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Review Article

# Identifying implant abutments and fixtures by application of deep learning concept through artificial intelligence – A review

**Ilavarasan Anbazhagan[1]*, R Ravichandran[1], Harsha Kumar K[1], Vivek V Nair[1]**

[1]*Dept. of Prosthodontics, Government Dental College, Trivandrum, Kerala, India*

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ABSTRACT

Artificial intelligence (AI) is an evolving and assuring approach in healthcare and has begun to improve the dental science ever since. A subgroup of AI called deep learning (DL) related convolutional neural network algorithm have showed significant applications in computer based tasks and have been shown to be fairly applicable for dental image recognition and treatment planning analysis. This article aims to review the adaptation of artificial intelligence in identifying implant systems and abutments using deep learning concept.



## 1. Introduction

Dental implants have been a forerunner and an emerging choice of rehabilitation of missing teeth. The history of developement of dental implants has a royal and innovative travelogue through time.[1] From using gold wire and pieces of shell during 600 AD by the Mayan population to the development of threaded titanium root form implants by Branemark in 1970's and making its way to the utilisation of tissue engineering supported Liga implants, the journey and new unfolding in this field everyday makes it enthralling and noteworthy.

Thousands of manufacturers worldwide are in a race to invent and distribute over 2000 different kinds of dental implant systems that differ in size, shape, dimensions, diameter, coating ,surface materials and properties.[2,3] The success of an implant is variable and depends on several factors such as patient factors, implant factors, procedural factors and post procedural care. Osseointegration of implant is an indicator of implant success. Several surface modifications such as acid etching, anodization, plasma spraying to the use of nanoscale materials through design and interfacial engineering have revamped the odds of clinical success of implants. It is pivotal for the practitioners to select appropriate DIS (dental implant system) for particular clinical indication and contra-indications based on their personal experience and skillset.

The inability to trace implantable devices (IMD) is a major limitation of modern medicine. The number and diversity of implantable device's are on the rise in all surgical fields making it more challenging to identify.[4] In the field of implant dentistry this issue translates into difficulty in identifying the system of implant placed by a dentist, hassle in pinning down the cause of failure of a system due to lack of traceability of manufacturer, challenges in forensic identification of an individual and post mortem aids in natural calamities to list a few.

Artificial intelligence (AI) is an innovative and assuring approach in oralcare and has started to change the future of dental field ever since. A sub-group of AI , deep learning (DL) based convolutional neural network algorithm have shown significant applications in computer insights and have proven to be mostly recommended and suitable for dental image recognition and treatment planning.[5] Many

* *Corresponding author*.
*E-mail address*: anbu.ilaa@gmail.com (I. Anbazhagan).

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new studies have suggested the precedence of DL in the identifying and differentiation of dental implant systems. This article aims to review the recent literatures and highlight the applications of deep learning in implantology and finding of implant systems and abutments.

## 2. Rise of AI in Today's Era

The booming industrial exploration opens a new digital era of most significant contributions is deep learning and artificial intelligence (AI).[6] AI is growing and spreading rapidly in all fields from its initial discovery in early 1950's with the rise of computer knowledge and AI algorithms, greater expectations to use AI in the medical and dental fields are being tried and tested every day. AI had its breakthrough in mid-1980's and divided into two category: Expert systems and Machine learning (ML). Expert systems human experts feed all possible situations and solutions in advance while Machine learning allows the computer to find a solution by learning and summarising by itself.[7]

### *2.1. Working pillars of AI*

Artificial intelligence is a adaptive term of non-human intelligence.[6] Artificial intelligence can be broadly categorised as strong AI and weak AI. Strong AI refers to intelligence and ability of AI equalling humans. Weak AI are used to perform a simple task. Expert systems and ML are subdivision of weak Artificial Intelligence. Deep learning is a major research area, and a subfield of Machine Learning. Neural networks (NN) are of biologically oriented networks that can be considered as pillars of deep learning algorithms. Convolution neural network (CNN) is one of the of neural network that is mainly used for image recognition and analysing.

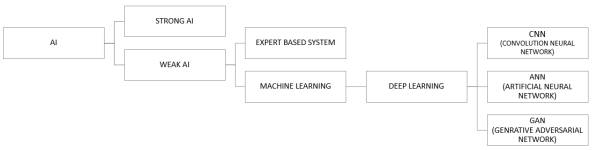


**Figure 1:**

### *2.2. Principle*

The main principle of Convolutional Neural Network in image recognition is to feed in to a computer data which have many previously sorted images and teaching to automatically identify it by using computed calculations.[8] The information data passes from first level input to the last level output by getting sorted at each level. The principle of working allows to identify the common shape of images, next layer identifies the angles and then its edges, structures and points. After passing through layers of the neural network the image is interpreted by the computer algorithms and the image is identified.

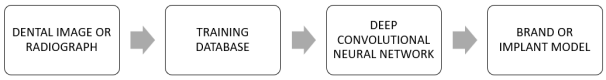


**Figure 2:**

### *2.3. Individualised Patient Care – AI Supported Dentistry*

Providing Help to clinical practitioners by providing better care on a consistent basis is one of the main goals of implementing AI in clinical implant dentistry. Data analysing and AI applications are applied at all levels of the patient journey and in every dental specialty fields and departments.[6]

The application of AI can be broadly classified into

The numerous studies using AI, especially deep and machine learning, is rapid expanding in dentistry mainly in dental implantology. Artificial intelligence assists to make clinical decisions, to diagnose patients and predict dental failure may alert dental practitioners in every ways, hence decreasing chair time, giving additional steps, implementing excellent infection control, and acheiving good quality dental treatment. Anyways AI is still in the starting stages of research yet More research is important to analyse the clinical performance of AI methods in dentistry. This study has provided an outlook of available research that assessed Artificial intelligence models for implant abutment and fixture recognition.

## 3. Application of AI in Implant Identification

### *3.1. Implant identification from periapical and panoromic radiographs*

Several studies have been done in past decade that have compared various convolutional neural network algorithms in recognition of dental implant types and systems from periapical and panoramic images. The studies have been enlisted in the Table 2.

### *3.2. Implant identification from CBCT using AI*

Bayrakdar et al[14] conducted a study using seventy five CBCT images to compare the manual assessment of bone thickness and height with the deep convolutional neural network algorithm. While measuring bone density, there were statistically alarming differences between manual and AI measurements in all regions of mandible and maxilla ($p < 0.001$). Also, the percentage of correct detection was 72.2% for canals, 66.4% for fossae and 95.3% for missing

**Table 1:**

| | Image analysis | Data analysis and prediction | Treatment outcome | Patient interaction |
|---|---|---|---|---|
| Prosthodontics | Dental implant system identification | Bone analysis for implant planning | Implant implacement | |
| | Forensic odontology | | Fixed and removable prosthesis planning | Educaton of patient regarding • Results • Possible complications • alternative treatment options • Customisation and individualised care |
| | Implant failure detection | Crown placement and shade selection | Crown debonding | |
| | Evaluation of occlusion | Maxillofacial prosthetic planning | Dental arch classification | |
| Periodontology | Image enhancement and noise reduction | Periodontal bone loss detection | Severity of periodontal disease progression | |
| | | Severity of periodontally compromisd teeth | | |
| Oral and maxillofacial surgery | Ian and third molar relation | Anticipated difficulties in planned surgical procedures | Premalignant conditions diagnosis | |
| | Pathology detection in cbct and periapical radigraphy | | OSCC diagnosis | |
| Endodontics | Periapical radiography interpretation | Dental caries and wasting diseases identification | Preogression of periapical pathology | |
| | Appreciation of post endodontic seal | Periapical lesion detection | | |
| | | Tooth fracture diagnosis | | |
| Orthodontics | Tooth and alveolar bone segmentation | Orthodontic treatment prediction | Tooth extraction determination in orthodontic treatments | |
| | Cephalomteric landmark location | Need for surgical intervention | | |

tooth areas. They concluded that growth of AI systems and their application in future for implant treatment planning will both initiate the work of physicians and will be a major support mechanism in dental implantology departments.

Similar study by Yang et al[15] to analyse deep learning and their supporting application software to recognize and categorize three dimensional (3D) (CBCT) images of dental implants and concluded that the ResNet 152 V2 has the best classification criteria effect on identifying implants. The artificial intelligence application and identification system software based on this algorithm can accurately and efficiently recognize the specifications and brands.

In a systematic review by Chaurasia et al[16] documented that Deep Learning can be used as primary decision-aid tool for skilled dental clinicians to improve the accuracy of the detection of Dental Implant System. And it is believed that, since Deep Learning algorithms are continously improving, it is not advisable to differentiate Dental implant System solely based on these data, and clinical knowledge should be supported by AI to make this decision.

A systematic review by Revilla-León et al[17] observed that total accuracy range of 93.8%-98% of the Artificial intelligenceI models in the various research studies. Many of the research studies derived data from a 2 Dimensioal radiograph, such as a periapical or panoramic radiograph. So far, CBCT is not been applied for data derivatives to practice AI models. This is previously supported by a review by Correa et al[18] who had queries on the sharpness and resolution of CBCT and suggested that it may be as less as compared to peripheral and panaromic radiographic images. Hence, whether CBCT can be used for the identification and classification of DIS by AI is still under debate.

## 4. Discussion

The usage of AI has already started to change the future of dental science, since Artificial intelligence models have shown same or more accuracy to that of dental practitioners and professionals in many clinical areas, including endodontics, implantology, prosthodontics, maxillofacial surgery,periodontics and orthodontics. many recent studies have concluded that deep learning is superiorly accurate in the classification and identification of various types of DISs, and the classification efficiency of deep learning systems

**Table 2:**

| Author | Source | Implant system | Convolutional neural network – algorithm | Results/conclusion |
|---|---|---|---|---|
| Hadj said et al (2020) [8] | 1206 dental radiographic images | 6 , Brånemark System, Nobel Active, , , Zimmer Biomet Tapered Screw-Vent, SwissPlus,Nobel Biocare, Straumann BL and TL | Pre trained Google Net Inception v3 | Diagnostic sensitivity – 93.5% Specificity – 94.2%, Negative predictive value – 91.5%, Positive predictive value – 92% |
| Lee et al (2020) [9] | 10,770 panaromic and periapical images | 3 ( Dentium Superline ,TSIII, , Straumann BLT, Osstem) | pre trained Fine-tuned Google Net Inception v3 | Deep CNN architecture was very useful in identification and classification of dental implant by using panoramic & periapical radiographic images. |
| Kim et al (2020) [10] | 801 periapical images | 4 ( Straumann BL and TL , Dentium Implantium Brånemark Mk TiUnite, ,) | ,Squeeze Net GoogLeNet, Pre trained ResNet-18, Pre trained Mobile Net-v2, and Pre trained Res Net-50 | All CNN models Have shown a test accuracy of 90% CNN can divide the 4 implant fixtures with more accuracy even with a relatively less network and minimal number of images. |
| Sukegawa et al (2020) [11] | 8859 panaromic images | 11 (, Astra EV 4.2, Astra OsseoSpeed TX 4.0/4.5, Zimmer Biomet Full OSSEOTITE 4.0 Astra MicroThread 4.0/4.5, , FINESIA 4,.2, Brånemark Mk III 4.0 Replace Select Tapered 4.3, , Straumann SP 4.1, Nobel Replace CC 4.3) | | Finely tuned VGG19 and VGG16 CNNs accurately classified dental implant systems in 11 different types of panoramic radiographic images |
| Takahashi et al (2020) [12] | 1282 panaromic images | 6 ( MK III Groovy , Speedy Groovy Nobel , Straumann BL Biocare MK III, , MK IV, MK IV, , GC Genesio Plus ST) | YOLO v3 with fine-tuning | Implants can be found from xray and panoramic radiographic images using AI deep learning-based object implant detection - helps clinicians and patients suffering from implant related issues. |
| Lee et al (2022) [13] | 7325 panaromic images | 6 (Astra OsseoSpeed TX, Osstem TSIII, Dentium Superline and Implantium, Straumann BL and BLT) | Customized deep convolutional neural network algorithm with automated architecture | outstanding improvement in the average division accuracy of DISs of mean accuracy: 78.88%) compared to that without the usage of the Deep learning algorithm where its mean accuracyis 63.13% |

has been proved to be similiar or superior to that of dental clinicians specialized or non-specialized in implantology.

The process of implant identification includes several steps. The images of dental implant were collected and pre-processed to remove any exploitable data. The images were augmented further to improve the image training. This forms the image training database. Convolutional neural network algorithm consists of interconnected nodes organised in several layers. As the implant image passes between the layers of CNN, each layer of the algorithm filters the image based on its character such as shape, size , surface etc.. until a assumption is made at the final level.

Several studies have been performed using various CNN systems to compare the identification of implant systems using dental radiographs and CBCT. These studies have stressed on the advantages of using deep learning methods in implant identification when compared to conventional implant identification methods. A metanalysis by Akhilanand Chaurasia et al[16] concluded that Deep Learning models proved superior accuracy in classifying and identifying Dental Implant Systems using periapical and panoramic radiographic images. Therefore, Deep Learning models are assuring methods to be used as decision-making tools and decision aids.

Although several advantages of deep learning models have been discussed, drawbacks of using artificial intelligence should never be overlooked. Most of Artificial Intelligence for health interventions introduced to date lack demonstrations of clinical or further benefit when compared with standard of dental care. The possible challenges in the field of AI dentistry include bias, selective accessibility of data, interoperability difficulties, reliability and validity of data to name a few.

Often, little, uneven or unrecognized datasets are used, resulting in AI suffering from less accuracy and generalizability as well as biases. This is to the core in data being siloed, limitedly interoperable, without standardized, and generally not available in sufficient breadth to retrieve representativeness. Recent steps for scientific data management need data to be acceptable, accessible, detectable, interoperable, and reusable by machines (FAIR principles).[19]

## 5. Conclusion

Based on the review of literature we would like to conclude that in an era of computer revolution and deep learning, artificial intelligence is a blooming field of research. The applications of AI in dentistry has improved patient care and treatment outcome. In days to come, artificial intelligence can overcome many of the possible drawbacks of prosthodontic speciality treatment, enhancing the accuracy and precision in its final outcome. In a way, the days are not far in which artificial intelligence will takeover by making treatment faster and accurate with minimal complications.

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## 7. Conflict of Interest

None.

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## References

1. Abraham CM. A Brief Historical Perspective on Dental Implants, Their Surface Coatings and Treatments. *Open Dent J*. 2014;8(1):50–5.
2. Jokstad A, Braegger U, Brunski JB, Carr AB, Naert I, Wennerberg A. Quality of dental implants. *Int Dent J*. 2003;53(6 Suppl 2):409–43.
3. Esposito M, Ardebili Y, Worthington H. Interventions for replacing missing teeth: Different types of dental implants. *Cochrane Database Syst Rev*. 2014;22(7):CD003815. doi:10.1002/14651858.CD003815.pub4.
4. Coombes R. Surgeons call for compulsory registers of all new medical devices. *BMJ [Internet]*. 2018;363:5010. doi:10.1136/bmj.k5010.
5. Lee J, Kim DH, Jeong SN, Choi SH. Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm. *J Periodontal Implant Sci*. 2018;48(2):114–23.
6. Ding H, Wu J, Zhao W, Matinlinna JP, Burrow MF, Tsoi JKH, et al. Artificial intelligence in dentistry-A review. *Front Dent Med*. 2023;4:1–13. doi:10.3389/fdmed.2023.1085251.
7. Schmidhuber J. Deep Learning in neural networks: An overview. *Neural Networks*. 2015;61:85–117.
8. Saïd MH, Roux MKL, 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(6):1077–82.
9. 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(11):910. doi:10.3390/diagnostics10110910.
10. Kim JE, Nam NE, Shim JS, Jung YH, Cho BH, Hwang JJ, et al. Transfer learning via deep neural networks for implant fixture system classification using periapical radiographs. *J Clin Med*. 2020;9(4):1117. doi:10.3390/jcm9041117.
11. 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(6):815. doi:10.3390/biom11060815.
12. 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(1):53. doi:10.1186/s40729-020-00250-6.
13. Lee JH, Kim YT, Lee JB, Jeong SN. Deep learning improves implant classification by dental professionals: a multi-center evaluation of accuracy and efficiency. *J Periodontal Implant Sci*. 2022;52(3):220–9.
14. Bayrakdar SK, Orhan K, Bayrakdar IS, Bilgir E, Ezhov M, Gusarev M, et al. A deep learning approach for dental implant planning in cone-beam computed tomography images. *BMC Med Imaging*. 2021;21(1):86. doi:10.1186/s12880-021-00618-z.
15. 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. doi:10.1038/s41598-023-45757-1.
16. Chaurasia A, Namachivayam A, Koca-Ünsal RB, Lee JH. Deep-learning performance in identifying and classifying dental implant systems from dental imaging: a systematic review and meta-analysis. *J Periodontal Implant Sci*. 2023;53(3):1–10.
17. Revilla-León M, Gómez-Polo M, Vyas S, Barmak BA, Galluci GO, Att W, et al. Artificial intelligence applications in implant dentistry: A systematic review. *J Prosthet Dent*. 2023;129(2):293–300.
18. Correa LR, Spin-Neto R, Stavropoulos A, Schropp L, Silveira HD, Wenzel A, et al. Planning of dental implant size with digital panoramic radiographs, CBCT-generated panoramic images, and CBCT cross-sectional images. *Clin Oral Implants Res*. 2014;25(6):690–5.
19. Wilkinson MD, Dumontier M, Aalbersberg I, Appleton G, Axton M, Baak A, et al. Comment: The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data*. 2016;3:160018. doi:10.1038/sdata.2016.18.

## Author biography

**Ilavarasan Anbazhagan,** Post Graduate Student https://orcid.org/0009-0000-8946-4095

**R Ravichandran,** Professor https://orcid.org/0000-0001-9518-7717

**Harsha Kumar K,** Vice Principal and HOD & Professor https://orcid.org/0000-0003-4417-5032

**Vivek V Nair,** Professor https://orcid.org/0000-0002-5833-5212

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