

# Resistance of a novel denture identification system to various assault: An *in-vitro* study

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## Abstract

**Aim:** Denture marking has been advocated and recommended by many forensic organizations. The prosthodontists can play a significant role in the identification of geriatric population by adopting denture marking as a routine procedure. These stickers are easily readable and can be connected to smartphone devices without the need of specific equipment, store information in variety of ways, and cost-effective. The purpose of this study is to evaluate NFC stickers against physical insult; acid, base, and heat.

**Settings and Design:** *In-vitro* evaluation study.

**Materials and Methods:** Denture bases were fabricated, using chemical and heat-cured acrylic resin. NFC stickers were incorporated using postfabrication inclusion method for chemically cured resin base and prefabrication inclusion method for heat-cured acrylic resin base. These bases were subjected to acid, alkali, and thermal insults.

**Statistical Analysis Used:** Descriptive statistics.

**Results:** Both pre and postfabrication inclusion NFC stickers were capable of withstanding various chemical and thermal assaults.

**Conclusion:** NFC stickers could be used as an adjunct to radio frequency identification (RFID) tags for denture identification. NFC stickers appear to be easy to use and more cost-effective than RFID tags.

**Keywords:** Denture labeling, forensic identification, near-field communication, radio frequency identification

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## INTRODUCTION

Forensic odontology is the branch of dentistry, that in the interest of justice, involves the management, examination, evaluation, and presentation of dental evidence in criminal or civil proceedings.<sup>[1,2]</sup> Forensic

odontology can help identification of individuals in mass disasters, detecting domestic violence in suspicious cases, and recognition of victims in situations where other evidence for identification are deliberately tampered. Various methods used in forensic odontology

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are previous dental records, bite marks, radiographs, denture ID tags, etc.

Denture identification has been around for many years. There are documented cases of dentures being used in postmortem identification from as early as 1835.<sup>[3-6]</sup> Apart from their advantage in forensic odontology, denture identification can help solve the ownership problem of lost dentures in long-term care facilities and hospitals.<sup>[7,8]</sup> Multiple different techniques and methods are practised that include surface engraving or embossing and incorporation of bar codes, photographs, PIN or radio frequency identification (RFID) tags,<sup>[5,6]</sup> but none of them fulfills the “ideal” of being simple, practical, affordable and universally acceptable.<sup>[2,9,10]</sup>

Near field communication (NFC) is a type of RFID technology that operates at a frequency of 13.56 MHz. They have a short distance of communication which is in range of 10 cm. The major advantage of NFC is that no specific interrogator AKA reader and controller is required (used in case of RFID)<sup>[8,11]</sup> as peer-to-peer (P2P) communication can be established between a smartphone and NFC tag.<sup>[12]</sup>

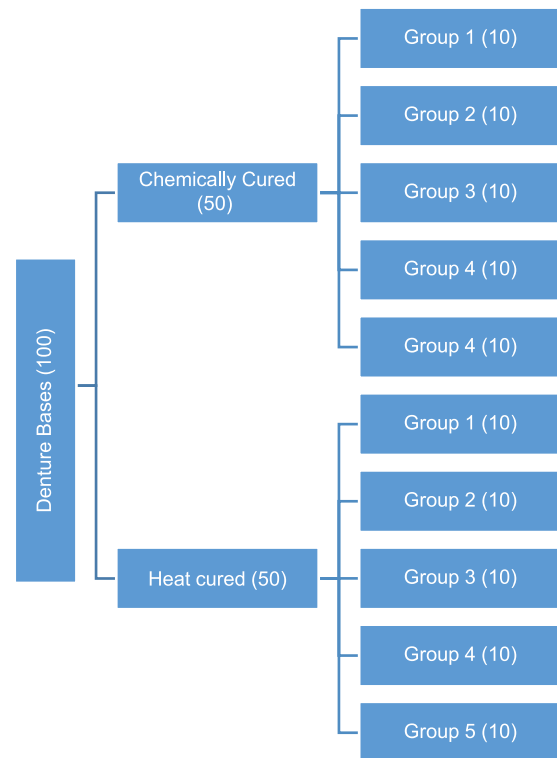
NFC technology is used in medical science as monitoring and home-based management system for variety of chronic disease. MiniME<sup>®</sup> by Ergonomidesign is one such device that monitors various parameters such as electrocardiography, heart rate, pulse and transmits the data to cloud through NFC. Another such device is FITBIT<sup>®</sup> which uses NFC to transfer details such as calories burned, number of steps taken.<sup>[13]</sup> Literature also mentions some recent concept about miniature NFC sensors that can be either implanted on skin, fingernails, teeth, or eyes to collect information from body fluids.<sup>[12]</sup>

Practical application of NFC in the field of dentistry is not limited to identification of complete dentures, removable prosthesis, orthodontic appliances, etc., or in forensic odontology as an aid for postmortem identification of deceased. However, they can also be used in finding lost dentures which will be discussed further in this article.

The purpose of this study is to evaluate NFC stickers against physical insult; acid, base, and heat.

## MATERIALS AND METHODS

The study was approved by Institutional review board. One hundred denture bases were fabricated, fifty with chemically cured acrylic resin (DPI, India) and other 50 using heat-cured acrylic resin (Pyrex, India) [Flow Chart 1]. Commercially available NFC stickers (LINKS<sup>®</sup>, India) NTAG216 NFC tag measuring 8 mm × 18 mm [Figure 1] were incorporated into denture bases.



**Flow Chart 1: Grouping of Samples**

### Prefabrication inclusion technique

Used for heat-cured acrylic resin, Tags were incorporated while packing. Small rectangle of 10 mm × 20 mm was cut from baseplate wax of 1 mm thickness. This wax piece was further wrapped in aluminum foil [Figure 2] and placed in the flask along with heat-cured polymethyl-meth acrylate (PMMA) in dough stage. A damped cellophane sheet was then placed and trial closure was performed. The flask was opened, wax-aluminum spacer was retrieved and NFC tag was placed along with heat-cured PMMA. Finally, the flask was closed, allowed to bench set and was cured at 100°C for 90 min [Figure 3a].

### Postfabrication inclusion technique

Used for chemically cured acrylic resin, a channel was cut at the palatal area of denture base of dimension 10 mm × 20 mm × 1 mm using a small round bur. NFC tag was placed, covered with self-cure clear acrylic (DPI, India), and cured under 30 psi pressure for 20 min [Figure 3b].

These bases were divided into five groups to check for different types of physical insult [Table 1].

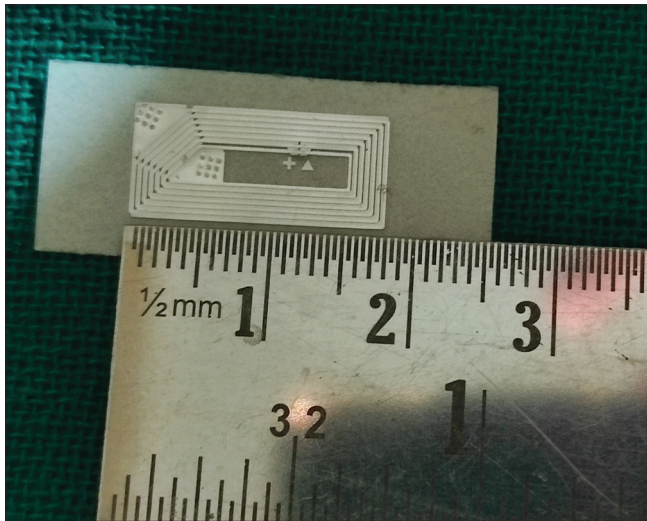
Group 1: Samples were immersed in 90% concentrated sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) for 24 h [Figure 4a].

Group 2: Samples were immersed in 98% concentrated sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) and evaluated after 24 h [Figure 4b].

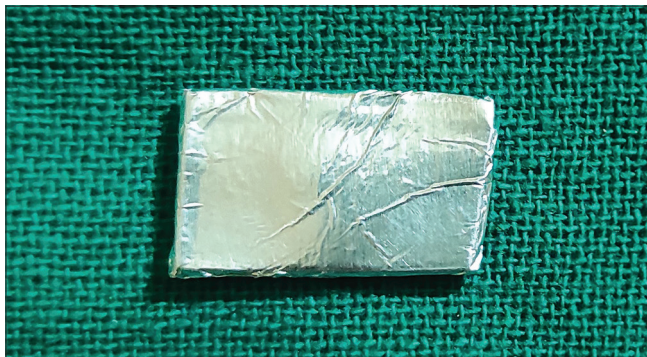
Group 3: Samples were kept in 60% concentrated sodium hydroxide (NaOH) for 24 h [Figure 4c].

Group 4: Incineration at 200°C for 20 min, followed by raising the temperature to 400°C and maintaining for 10 min [Figure 4d].

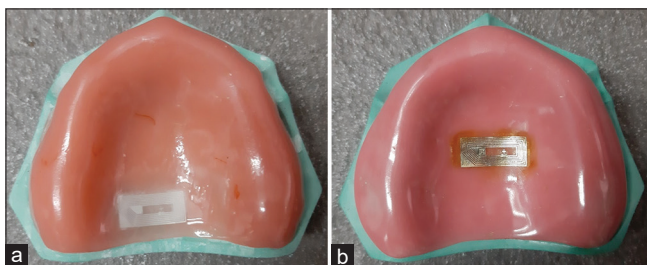
Group 5: Direct flaming of denture bases was done using a butane microtorch (Roburn, Taiwan) for 1 min, samples were allowed to burn for 3 min and then extinguished and assessed [Figure 4e].



**Figure 1:** NFC sticker (LINQS®, India) NTAG216 NFC tag; NFC: Near-field communication



**Figure 2:** Wax-aluminum foil spacer



**Figure 3:** Sample denture bases with NFC tag incorporated (a) heat-polymerizing PMMA sample, (b) self-polymerizing PMMA sample. PMMA: Polymethyl-meth acrylate, NFC: Near-field communication

After incorporating the tags using prefabrication and postfabrication inclusion technique, they were programmed with OnePlus 7T smartphone device (One Plus Tech. Co. Ltd., China) using NFC Tools application (downloaded from Google Play). Information fed to NFC tag included: (1) Sample number; (2) Type of PMMA used for fabricating base; (3) Physical insult performed on sample [Figure 5].

## RESULTS

The results of all groups are shown in Tables 1 and 2. Group 1 [Figure 6a], where the specimens were placed in 90% conc.  $H_2SO_4$  for 24 h showed complete deterioration of acrylic surface, however, the NFC tags were readable when tested after completely neutralizing the acid. Increased conc. Of  $H_2SO_4$  in Group 2 (98% conc.) lead to nonresponding NFC tags after 24 h. Only 2 out of 10 tags responded in heat-polymerizing PMMA group and none of the tags responded in self-polymerizing PMMA group. Group 2 [Figure 6b] depicted 20% positive result for heat acrylizing PMMA.

Group 3 [Figure 6c] involved placing NFC tags in 60% conc. NaOH. No physical change was seen on the surface of acrylic after a period of 24 h and all NFC tags were easily readable. For Group 4 [Figure 6d], Denture bases were placed in a preheated furnace at 200°C for 20 min, temperature was then raised to 400°C and maintained for another 10 min. Both denture bases suffered significant

**Table 1: Results of various assault experiments**

| Group | Type of assault                     | Result         |                |
|-------|-------------------------------------|----------------|----------------|
|       |                                     | Self-cure PMMA | Heat-cure PMMA |
| 1     | 90% concentrated $H_2SO_4$ for 24 h | 10/10          | 10/10          |
| 2     | 98% concentrated $H_2SO_4$ for 24 h | 0/10           | 2/10           |
| 3     | 60% concentrated NaOH for 24 h      | 10/10          | 10/10          |
| 4     | Incineration in a furnace           | 8/10           | 9/10           |
| 5     | Direct flaming (3 min)              | 10/10          | 10/10          |

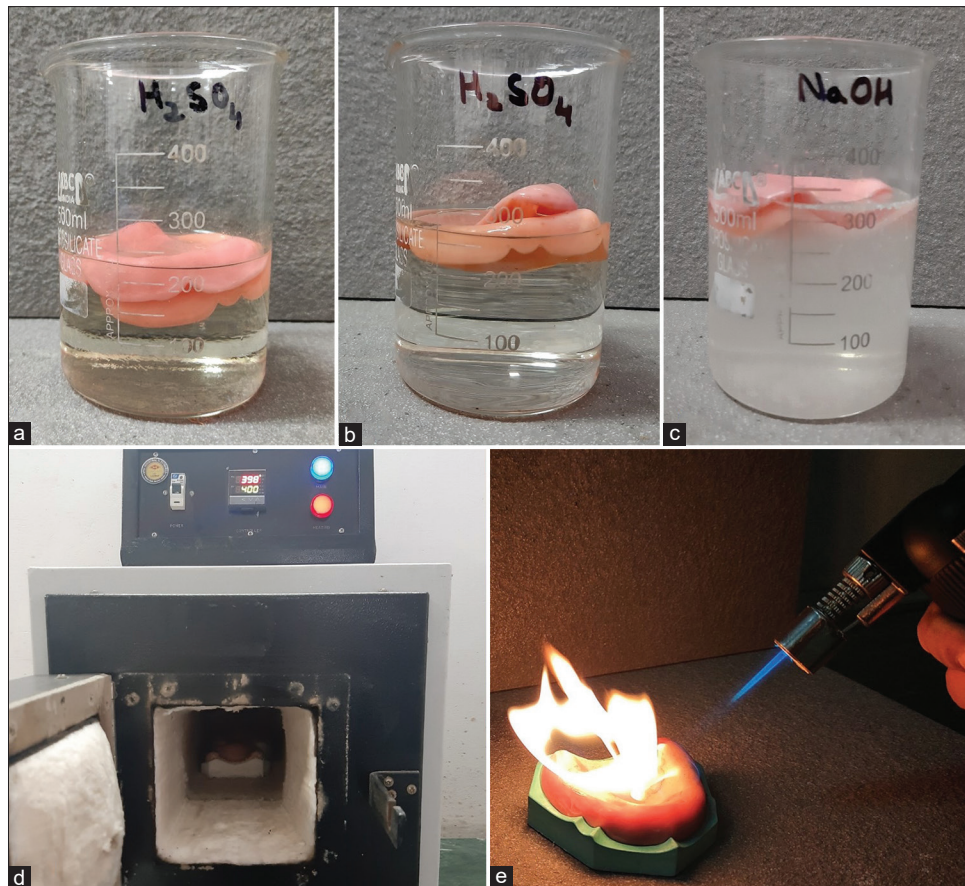
Result; NFC tags working out of total samples tested. PMMA: Poly-methyl meth-acrylate,  $H_2SO_4$ : Sulphuric acid, NaOH: Sodium hydroxide, NFC: Near-field communication

**Table 2: Reaction of NFC stickers to different assaults**

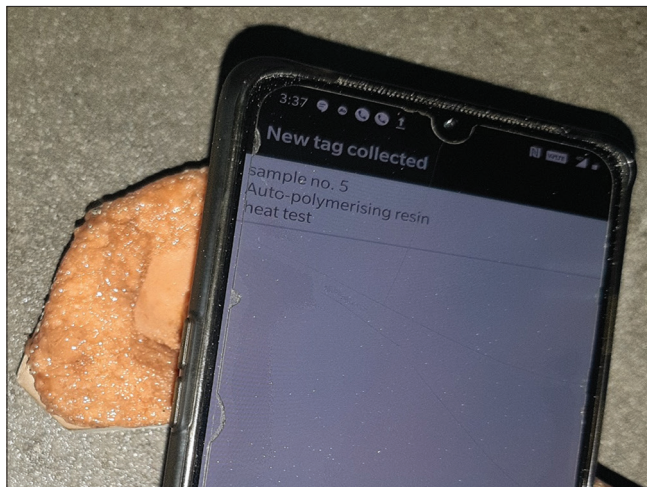
| Group | Type of assault                     | Result         |                |
|-------|-------------------------------------|----------------|----------------|
|       |                                     | Self-cure PMMA | Heat-cure PMMA |
| 1     | 90% concentrated $H_2SO_4$ for 24 h | ✓              | ✓              |
| 2     | 98% concentrated $H_2SO_4$ for 24 h | X              | X              |
| 3     | 60% concentrated NaOH for 24 h      | ✓              | ✓              |
| 4     | Incineration in a furnace           | ✓              | ✓              |
| 5     | Direct flaming (3 min)              | ✓              | ✓              |

✓: Functioning tags, X: Nonfunctioning tags (group with at-least 80% of result is considered functioning).  $H_2SO_4$ : Sulphuric acid, NaOH: Sodium hydroxide, PMMA: Poly-methyl meth-acrylate





**Figure 4:** Samples subjected to various assault; (a) 90% conc. Sulphuric acid, (b) 98% conc. Sulphuric acid, (c) 60% conc. Sodium hydroxide, (d) incineration, (e) direct flaming



**Figure 5:** Reading tags with OnePlus 7T smartphone device (One Plus tech. Co. Ltd., China)

damage of the surface but the NFC tags were in their functional state. Nine out of 10 tags were found functional in heat-polymerized PMMA group and 8 out of 10 tags were working in self-polymerizing PMMA group. For Group 3, 100% samples were in functional state and for group 4, 90% samples of heat-polymerized group and 80%

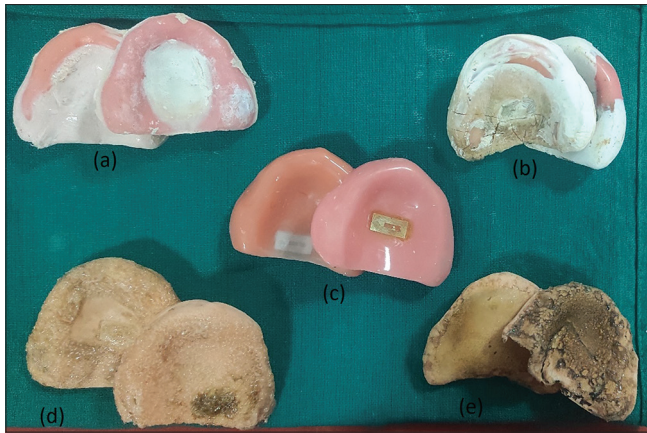
for self-polymerizing group were found working at the end of the experiment.

For direct flaming; Group 5 [Figure 6e], Denture bases were set on fire with a butane-based torch by direct flaming for 1 min. After which, samples were left to burn. All tags were functioning well after a period of 3 min. 100% samples responded for both PMMA material.

## DISCUSSION

An attempt is made by the authors to use commercially available NFC stickers and incorporating them to dentures to facilitate their identification.

Forensic odontology demands a denture identification method that is not only easy to access but also resistant to thermal and chemical insults that otherwise make it difficult to identify deceased individuals. In this study, NFC tags has been put to various thermal and chemical assaults. Similar study was performed by Richmond and Pretty with ten different denture marking systems incorporated in a large PMMA block at a depth of 2 mm. Although, NFC, in particular, was not used; the RFID tags tested in their study



**Figure 6:** Remains of samples after being subjected to various assault; (a) 90% conc. Sulphuric acid, (b) 98% conc. Sulphuric acid, (c) 60% conc. Sodium hydroxide, (d) incineration, (e) Direct flaming

performed well in terms of acid and base assaults but failed to respond after placing in a furnace at 800°C for 20 min.<sup>[4]</sup> To increase the clinical applicability of this study, denture bases were used instead of a large PMMA block while preparing samples. For placement of tag at an appropriate depth, a modified technique of one demonstrated by Reeson and Venkat Nag & Shenoy was used.<sup>[14,15]</sup> To attain correct vertical depth, a small wax-aluminum spacer was incorporated at the stage of trial closure, which was later replaced with tag and filled with PMMA before final closure. This could be a simple and more accurate technique for placing any denture identification material of choice. Although, the inability of RFID to withstand extreme temperatures had been mentioned in literature.<sup>[4]</sup> However, Thomas *et al.* observed that dentures, if present in the mouth at the time of incineration are well protected from direct fire by the surround soft tissue.<sup>[4,16]</sup> Furthermore, it has been reported that under such conditions, one-half to one-third of dentures will survive.<sup>[4,17]</sup> Hence, NFC tags can be expected to survive incineration in an unfortunate situation as long as they are located in the oral cavity.

NFC stickers are passive tags that are powered externally by NFC reader modules. These modules were first introduced as shells for cell phones by Nokia in 2004, These specifically designed covers would clip over Nokia 5140 devices to read and write NFC tags.<sup>[18]</sup> Currently, there are >500 commercially available smart devices that support reading/writing of NFC tags worldwide.

Apart from simply storing information, these tags can be programmed to initiate certain tasks on smart devices that include sending text messages and sharing GPS coordinates. This feature can help locate lost dentures, when scanned these tags can initiate location sharing via

text message to any registered number. Once the details of reader are shared to registered number, patient or clinician can easily contact the reader device and locate lost denture.

Alternatively, patients home location and other relevant details can be stored on tags and once found, dentures can be safely returned to patient. Intelligence and ease of connection (through smartphone, which is commonly available) play a major role in making this possible.

Almost all denture labeling systems have some drawback. While many including limited amount of storage, are solved by RFID tags; The price and availability of RFID reader have always been an issue.<sup>[8,19]</sup> Apart from managing this, these NFC stickers allow complete control over information, i.e., information can be added, removed, amended, or even locked by reader device. NFC stickers are extremely thin, flexible, and resistant to heat at denture curing temperatures, making them a potential material to be used in denture labeling.

## CONCLUSION

Within the limitations of this study, it can be concluded that NFC stickers have a better potential to be an ideal material for denture labeling than currently available methods. NFC stickers can overcome disadvantages of RFID system including cost factors, difficulty in rewriting/adding information, and requirement of additional equipment.<sup>[8,11]</sup>

Further studies are required to evaluate the efficacy of these stickers under *in-vivo* conditions with a significant clinical period of use.

Studies are also required to check the effect of normal denture cleaning procedures on these stickers.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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