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Artificial intelligence and robotics: The enhanced paediatric dentist

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ABSTRACT

Automation would be an inevitable course of manual work facing every field in the future in view of technological advancements. The mental and physical strain incumbent on the pediatric dentist due to long hours of managing the child and the unwavering focus that the trade demands may compromise the quality of service. A system capable of physical manipulation that is powered by an intelligent program would be the ideal assistant to the dentist for carrying out technique sensitive procedures. Data management, diagnosis, treatment planning and student education can transcend to a new plane of execution with Artificial Intelligence and Robot enhanced Paediatric Dentist at the epicenter. Among the many hurdles faced by the idea of turning robotics in dentistry into a tangible reality is the extreme cost and bureaucratic resistance.

Keywords*: Artificial Intelligence, Robotics, Nanorobotics, Paediatric Dentistry*

1. INTRODUCTION

Automation would be an inevitable course of manual work facing every field in the future in view of technological advancements. There has been widespread advocation from experts to digitize the healthcare system to reduce variation of approach and improve quality of treatment. The mental and physical strain incumbent on the paediatric dentist due to long hours of managing the child and the unwavering focus that the trade itself demands may compromise the quality of service which is one of the most motivating human factors supporting this argument.[1] The inclusion of Robotics and Artificial Intelligence (AI) in dentistry would be a step towards progress as its applications are immense. A system capable of physical manipulation that is powered by an intelligent program would be the ideal assistant to the paediatric dentist for carrying out technique sensitive procedures.[2]

2. APPLICATIONS IN PAEDIATRIC DENTISTRY

Management of the paediatric patient in dentistry is a daunting task requiring patience in behavior management apart from the skill to perform the usual procedures. Arntz A, Van Eck M and Heijmans M[3] has shown that the sight and sensation of a local anesthetic injection and the dental drill deliver the most potent triggers for dental anxiety in children crippling the quality of interaction with the dentist and the subsequent treatment. Data management, diagnosis and treatment planning can transcend to a new plane of execution with the AI and Robot enhanced Paediatric Dentist at the epicenter. AI is in a continual state of evolution from the older Hebbian learning algorithm which is based on the proportional strength of a bineuronal synapse in relation to its individual neuronal similarity to the more recent back-propagation algorithm which is based on tuning the given parameters in a network laying the foundation for many sequential processing tasks, including but not limited to language processing, video comprehension and time series analysis and forecasting. Machine Learning, a subset of AI is more concerned with applying algorithms to perform tasks by spotting and assimilating patterns from data while forgetting the information in the data that it has processed. Continual learning is a basic skill in biological intelligence that is used to learn a new task without forgetting previous ones. Reinforcement learning relates to how AI agents take action and interact with the environment. Every avenue of AI has a potential application in the dental environment.[2] The Robot Institute of America defined a robot as "a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks."[4] Starting from a brain biopsy in 1985, robotics in medicine has expanded its reach to neurosurgery, gynecology and cardiothoracic surgery among other disciplines.[2] In 1974, Norio Taniguchi at the University of Tokyo used the term "nanotechnology" relating it to the ability to engineer materials precisely at the nanometer level.[5] Administering local anesthesia without a needle or a single visit orthodontic realignment may have sounded more fiction than science but such views have become open to change in this day and age. The use of miniature robots in the scale of nanometers built using complex nanoscale components and capable of undertaking enterprises such as permanent desensitization or regular oral health maintenance was hypothesized by Robert Frietas Jr.[6] Complete reliance on the dentist's skills and the dentist-patient rapport-model of contemporary healthcare can make a relatively easy transition to one that accommodate both Robotics and AI with the human elements, preserving the human aspects of dental care.[7]

2.1 Diagnosis, Treatment plan and Data management

Dental diagnosis comprises of interpretation of patient information collected through observation and examination, diagnosis formulation and a treatment plan. Such a process needs an intelligent agent which can crunch the input data and construct a personalized output. AI makes room for a more systematic and organized collection of patient's data, reduces routine tasks, facilitates research and development and is a promising alternative for a more participatory healthcare system. AI is more focused on fabricating a well-built system for each process through extracting appropriate data from a sizeable amount of medical records to assist dental professionals in making decisions along with helping patients to understand the disease and its prognosis. Clinical Decision Support Systems (CDSS) were developed to manage the increments in patient data through time and analyze it with the aid of an inbuilt clinical database thereby assisting dental professionals in making decisions regarding diagnosis, prevention, treatment and prognosis of the disease. The modus operandi of a CDSS would be to classify a patient with a complaint of toothache according to caries risk assessment by formulating a short questionnaire which includes last visit to the dentist, past restoration history, sugar exposure history and fluoride exposure history. A suggested treatment plan is automatically generated thereby providing valuable information to the dentist and the patient while benefitting the economy of time and superior efficiency. [7]

2.2 Prediction models

Genetic Algorithms (GA) are a set of versatile search systems based on the principle of survival of the fittest in natural selection. Unlike the calculus-based models or enumerative schemes that require lucid theories for an analytical approach, GA use cumulative data in a population of state vectors efficiently in time. Their greatest advantage is that they work on the basis of problem-solution as opposed to the conventional concepts of analytical relations. They are powerful optimization tools but work on simple rules.[8] Łodygowski T, Szajek K and Wierszycki M[9] used them for optimization of a dental implant system. Another study by Li H, Lai L, Chen L, Lu C and Cai Q[10] with an aim to improve tooth color matching in esthetic dentistry used them in conjunction with a back propagation neural network. A recent study reported a GA based approach to detect and prevent dental caries in early stages, which is the cynosure of minimally invasive dentistry. [11]

Analysis of space lost due to a number of factors including proximal caries and premature tooth loss is essential in the prediction of future arch form and devising the appropriate treatment plan for management of aberrations. Regression equations from measurements derived from diagnostic casts, radiographic methods and a combination of both were developed to meet this need with varying success. Some of the more successful methods include the Tanaka Johnston's analysis, the Moyers mixed dentition analysis and the Hixon and Oldfather approach which were developed on the basis of data acquired from native populations at a certain period. However, their applicability to populations of other ethnicities is questionable.[12] GA and Artificial Neural Networks (ANN) have found use in prediction and interpretation of biological activities such as dental caries. If a proper training database representing values for a particular population is established, GA and ANN can be used to predict the sizes of unerupted teeth. An artificial neural network derived model was used in a study predict toothache on the basis of its association with tooth-brushing time, daily tooth-brushing frequency, toothbrush replacement to pattern, use of dental floss, undergoing scaling and other epigenetic factors such as diet and exercise. The result was a toothache predictive model of great accuracy which recognized oral hygiene, adequate eating habits and prevention of stress as the essential factors in preventing toothaches.[7] A study by Nieri M, Crescini A, Rotundo R, Baccetti T, Cortellini P and Prato GP[13] using a Bayesian network analysis to identify links between pretreatment and post-treatment data of patients and other patient related variables and their impact on the treatment outcome of impacted maxillary canines concluded the suitability of AI to assist dental professionals. Another study by Käkilehto T, Salo S and Larmas M[14] constructed a model using the ANN to predict the necessity of extraction during orthodontic treatment.

2.3 Local anesthesia and Restorative procedures

In children, anesthetic nanorobots if introduced in a suspension into the quadrant of interest, will reach the pulp via the gingival sulcus, lamina propria and the dentinal tubules and block the action potentials in the sensory nerves upon activation by the dentist until such time as decided by the dentist when he/she can command the robots to deactivate.[4] Based on origin and structure of component materials, nanorobots can be classified either as bionanorobots with DNA and ATP based molecular machines or inorganic robots which have "diamondoid materials" composed of circular saturated hydrocarbons, structurally similar to a diamond with chemical and thermal stability due to their exceptional molecular structure and "fullerenes" which are spherical aromatic carbon compounds, have been proposed as raw materials for construction of such robots.[6] With an average travel speed of 100 μm\second, nanorobots can complete the voyage from the surface into the pulp chamber in about 100 seconds similar to the native immune cells.[4,5] Restorative dentistry demands precision to the micrometer scale both in preparation of tooth and restoration with adhesive materials. Augmented reality (AR) is a type of technology in which an environment is enhanced through the process of superimposing computer-generated virtual content over real structure, enhancing the sensory perception of reality. AI in conjunction with AR can utilize photon emission tomography, near infrared spectroscopy, dyes, haptic force feedback and robotics for better outcome in restorative dentistry. In order for the overlaid image to keep pace three dimensionally with the movements of the dentist and the movements of the patient which is more frequent in children, proper maintenance of orientation, scale and depth perception with fast computing algorithms is essential.[15] Algorithms engineer a network of artificial neurons connected in assembled layers which is competent in solving tasks such as image classification that can be applied in radiographic imaging showing the extent of decay in a tooth. Deep Learning is another subset of Machine learning that is a complex multilayer system that permits the visualization of simple features such as lines, edges, corners and macroscopic patterns in a hierarchical structure, which can find practical use in conservative caries excavation and tooth preparation for accommodating restorations. [1]

Replenishing lost tooth mineral using reconstructive dental nanorobots with materials such as sapphire and diamond can redefine the limits of remineralization strategies thereby enhancing the durability and esthetics of teeth. Nanorobots can be used for caries excavation and subsequent restoration with tissue engineered biological materials resulting in a near original form of the teeth with respect to shape and thickness.[6] An onboard nanocomputer with preprogrammed functions and storage capability, a two-way communication by means of electromagnetic waves, optical or chemical nanosensors with the operating dentist and with other nanorobots and a multi-armed spider like design seems more suitable for dentistry as it enhances motility and capability. Energy can be utilized from internal sources (radioactive particles and solar cells) or external sources (blood glucose or body heat). [16]

2.4 Endodontic and Orthodontic procedures

Data acquired from diagnostic imaging such as periapical radiographs, computed tomography scans and magnetic resonance imaging scans can be good sources of input for AR information. This allows the dentist to obtain critical information such as the intricate anatomy of root canals while maintaining focus on the operating field in contrast to the conventional systems. Such real-time information presented three dimensionally on the patient's body is more efficient and avoids confusion in comparison to being presented on a separate screen. Success has been reported in orthognathic surgery and implant placement using Head Mounted Display (HMD). Guided bracket placement in orthodontics and orifice detection in endodontics was achieved using k-nearest algorithms and Euclidean distance based segmentation.[15] The success rate of the endodontic procedure can be significantly increased with robotic assistance from averages of 60-70% and 80-90% for general dentists and endodontic specialists respectively. Economy of time can be improved and injury arising from consistent unergonomic postures can be avoided. Orthodontic rotation, translation or a combination of such movements can be carried out within minutes to a few hours. [6,17]

2.5 Biofilm Control and Regenerative procedures

Reservoirs or incubation zones of pathogenic plaque biofilms such as the pericoronal flaps, distal aspects of third molars and tonsillar crypts can be checked by nanorobots incorporated into mouthrinses and dentifrices. Implantation of in vitro grown natural teeth into extraction sockets and establishing neurovascular networks with the help of nanorobots can mark the beginnings of a truly regenerative procedure.[16]

2.6 Training of dental students

Long standing ethical issues and the new normal era after the covid 19 pandemic have made clinical training difficult. 'Phantoms', consisting of a functional cephalic region and an arrangement of teeth that hardly simulates a real patient have spurred interest in the concept of a dental patient robot. Some of the robots developed include the Showa Hanako models that mimic typical patient gestures and responses with a realistic silicone skin, ability to blink, roll eyes, sneeze and even display fatigue or a gag reflex from having to keep the mouth open for long. The Geminoid DK is another such robot which bears a remarkable resemblance to Professor Henrik Scharfe of Aalborg University. Simroid is a next generation training robot for the dental student which has exceptional emotional output caliber with an ability to react to an inappropriate touch by the dentist.[4] The VirDenT project was developed for teaching dental students on abutment preparation through augmented audio and video rendering. In another study, students trained using AR displayed better class I cavity extension and better divergence of proximal walls in class II cavities.[15]
Fuzzy logic is another aspect of machine learning that imitates the ability of human reasoning that works with vague terms and provides valuable solutions for the fuzzy (blur) problem.[7] A system based on fuzzy logic was designed to assist dental professionals in a study by Mago VK, Mago A, Sharma P and Mago J[18] which uses imprecise values relating to the signs and symptoms of mobile teeth. In another study by Ambara B, Putra D and Rusjayanthi D[19], a fuzzy logic based system was developed which modified the consultation process so as to alleviate fear in the patient while being beneficial with respect to time and cost.

3. CONCLUSION

Innovation leading to improved therapy is a responsibility on the shoulders of every physician without which progress cannot be made. Abandoning such endeavors on the grounds of cost, fear of negative effect on business or threat to dentists would be doing disservice to humanity. The success of rotary endodontics owing to metallurgical improvements in the NiTi alloy today, which was once criticized in the days of stainless steel instruments, is a case in point for this argument.[20] Unavailability of accurate and sufficient data is an obstacle in the way of AI and it is the paedodontist's responsibility as any other healthcare professional to collect and cache an authentic database for optimum utilization for AI in dentistry in the near future. Despite its immense advantages, confidential data management and economic considerations are some of the most pressing uncertainties handicapping its use. The road to reality in nanorobotics certainly is worth pursuing; however, it is paved with challenges such as a high cost in research and development and bureaucratic resistance. Insulating the robots, so as to avoid any stray electromagnetic fields that might affect other biomolecular systems in the body and vice-versa and the availability of biocompatible materials, which would eliminate the risk of self-replication in these devices, are matters that warrant consideration.

4. REFERENCES

[1] Grischke J, Johannsmeier L, Eich L, Griga L and Haddadin S. Dentronics: Towards robotics and artificial intelligence in dentistry. Dental Materials. 2020 Apr 27;36(6):765-778
[2] Fan J, Fang L, Wu J, Guo Y and Dai Q. From Brain Science to Artificial Intelligence. Engineering. 2020 Mar 1;6(3):248-52.
[3] Arntz A, Van Eck M and Heijmans M. Predictions of dental pain: The fear of any expected evil, is worse than the evil itself. Behaviour Research and Therapy. 1990 Jan 1;28(1):29-41.
[4] Rawtiya M, Verma K, Sethi P and Loomba K. Application of robotics in dentistry. Indian J Dent Adv. 2014 Oct 1;6(4):1700-6.
[5] Kukreja BJ, Dodwad V and Singh T. Robotic dentistry-the future is at the horizon. J Pharm Biomed Sci. 2012;16(1):1-4.
[6] Freitas Jr RA. Nanodentistry. The Journal of the American Dental Association. 2000 Nov 1;131(11):1559-65.

[7] Tandon D and Rajawat J. Present and future of artificial intelligence in dentistry. Journal of Oral Biology and Craniofacial Research. 2020 Jul 24.

[8] De Weijer AP, Lucasius CB, Buydens L, Kateman G and Heuvel HM. Using genetic algorithms for an artificial neural network model inversion. Chemometrics and Intelligent Laboratory Systems. 1993 Aug 1;20(1):45-55.

[9] Łodygowski T, Szajek K and Wierszycki M. Optimization of dental implant using genetic algorithm. Journal of Theoretical and Applied Mechanics. 2009;47:573-98.

[10] Li H, Lai L, Chen L, Lu C and Cai Q. The prediction in computer color matching of dentistry based on GA+ BP neural network. Computational and mathematical methods in medicine. 2015 Mar 22;2015:1-7.

[11] Tripathi P., Malathy C. and Prabhakaran M. Genetic algorithms based approach for dental caries detection using back propagation neural network. Int J Recent Technol Eng. 2019;8: 2277-3878.

[12] Moghimi S, Talebi M and Parisay I. Design and implementation of a hybrid genetic algorithm and artificial neural network system for predicting the sizes of unerupted canines and premolars. The European Journal of Orthodontics. 2012 Aug 1;34(4):480-6.

[13] Nieri M, Crescini A, Rotundo R, Baccetti T, Cortellini P and Prato GP. Factors affecting the clinical approach to impacted maxillary canines: A Bayesian network analysis. American journal of orthodontics and dentofacial orthopedics. 2010 Jun 1;137(6):755-62.

[14] Käkilehto T, Salo S and Larmas M. Data mining of clinical oral health documents for analysis of the longevity of different restorative materials in Finland. International Journal of Medical Informatics. 2009 Dec 1;78(12):e68-74.

[15] Kwon HB, Park YS and Han JS. Augmented reality in dentistry: A current perspective. Acta Odontologica Scandinavica. 2018 Oct 3;76(7):497-503.

[16] Lumbini P, Agarwal P, Kalra M and Krishna KM. Nanorobotics in dentistry. Ann Dent Spec. 2014 Jul;2:95-6.

[17] Gulrez T, Shahid AK, Sana U and Chaudhary NG. Visual guided robotic endodontic therapeutic system. In2010 International Conference on Information and Emerging Technologies 2010 Jun 14 (pp. 1-6). IEEE.

[18] Mago VK, Mago A, Sharma P and Mago J. Fuzzy logic based expert system for the treatment of mobile tooth. Advances in Experimental Medicine and Biology 2011Jan 1;696:607-614.

[19] Ambara B, Putra D and Rusjayanthi D. Fuzzy Expert System of Dental and Oral Disease with Certainty Factor. 2017 May 1;14:22-30.

[20] Anthony J. Rotary instrumentation. Clinical techniques in small animal practice. 2001 Aug 1;16(3):182-5.

