion

Our experimental results from the randomized controlled study show that sharing pertinent insights with patients contributes positively towards the recall rate as opposed to sharing general medical information. In addition, our survey results further indicate that patients become more informed through personalized recall reminders, which allow them to make evidence-based decisions. Thus, the overall results from this study validate the conclusion that our semi-autonomous AI application, deployed in actual dental practice, raised awareness about the importance of patient recall. However, it is worth mentioning that the patient survey has a survival bias since it was overwhelmingly answered by patients who returned for a recall. Here we would also like to mention one particular case to highlight why a fully-automated AI application may not be realizable in practice. The supervising dentist deemed it risky to send a health-related recall message to a pregnant patient in her third trimester with a history of severe clinical depression and anxiety attacks. This case emphasizes the need for a dental expert in our application who can intervene appropriately whenever necessary.

References

[1] Hescot P. The New Definition of Oral Health and Relationship between Oral Health and Quality of Life. *Chin J Dent Res*. 2017; **20**(4):189-192.
[2] Gil-Montoya, José Antonio et al. “Oral health in the elderly patient and its impact on general well-being: a nonsystematic review.” *Clinical interventions in aging* vol. **10** 461-7. 11 Feb. 2015.
[3] Gift HC, Atchison KA. Oral health, health, and health-related quality of life. *Med Care*. 1995.
[4] Jamieson, L.M., Paradies, Y.C., Gunthorpe, W. *et al.* Oral health and social and emotional well-being in a birth cohort of Aboriginal Australian young adults. *BMC Public Health* 11**,** 656 (2011).
[5] Yakar, N., Türedi, A., Emingil, G. *et al.* Oral health and emotional well-being in premenopausal and postmenopausal women: a cross-sectional cohort study. *BMC Women's Health* 21**,** 338 (2021).
[6] Lockhart, Peter B et al. “Poor oral hygiene as a risk factor for infective endocarditis-related bacteremia.” *Journal of the American Dental Association (1939)* vol. **140**,10 (2009): 1238-44.
[7] Hwang, Sunah S et al. “The association between maternal oral health experiences and risk of preterm birth in 10 states, Pregnancy Risk Assessment Monitoring System, 2004-2006.” *Maternal and child health journal* vol. **16**,8 (2012): 1688-95.

[8] Park SY, et al. Improved oral hygiene care attenuates the cardiovascular risk of oral health disease: a population-based study from Korea. *Eur Heart J*. 2019 Apr 7;**40**(14):1138-1145.
[9] Son M, Jo S, Lee JS, Lee DH. Association between oral health and incidence of pneumonia: a population-based cohort study from Korea. *Sci Rep*. 2020 Jun 12;**10**(1):9576.
[10] Haigh AF. Dental recalls are useful for detecting oral cancer. *BMJ*. 2000 Mar 18;320(7237):803-4.
[11] Kay EJ. How often should we go to the dentist? *BMJ*. 1999;319(7204):204-205.
[12] Deep P. Screening for common oral diseases. *J Can Dent Assoc*. 2000 Jun;**66**(6):298-9.
[13] Gift HC. Prevention of oral diseases and oral health promotion. *Curr Opin Dent*. 1991 Jun;**1**(3):337-47.
[14] Niessen LC, et al. Clinical strategies for prevention of oral diseases. *J Esthet Dent*. 1996;**8**(1):3-11.
[15] Deutscher H, Derman S, Barbe AG, Seemann R, Noack MJ. The effect of professional tooth cleaning or non-surgical periodontal therapy on oral halitosis in patients with periodontal diseases. A systematic review. *Int J Dent Hyg.* 2018 Feb;**16**(1):36-47.
[16] Patel S, Bay RC, Glick M. A systematic review of dental recall intervals and incidence of dental caries. *J Am Dent Assoc*. 2010 May;**141**(5):527-39.
[17] Watanabe Y, et al. Oral health for achieving longevity. *Geriatr Gerontol Int*. 2020 Jun;**20**(6):526-538.
[18] Tanaka T, et al. Oral Frailty as a Risk Factor for Physical Frailty and Mortality in Community-Dwelling Elderly. *J Gerontol A Biol Sci Med Sci*. 2018 Nov 10;**73**(12):1661-1667.
[19] Jamleh A, et al. Recall Practice among Dental Practitioners in Riyadh, Kingdom of Saudi Arabia. *J Contemp Dent Pract.* 2019 Jan 1;**20**(1):26-31.
[20] Garla BK, Satish G, Divya KT. Dental insurance: A systematic review. *J Int Soc Prev Community Dent*. 2014 Dec;**4**(Suppl 2):S73-7.
[21] Toor RS, Jindal R. Dental insurance! Are we ready? Indian J Dent Res. 2011 Jan-Feb;22(1):144-7.
[22] D'Cruz, Audrey M, and M R Shankar Aradhya. "Health literacy among Indian adults seeking dental care." *Dental research journal* vol. **10**,1 (2013): 20-4.
[23] Grossi SG, Genco RJ. Periodontal disease and diabetes mellitus: a two-way relationship. *Ann Periodontol.* 1998 Jul;**3**(1):51-61.
[24] Liccardo D, Cannavo A, Spagnuolo G, Ferrara N, Cittadini A, Rengo C, Rengo G. Periodontal Disease: A Risk Factor for Diabetes and Cardiovascular Disease. *Int J Mol Sci*. 2019 Mar 20;**20**(6):1414.
[25] Grossi SG, Skrepcinski FB, DeCaro T, Robertson DC, Ho AW, Dunford RG, Genco RJ. Treatment of periodontal disease in diabetics reduces glycated hemoglobin. *J Periodontol*. 1997 Aug;**68**(8):713-9.
[26] Terpenning M, et al. Oral health is cost-effective to maintain but costly to ignore. *J Am Geriatr Soc*.
[27] Borreani E, et al. Informing the debate on oral health care for older people: a qualitative study of older people's views on oral health and oral health care. *Gerodontology*. 2010 Mar;**27**(1):11-8.
[28] Mathur, R., et al. (2018). National ethical guidelines for biomedical & health research involving human participants, 2017: A commentary. *The Indian journal of medical research*, **148**(3), 279–283.
[29] Daniel Ramage, et al. 2009. Labeled LDA: a supervised topic model for credit attribution in multi-labeled corpora. *EMNLP* 2009.
[30] Mihalcea, Rada, and Paul Tarau. "Textrank: Bringing order into text." *EMNLP* 2004.
[31] Gerlovin H, Michaud DS, Cozier YC, Palmer JR. Oral Health in Relation to Pancreatic Cancer Risk in African American Women. *Cancer Epidemiol Biomarkers Prev*. 2019 Apr;**28**(4):675-679.
[32] Pia Heikkilä, Anna But, Timo Sorsa, Jari Haukka. Periodontitis and Cancer Mortality: Register-based Cohort Study of 68 273 Adults in 10-year Follow-up. *International Journal of Cancer*, 2018.
[33] Mikolov, T., et al. (2013). Efficient estimation of word representations in vector space. *arXiv preprint.*
[34] National Collaborating Centre for Acute Care (UK). Dental Recall: Recall Interval Between Routine Dental Examinations. London: National Collaborating Centre for Acute Care (UK); 2004 Oct.
[35] Bader, J. Risk-based recall intervals recommended. *Evid Based Dent* 6, 2–4 (2005).
[36] Fee, Patrick & et al., Dwayne & Beirne, P.V. (2020). Recall intervals for oral health in primary care patients. *The Cochrane database of systematic reviews*. 10.
[37] Declaration of Helsinki: ethical principles for medical research involving human subjects. Fortaleza: *World Medical Association*. 2013.
[38] The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. The Belmont report: ethical principles and guidelines for the protection of human subjects of research. Washington DC: *Department of Health, Education and Welfare*; 1979.
[39] C. D. Manning, et al. Introduction to Information Retrieval. Cambridge University Press. 2008.
[40] Fernández-Martínez G, et al. Oral health-related quality of life in primary Sjögren's syndrome. *Reumatol Clin (Engl Ed)*. 2020 Mar-Apr;**16**(2 Pt 1):92-96.