ISSN: 2582-9904

LITERATURE REVIEW

Dental Implant Identification Methods - a Narrative Review

Veena Benakatti[a]

ABSTRACT

Dental implants are a well-accepted prosthetic alternative for missing teeth. After implant restoration, they will need maintenance in due course of time due to biological and mechanical complications, during which information about the implant system is required. Until today there is no well-established method for implant identification and conventional tools such as interpretation from radiographs need time and effort. Researchers have proposed several methods for implant identification and the review focuses on a comprehensive discussion of the proposed methods. For this review, comprehensive data from databases, including PubMed, Scopus, Web of Science, Cochrane, and Google Scholar, was thoroughly examined ensuring the most up-to-date and relevant information regarding implant identification. The proposed methods include an interpretation from radiographs based on the implant design specifications listed, implant records, implant recognition software, retrieving implant information through a wireless reader from a radiofrequency chip fitted into an implant screw hole, QR-encoded implant identification wallet, bar code encryption by implant manufacturers, incorporating laser-etched batch and serial numbers in implant collars, Sharma Jhingta system of implant identification and artificial intelligence methods. Amongst existing methods, AI research shows potential in offering a quick and accurate method of implant identification however developing a robust AI model with a comprehensive database is a complex task and requires considerable effort and time.

Key words: Dental implants, Radiographs, Artificial intelligence

How to cite this article: *Veena Benakatti. Dental Implant Identification Methods-a Narrative Review. J Clin Prosth Impl 2024;6(2):36-40.* ***https://doi.org/10.55995/j-cpi2024008***

INTRODUCTION

Teeth make an integral part of general well-being, missing teeth can impact significantly and addressing this becomes a priority to restore optimal health. Dental implants have become the most accepted prosthetic alternative for missing teeth and are expected to remain a preferred choice for clinicians and patients. Dental implants offer varied advantages over conventional replacement alternatives. Dental implants will need further repair and maintenance in due course of time due to biological and mechanical complications. During this phase, clinicians need information about the implant system used, abutment type, fixation method etc.[1,2]

Each implant is unique to its brand and varies in make, shape and design, and will need specific components or tools during the repair. Identifying the implant brand is crucial for further intervention and the conventional tools available for implant identification are the patient's previous records and radiographs. When implant records are not available or the patient chooses to make follow-ups in other regions of the world, the identification process becomes challenging to the clinicians.[3] Then clinician turns to radiographs making an assumption about the implant system in question based on the make and shape of the implant, which is less accurate and needs significant time and effort. Errors in implant identification may result in compromised treatment, potential complications, unnecessary expenses incurred in the refabrication of prostheses etc.[4]

The difficulty of implant identification is influenced by factors such as implant market size and variety of designs, dental tourism, and the clinician's experience.[3] The plethora of designs by over 220 implant manufacturers across the globe,[5] evolving implant designs to meet changing needs makes it challenging for clinicians to remember these different designs and identify when needed. Dental tourism has become a trend today as patients travel globally for dental treatment based on cost and convenience. Patients may get dental implants placed at one place and may choose to restore or follow up at another region.[3] Clinicians face significant challenges in identifying implants without relevant records. The ease of identification is proportional to the experience of the clinicians. It becomes a

[a] Reader, Department of Prosthodontics and Crown and Bridge, KAHER'S KLE VK Institute of Dental Sciences, Belagavi, Karnataka, India.

task for clinicians less familiar with various implant brands and designs.

Considering these challenges several methods have been proposed for implant identification and the current review focuses on discussing the various methods for implant identification spanning from earlier to current approaches.

MATERIALS AND METHOD

For this review, comprehensive data from databases, including PubMed, Scopus, Cochrane, and Google Scholar, was thoroughly examined. For a literature search, the keywords used were dental implant identification, dental implants, classification, artificial intelligence, deep learning and a combination of these keywords. Only English-language journal articles, conference proceedings and patents published until 2023 were included, ensuring the most up-to-date and relevant information regarding implant identification.

Figure 1 depicts a flowchart showing the process of study selection following PRISMA guidelines. The titles and abstracts were screened for inclusion criteria i.e., studies that provide insights into the methods and technologies used for the identification of dental implant systems. These included original research articles, review articles, systematic reviews, conference proceedings and patents. The full text of articles was screened adhering to the inclusion criteria. Studies that do not provide insights into dental implant identification methods were excluded.

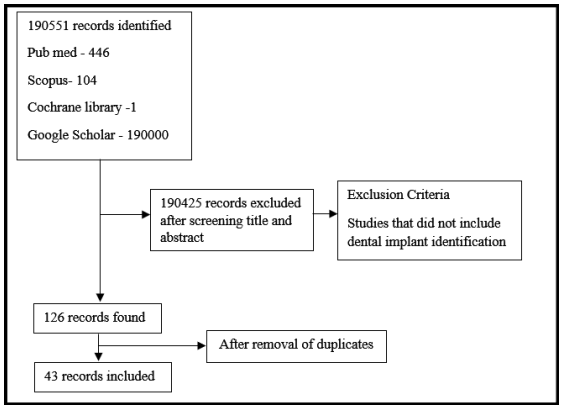

Figure 1: Flowchart showing the process of study selection by PRISMA guidelines.

RESULTS

The search strategy yielded forty-three articles that provided insights into dental implant identification. After screening the full text and eliminating duplicates, the data from selected articles were extracted in a Microsoft Excel sheet which included, the author, title, journal, year, language of publication, type of manuscript, objectives and findings of the study. The selected studies range from past to present perspectives and gave a wide range of insights about dental implant identification, emphasising the need for dental implant identification, challenges encountered in identification, different methods suggested by authors, and original research testing AI models in dental implant identification. Among selected studies, 27 studies tested the performance of AI models in dental implant identification.

Author	The proposed method of implant identification	Limitations
Sahiwal I G. et al[6]	Documented the basic design of dental implants that would help clinicians identify these design features in a radiograph to identify the brand	Limited database of dental implants which was not updated. It is a manual identification that may lead to errors and is subjective.
Sahiwal I G. et al[7,8]	Documented the design features from radiographic images of dental implants to help clinicians identify dental implants based on these features.	Limited database of dental implants which was not updated. It is a manual identification that may lead to errors and is subjective.
Michelinakis et al[9]	Implant recognition software	Limited database which was not updated later.
Rami Jandali[10]	Retrieving implant information from a radiofrequency chip fitted into an implant screw hole through a wireless reader.	A wireless reader sends electromagnetic waves to activate the chip which could be hazardous to humans, and every clinician may not be equipped with this special device.
Daher et al[11]	Implant record form	Records may become inaccessible due to various reasons.
Lustig et al[12]	QR-encoded implant identification wallet	QR code cards may be lost or become inaccessible due to various reasons.
Sharma D et al[13]	Sharma Jhingta system of implant identification	Records may become inaccessible due to various reasons.

Table 1: Proposed implant identification methods and their limitations.

DISCUSSION

The articles obtained from the search strategy were studied and the implant identification methods recommended are summarised and presented. Sahiwal I G. et al[6] documented the basic design of dental implants that would help clinicians identify these design features in a radiograph to identify the brand. They collected implants from manufacturers and segregated them as threaded, non-threaded, tapered and non-tapered and documented the design features into coronal, apical and midbody. These features included connection, thread type, collar, flange and some unique features. This document gives basic knowledge about the design of different implant brands and helps clinicians identify implants from radiographs. In similar studies conducted by the same researchers, the design features were documented using radiographic images of dental implants taken at specific angulation between –10°and +10°vertical inclination.[7,8] In the initial study, visual features were documented and in the subsequent study, they documented radiographic features to provide basic knowledge of implant designs. Although design documentation gave basic information, it was limited to a few implant systems and clinicians had to read features from the document and correlate them in a radiograph which would be time and

effort-consuming. Michelinakis et al[9] proposed implant recognition software. They collected all relevant information including images of different implant brands through an internet search using the keywords, dental implants, dental implant manufacturers, and dental implant companies. With 231 implant designs produced by 87 manufacturers across 21 countries, they created a database of known implant systems. Several leading questions regarding the implant in question will retrieve possible matching implants from the database. To identify an implant, information in each of the drop-down menus i.e., implant details should be fed manually. It will provide possible matching implants based on information fed, and then, a dentist has to match with that of the implant in question to conclude regarding the implant system. The software does not directly analyse the images but provides matching implants based on answers to the queries, and then, a dentist has to match them with that of the patient which is time-consuming. Although the software initially offered some help, later it was not updated with a comprehensive database. Rami Jandali developed a miniature radiofrequency chip which is fitted into a dental implant screw hole, and the chip is laden with information about the implant system. A wireless reader communicates with the chip and implant information is retrieved.[10] A wireless reader sends electromagnetic waves to activate the chip which could be hazardous to humans, and every clinician may not be equipped with this special device. Daher et al recommended maintaining an implant record form with complete information about the implant and one copy to be given to the patient and another to be retained with the clinician.[11] Patients may lose the form or may choose to visit another clinic at another place based on their preference and convenience, either way, the record is of no use. Lustig et al proposed the use of a QR-encoded implant identification wallet providing a universal identification method. The software for creating these QR-encoded cards is CardExchange Producer Premium available online from CardExchange Solutions. The process for creating the cards involves opening the CardExchange program, configuring the layout, and connecting to a patient database, the database should include patient information such as name and details about the implant. Patient information is imported into the card design, including implant site, company, type, restoration, and torque value. The finalised card is saved and printed, featuring scanning capabilities for quick identification using a smartphone equipped with a QR Reader.[12] Sharma D et al surveyed 104 implantologists to understand record-keeping systems and dental implant identification process for dental implant patients. 86.7% of the practitioners used conventional patient treatment cards to maintain data and practice management software and photographs were used by 5.3%. They found that 77% depended on clinical judgement and radiographic interpretation for implant identification. Seeking colleague's help and internet sources was considered by 37.3% of professionals. 9.3% sought help from implant identification apps.[13] Sharma D et al proposed the Sharma Jhingta system of implant identification, numbering, and nomenclature system. The first and second components of the system involved quadrant and tooth numbers as per the FDI system revealing implant location. The third component involves a symbol for an endosseous implant. The fourth component involves the diameter and length of the implant. The fifth component involves the brand and manufacturer of the implant. implant manufacturer reference card/ warranty card suggested to be attached with patient card. The sixth component gave information about prosthesis, material and retention type. The seventh component is for additional information such as implant abutment connection. This system was suggested by authors for documentation and communication.[13] The use of bar code encryption by implant manufacturers to be adopted as medical device regulations and incorporating laser-etched batch and serial numbers in implant collars to retrieve implant information have been suggested in the literature.[13-15]

Morais P et al proposed a novel computer-aided framework for dental implant recognition. This method was based on image processing concepts using a machine learning technique, the k-nearest neighbour (k-NN) classifier. A KNN classifier compares the unknown input data with all the labelled data present in the reference database and puts it into a category that is most similar to input data. This study aimed to introduce the concept of identifying an unknown dental implant using a framework based on image-processing concepts.[16] With advancements in technology, new tools like artificial intelligence (AI) have been researched for implant identification. Artificial intelligence, a branch of computer science can replicate human cognition to produce human-like responses to accomplish specific tasks. AI is gaining significant importance in medical imaging diagnosis as it can analyse complex patterns in an image and offer predictions and classifications.[17,18] This was adopted by several researchers to identify implants in radiographs. A special class of AI suited for image classification is deep learning (DL) which automates data preprocessing to generate features for optimising classification tasks. DL performs the task of image recognition and classification through convolutional neural networks (CNN). The CNNs when applied to input data isolate patterns like vertices, edges, and other high-level elements in the

implant image to classify implants.[17,18] Image classification using DL technology typically involves data collection, labelling, training, and performance analysis using metrics. The data to train the DL model comprises digital radiographs of implants, the data is split into training and testing datasets, the training dataset is used to train the DL model while the testing dataset analyses the performance of the trained DL model. Many studies[19-23] have tested different DL models such as YOLOv3, VGG-19 (visual geometry group), GoogLeNet Inception-v3, ResNet-50, Pretrained GoogLeNet Inception, SqueezeNet, EfficientNet, Res2Next, ResNet-18, MobileNet-v2, ResNet-50 etc and reported accuracies range from 71% to 98%. This indicates the potential of DL models in implant identification. The studies[24-31] using AI in implant identification are rising with time indicating the advent of AI technology in the realm of implant recognition. With the upcoming state-of-the-art image processing DL models and larger sample sizes, it is possible to achieve a higher accuracy in implant identification. While the previous AI studies used digital radiographs for model training, Yang S et al evaluated implant identification of DL models using CBCT images and achieved great accuracy.[32] To develop AI models, larger and well-organised datasets are crucial, however, the healthcare domain poses a unique challenge due to patients' privacy and confidentiality issues. More diverse studies across the globe employing various DL models with larger datasets will prove the generalizability of AI in implant identification. However, several websites and apps offer AI-based implant identification but the accuracy remains variable. Following Table 1 summarises the proposed implant identification methods and their limitations.

CONCLUSION

As global awareness of oral health is rising, patients seeking dental implants will continue to grow and so the implant market. Maintenance of implants will need information about the implant system and identifying the implant when lacking access to records is a challenging task for clinicians. The available methods are inaccurate and need time and effort. Although certain apps and websites are offering implant identification services their accuracy remains questionable. This problem requires immediate attention necessitating the development of a quick and scientific method for implant identification. AI research shows potential in offering a quick and accurate method of implant identification however developing a robust AI model with a comprehensive database of active and discontinued implant brands is a complex task and requires considerable effort and time.

CONFLICT OF INTEREST:

There was no conflict of interest

REFERENCES

1. Lee JH, Kim YT, Lee JB, Jeong SN. A performance comparison between automated deep learning and dental professionals in the classification of dental implant systems from dental imaging: A multi-center study. Diagnostics (Basel) 2020; 10:910.
2. Takahashi T, Nozaki K, Gonda T, Mameno T, Wada M, Ikebe K. Identification of dental implants using deep learning-pilot study. Int J Implant Dent 2020; 6:53.
3. Saghiri MA, Freag P, Fakhrzadeh A, Saghiri AM, Eid J. Current technology for identifying dental implants: A narrative review. Bull Natl Res Cent 2021; 45:1-11.
4. Kim JE, Nam NE, Shim JS, Jung YH, Cho BH, Hwang JJ. Transfer learning via deep neural networks for implant fixture system classification using periapical radiographs. J Clin Med 2020; 9:1117.
5. Sukegawa S, Yoshii K, Hara T, Yamashita K, Nakano K, Yamamoto N, et al. Deep neural networks for dental implant system classification. Biomolecules 2020; 10:984.
6. Sahiwal IG, Woody RD, Benson BW, Guillen GE. Macro design morphology of endosseous dental implants. J Prosthet Dent. 2002; 87:543-51.
7. Sahiwal IG, Woody RD, Benson BW, Guillen GE. Radiographic identification of threaded endosseous dental implants. J Prosthet Dent. 2002; 87:563-77.
8. Sahiwal IG, Woody RD, Benson BW, Guillen GE. Radiographic identification of nonthreaded endosseous dental implants. J Prosthet Dent. 2002; 87:552-62.
9. Michelinakis G, Sharrock A, Barclay CW. Identification of dental implants through the use of Implant Recognition Software (IRS). Int Dent J 2006; 56:203-8.
10. Jandali R. Global Implant Solutions llc. Dental Implant Identification System. United States Patent US20090155744A1; 18 June 2009.
11. Daher T, Goodacre CJ, Morgano SM (2009) Implant treatment record form. J Prosthodont Implant, Esthetic Reconst Dent 2009:18:366–68
12. Lustig LL, Gozalo-Diaz D. Creating QR-coded identification cards using CardExchange for straightforward

identification of implant systems. J Prosthet Dent. 2020; 124:623-24.
13. Sharma D, Jhingta P, Bathla SC. Challenges in Dental Implant Identification and Need of Universal Dental Implant Identification, Numbering, and Nomenclature System. Int J Prosthodont Restor Dent 2020; 10:146–50.
14. Berketa JW, Hirsch RS, Higgins D, James H. Radiographic recognition of dental implants as an aid to identifying the deceased. J Forensic Sci 2010: 55:66–70
15. Berketa J, James H, Marino V. Survival of batch numbers within dental implants following incineration as an aid to identification. J Forensic Odontostomatol 2010; 28:1–4.
16. Morais P, Queirós S, Moreira AHJ, Ferreira A, Ferreira E, Duque D, et al. Computer-aided recognition of dental implants in X-ray images. Proc. SPIE 9414, Medical Imaging 2015: Computer-Aided Diagnosis, 94142E
17. Huang C, Wang J, Wang S, Zhang Y. A review of deep learning in dentistry. Neurocomputing 2023: 554:126629.
18. Corbella S, Srinivas S, Cabitza F. Applications of deep learning in dentistry. Oral Surg Oral Med Oral Pathol Oral Radiol. 2021; 132:225-38.
19. Jae-Hong, L. Identification and classification of dental implant systems using various deep learning based convolutional neural network architectures. Clin Oral Impl Res, 2019;30: 217.
20. Lee JH, Kim YT, Lee JB, Jeong SN. A performance comparison between automated deep learning and dental professionals in classification of dental implant systems from dental imaging: A Multi-Center Study. Diagnostics (Basel). 2020; 10:910-19.
21. Hadj Saïd M, Le Roux MK, Catherine JH, Lan R. Development of an artificial intelligence model to identify a dental implant from a radiograph. Int J Oral Maxillofac Implants. 2020; 36:1077-82.
22. Takahashi T, Nozaki K, Gonda T, Mameno T, Wada M, Ikebe K. Identification of dental implants using deep learning -pilot study. Int J Implant Dent. 2020; 6:53-9.
23. Sukegawa S, Yoshii K, Hara T, Yamashita K, Nakano K, Yamamoto N et al. Deep neural networks for dental implant system classification. Biomolecules. 2020;10: 984-97.
24. Kim JE, Nam NE, Shim JS, Jung YH, Cho BH, Hwang JJ. Transfer Learning via Deep Neural Networks for Implant Fixture System Classification Using Periapical Radiographs. J Clin Med. 2020; 9:1117-28.
25. da Mata Santos RP, Vieira Oliveira Prado HE, Soares Aranha Neto I, Alves de Oliveira GA, Vespasiano Silva AI, Zenóbio EG et al. Automated identification of dental implants using artificial intelligence. Int J Oral Maxillofac Implants. 2021; 36:918-23.
26. Lee JH, Kim YT, Lee JB, Jeong SN. A performance comparison between automated DL and dental professionals in classification of dental implant systems from dental imaging: A multi-center study. Diagnostics (Basel). 2020; 10:910-19.
27. Lee JH, Jeong SN. Efficacy of deep convolutional neural network algorithm for the identification and classification of dental implant systems, using panoramic and periapical radiographs: A pilot study. Medicine (Baltimore). 2020;99: e20787.
28. Sukegawa S, Yoshii K, Hara T, Matsuyama T, Yamashita K, Nakano K et al. multi-task deep learning model for classification of dental implant brand and treatment stage Using dental panoramic radiograph images. Biomolecules. 2021; 11:815-29.
29. Kim HS, Ha EG, Kim YH, Jeon KJ, Lee C, Han SS. Transfer learning in a deep convolutional neural network for implant fixture classification: A pilot study. Imaging Sci Dent. 2022; 52:219-24.
30. Kong HJ, Eom SH, Yoo JY, Lee JH. Identification of 130 dental implant types using ensemble deep learning. Int J Oral Maxillofac Implants. 2023; 38:150-56.
31. Park W, Huh JK, Lee JH. Automated deep learning for classification of dental implant radiographs using a large multi-center dataset. Sci Rep. 2023; 13:4862.
32. Ou-Yang S, Han S, Sun D, Wu H, Chen J, Cai Y et al. The preliminary in vitro study and application of deep learning algorithm in cone beam computed tomography image implant recognition. Sci Rep. 2023; 13:18467.

Corresponding Author: Dr. Veena Benakatti, Dept of Prosthodontics and Crown and Bridge, KAHER'S KLE VK institute of dental sciences, Neharu nagar, Belagavi-590010, Karnataka, India
E-mail: drveenabenakatti@kledental.-bgm.edu.in , Ph.No.: +91 9481357779