ORIGINAL ARTICLE

An *In vitro* evaluation of the reliability of QR code denture labeling technique

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Abstract

Statement of Problem: Positive identification of the dead after accidents and disasters through labeled dentures plays a key role in forensic scenario. A number of denture labeling methods are available, and studies evaluating their reliability under drastic conditions are vital. **Aim:** This study was conducted to evaluate the reliability of QR (Quick Response) Code labeled at various depths in heat-cured acrylic blocks after acid treatment, heat treatment (burns), and fracture in forensics. It was an *in vitro* study. **Materials and Methods:** This study included 160 specimens of heat-cured acrylic blocks (1.8 cm × 1.8 cm) and these were divided into 4 groups (40 samples per group). QR Codes were incorporated in the samples using clear acrylic sheet and they were assessed for reliability under various depths, acid, heat, and fracture. Data were analyzed using Chi-square test, test of proportion. **Results:** The QR Code inclusion technique was reliable under various depths of acrylic sheet, acid (sulfuric acid 99%, hydrochloric acid 40%) and heat (up to 370°C). Results were variable with fracture of QR Code labeled acrylic blocks. **Conclusion:** Within the limitations of the study, by analyzing the results, it was clearly indicated that the QR Code technique was reliable under various depths of acrylic sheet, acid, and heat (370°C). Effectiveness varied in fracture and depended on the level of distortion. This study thus suggests that QR Code is an effective and simpler denture labeling method.

Key words: Acrylic sheet, forensics, hydrochloric acid, labeled denture, positive identification, Quick Response code, sulfuric acid

Introduction

Forensics was born when the body of Charles the Bold, was identified in the battle of Nancy by the absence of a tooth in the lower arch. Later, in 1835, the importance of prosthesis in forensics came into the picture when a burned body was identified by the gold denture of the victim. After World War II, out of 3,000 bodies of unidentified soldiers, 27.3% of the bodies were found to have dental prostheses, but only 0.3% of these could be identified.[1,2]

Labeled dentures can significantly contribute toward identifying the bodies of those who have died in accidents, natural calamities, and aviation disasters or in identifying people who have lost their memory, people in states of unconsciousness, and people who have misplaced

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dentures in nursing homes. Positive identification is an essential requirement for any medicolegal investigation in forensics.[2-4] Labeling of dentures is recommended by most international dental associations and forensic odontologists and regulated by legislation in the USA.

Certain ideal requisites of a denture marker exist: That it should be biologically inert, easy to apply, esthetically acceptable and readable, inexpensive, possible to retrieve after an accident, acid-resistant, durable without jeopardizing the strength of the prosthesis, resistant to everyday disinfecting agents, and able to survive elevated temperatures.[4,5] The recommended areas for marking therefore are the posterior regions of the lingual flange in the mandible and the palate of the maxillary denture.[6]

The two main methods in marking dentures are Surface Method and Inclusion Method. The Surface method includes the scribing technique, where the letters are engraved on the denture surface with a small round dental bur, and the embossing technique, where particulars of the patient are scratched on the master cast and it produces embossed letters on the impression surface of dentures. This technique is economical but problems such as food entrapment, infection, and irritation may occur.[5-7]

The Inclusion method involves enclosing labels in the denture. The mark should be placed in the denture without affecting its retention, esthetics and function.[8] The various denture markers include: Quick Response (QR) Code, where a Code is enclosed into dentures and the code can store a large amount of patient detail; Denture barcoding, which is a machine-readable code of a series of bars and spaces; Lenticular card, which is used to store the patient's information in an image form that can be viewed by changing the angle of view; ID band, a stainless steel metal band representing patient detail; Paper Strip, where a strip of typed onion skin paper is used; T bar, where a T-shaped clear Poly methyl methacrylate resin bar is enclosed into denture with a label;[9,10] Laser etching, in which a copper vapor laser is used to etch the patient's information on the denture; Electronic microchips, where patient's information is etched onto a microchip measuring 5 × 5 × 0.6 mm which are small, aesthetically acceptable and perform well under high temperatures; Photographs, where a patient's photograph is embedded in the denture but which is resistant only up to 200–300°C; Radio-Frequency Identification (RFID) Tags, in which a (8.5 × 2.2 mm^2) radio-frequency identification tag is enclosed within dentures; and Subscriber Identity Module (SIM) inclusion.[11-14] While labeling dentures is of great significance, gaining more knowledge on the reliability of denture markers is important. This study concentrated on QR Code inclusion, owing to its simplicity and accuracy.

Aim

This study was done to evaluate the reliability of QR Code labeled at various depths in heat-cured acrylic blocks after acid treatment, heat treatment (burns), and fracture in forensics, and this was an *in vitro* study.

The objectives of the study were to assess the ability of barcode scanners to reveal information when QR Codes were:

- Placed at different depths in the acrylic resin and covered with clear acrylic sheet
- Placed at various depths in acrylic resin and treated with strong inorganic acids
- Placed at various depths in acrylic resin and heated drastically
- Placed at various depths in acrylic resin and fractured at the center using a Universal Testing Machine.

Materials and Methods

The protocol of this study was approved by the Ethical Committee of Tagore Dental College and Hospital. The study was conducted at Tagore Dental College and Tagore Medical College over a period of 4 months. A total of 160 samples (heat-cured, acrylic resin, ALIKE™; GC America, ALSIP, USA) acrylic cubes of dimension 1.8 cm each side were fabricated and divided into four groups (40 per group). These were Group I, II, III, and IV, and QR Codes were placed at 1 mm, 2 mm, 3 mm, and 4 mm depths, respectively. In the context of this study the materials used were QR barcode generator software (Den so Wave Incorporated, Kariya, Aichi Prefecture, Japan), QR barcode scanner (Developed by WB Development Team, Viale Cesare Battisti, Volterra, Italy. Source: ZXing Group, Developers: Sean Owen, Daniel Switkin, ZXing team.), Inorganic acids sulfuric acid and hydrochloric acid (Reachem Laboratory Chemicals Private Limited, Ambattur, Chennai, India), clear acrylic sheets (MG Polyplast Industries Pvt. Ltd, New Delhi, India), cyanoacrylate adhesive (Fevi Kwik, Pidilite Industries Ltd, Mumbai, India), Universal Testing Machine (Lloyd instruments Limited, Fareham, Hants, United Kingdom), and burnout furnace (Anand Mediproducts Pvt Ltd, Punjab Bagh, New Delhi, India). The method of statistical analysis used in this study were Chi-square test, the test of proportion, and all data were analyzed using the statistical program SPSS version 16 for Windows XP, Developer: IBM Corporation, Armonk, New York, United States, level of significance was 95%, confidence interval (CI) 0.05%.

Generation of QR codes

After fabrication of acrylic samples, each patient's unique identification number and barcode printed on the patient's Aadhaar card as issued by the Unique Identification Authority of India (UIDAI) were scanned using a QR barcode reader, as the data were trustworthy. In case the Aadhaar card is not available then a case history of the patient can be taken. QR codes were generated using QR barcode generator software, at the dental office or laboratory. The patient information was entered in the QR Code generator software

or website (https://www.the-qrcode-generator.com/). The patient details incorporated in the QR Code were: Name, date of birth (DOB), age/gender, mobile number, Aadhaar ID number, and driving license number. The size of the QR Code printed is directly proportional to the amount of information incorporated in the QR Code. The format given above generated a QR Code of size 1.3 cm × 1.3 cm (at 50 pixels). More concise data can generate a QR Code of lower size, such as 9 mm × 9 mm. The QR Code was printed on an A4 sheet and cut.The QR Code scanner application was downloaded in the android device or smartphone and it scanned the QR Code within seconds. The size of the QR Code used in the study was 1.3cm × 1.3cm [Figure 1].

Figure 1: QR code containing patient data

QR code incorporation in samples

The cello tape was pasted on the front and back sides of the printed QR code paper. By doing this, the deterioration of code was prevented. A 1-mm deep space (to accommodate the QR Code) was created on the samples of Group I. Similarly 2-mm, 3-mm and 4-mm deep spaces were created respectively on the samples of Group II, Group III, and Group IV. One drop of cyanoacrylate adhesive was placed in the slot to position the label. The QR Codes were then placed over those spaces in the block. Clear acrylic sheets of appropriate thickness ness were placed over the label and the corners sealed with clear auto polymerizing acrylic resin (Dental Products of India, Mumbai, India).The acrylic block was finished and polished in the usual manner [Figure 2].

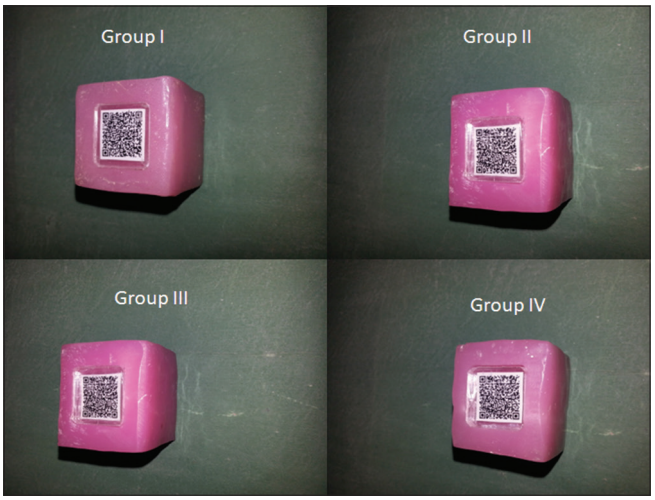

Figure 2: QR code incorporated in samples of Group I, II, III, and IV

Evaluation

The first 10 blocks containing QR Codes of each of the groups (Group I, II, III, and IV) were scanned for visual clarity of information [Figure 3]. The second set of blocks were treated with strong inorganic acids, i.e., sulfuric acid 99%, hydrochloric acid 40% for a time period of 1 h [Figure 4]. The third set of blocks were heated to a very high temperature (500°C) in a furnace and the QR Codes were evaluated [Figures 5 and 6]. Finally, the fourth set of blocks were fractured at the center using Universal Testing Machine and were checked for reliability [Figure 7].

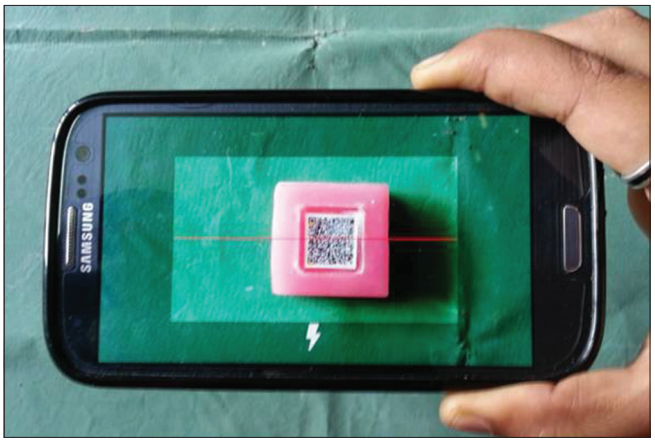

Figure 3: QR code scanned using a barcode scanner

Results

The reliability of QR Code was tested in *in vitro* conditions and was assessed and subjected to statistical analysis. The outcome was divided based on Criterion A - Depth, Criterion B - Acid (99% sulfuric acid and 40% hydrochloric acid), Criterion C - Heat (500°C), and Criterion D - Fracture (oblique plane) as follows:

- Criterion - A: The QR Code was readable when scanned under clear acrylic sheets of various thicknesses [Figure 8]
- Criterion - B: The QR Code was readable when treated with hydrochloric acid (40%) and sulfuric acid (99%) for 1 h [Figure 9]
- Criterion - C: QR Code was readable up to 370°C but was burned as the temperature approached 500°C [Figure 10]
- Criterion - D: The reliability of the QR Code when fractured at the center was variable. It depended on the level of distortion of the QR Code[Figure 11].

Discussion

Forensic medicine involves a multidisciplinary team effort relying on positive identification methodologies, and a

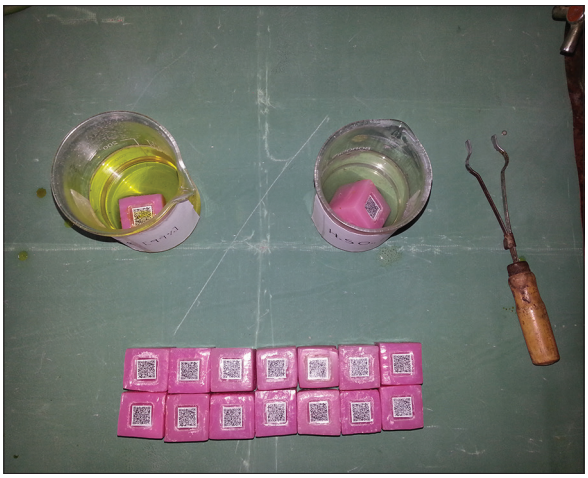

Figure 4: Samples treated with sulfuric acid (99%) and hydrochloric acid (40%)

Figure 6: Sample burned at 500°C

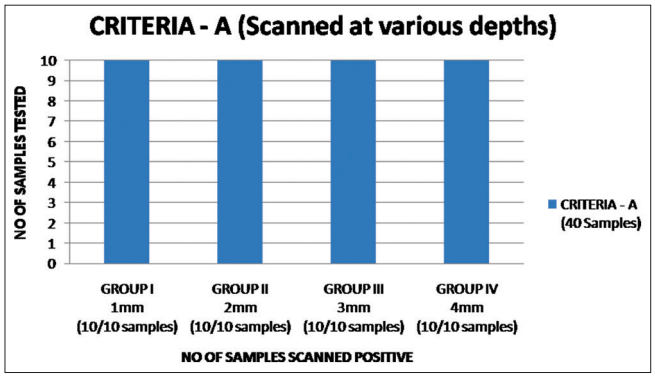

Figure 8: Graph demonstrating result when QR codes were scanned at various depths (Criterion A)

great deal of effort goes into identifying the victim. One method of identification in forensic odontology uses labeled dentures.[15-17]

The present study used the QR Code method of labeling dentures. QR Code is a type of two-dimensional barcode and is the latest system in denture identification. The QR Code was invented in Japan by the Toyota subsidiary Denso Wave in 1994. The QR code is detected as a two-dimensional

Figure 5: Sample heated to 370°C, QR code not destroyed

Figure 7: A fractured sample

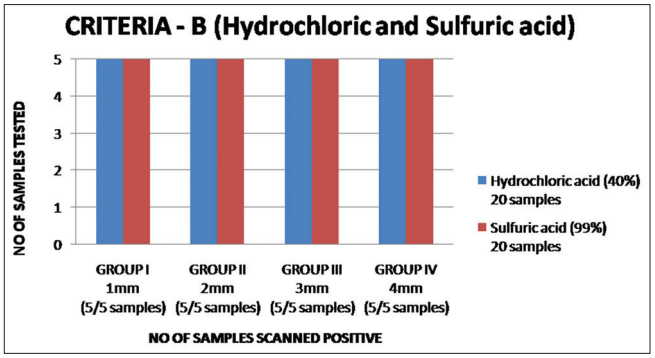

Figure 9: Graph demonstrating result when QR codes were exposed to inorganic acids (Criterion B)

digital image by a semiconductor image sensor and is then digitally analyzed by a programmed processor.[15] The advantages of QR Code technique are: QR Codes can be used in (smartphone) Android operating system and iOS devices (iPhone/iPad) or third-party barcode scanners, the scanning is completed in seconds, and free QR code software is available. QR codes are accurate, they are least expensive, and store large amounts of data.[18-21]

The reason for selecting QR Code inclusion in our study over the other methods was that it has many advantageous characteristics, such as simpler and handy technique, cost-effectiveness, and large data storage capacity. QR Code like any other marker is accurate as such, but its effectiveness in unfavorable conditions determines the clinical application. The size of the QR Code was carefully selected for ease of inclusion in dentures. Instead of clear auto polymerizing acrylic resin, clear acrylic sheets were used to cover the label as the probability of QR Code getting distorted by the monomer content is high and the porosity of auto polymerizing acrylic resin would affect the scanning result. Acrylic sheets of varying thickness are available, and these were cut according to the groove and placed.

The criteria for the test were chosen based on the accidents and injuries commonly encountered. Sulfuric acid and hydrochloric acid (Criterion B) were used because they are common laboratory chemicals and industrial accidents are possible among workers.[22] Fire (Criterion C) remains one of the major causes of morbidity and mortality throughout the world and identification of a body from a fatal fire remains a daunting task. The QR Code sample was also tested under high temperature as airplane crashes or other fire accidents can generate heat as high as 500–700°C or even higher.[23] Criterion D evaluated QR Code reliability after fracturing, as major road accidents often present fracture of the facial bones involving the maxilla or mandible.

Criterion A showed that the QR Code was effective irrespective of the thickness of overlying clear acrylic sheets. Criterion B demonstrated that the QR Codes were reliable even after treatment with sulfuric and hydrochloric acid. However, when exposed to sulfuric acid, an oily layer of acid remained attached to the acrylic sheet and hindered scanning, and hence the QR Codes were scanned while the blocks were still within the acid; the result was positive. Under Criterion C, 20 samples were heated gradually up to 500°C for 30 min and the result was negative, and 20 samples were heated up to 370°C and the result was positive [Figure 10]. Under Criterion D, some samples were split into two or three parts during fracture and the QR Code was split and the result was positive; and a few samples were crushed and the QR Code was distorted and the result was negative [Figure 11].

The results of our research provided valuable information regarding the reliability of the QR Code inclusion technique under various unfavorable conditions. Clinical trial of QR Code inclusion in dentures will reveal any biological complications, if present. Alteration in the technique will be carried out based on the success rate of clinical trials. Barcodes and QR Codes, which are usually associated with commercial products on the market, were applied in denture identification systems, which contributes greatly to forensic science.

Conclusion

Forensic dental identification of the victims is a challenging task. This article illustrated an efficient technique for positive denture identification and it highlighted the contribution of dentures toward forensic science. The reliability of QR Codes was tested under various conditions. Within the limitations of the study, by analyzing the results it was clearly indicated that:

- QR Code was reliable at various depths in acrylic resin when covered with clear acrylic sheet
- QR Code was effective even after sulfuric (99%) and hydrochloric (40%) acid exposure
- QR Code was reliable up to a temperature of 370°C
- Reliability of QR Code after fracture was variable and it depended on the level of distortion.

This study emphasized QR Codes, which promote positive identification in Forensics.

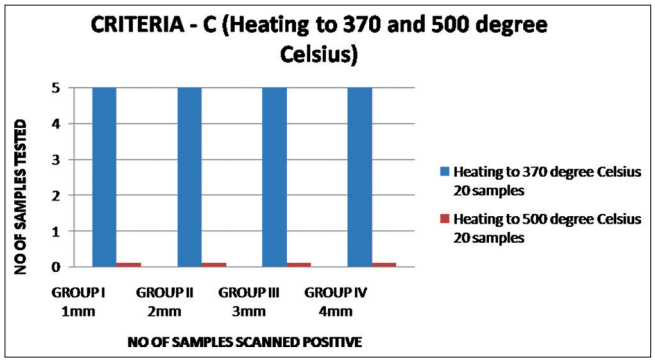

Figure 10: Graph demonstrating result when QR codes were heated drastically (Criterion C)

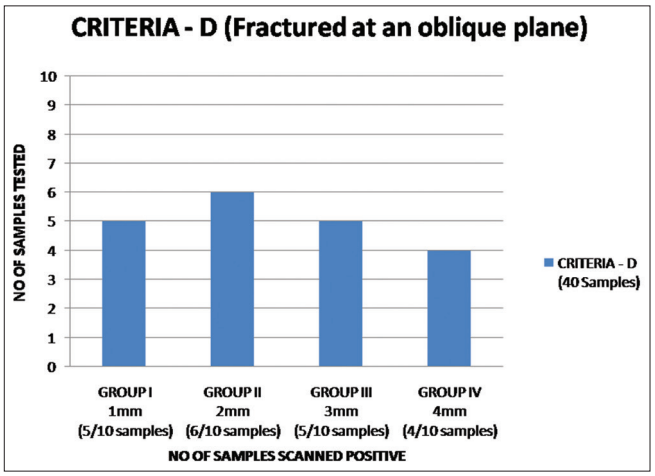

Figure 11: Graph demonstrating result when samples containing QR codes were fractured (Criterion D)

Clinical implication

It is the role of a dentist to motivate their patients toward denture labeling. Patients should be made aware that denture labeling can help in personal identification in case of misplacement in hospitals and during unfortunate fatal events. The QR Code technique can be applied in the denture of patients and a regular follow-up will reveal any biological complications, if present. The dentist must reassure the patient that this method will not affect the cosmetic appeal or the functional integrity of the prosthesis.

Limitation of study

The study was performed *in vitro*. Little is currently known about technical and biological complications when these codes are applied in patient dentures.

Future propect

Future prospects would entail enhancing the QR Code technique to make it resistant to temperatures as high as 500°C or more. The reliability can be expanded by switching over to materials in which the QR Code is printed so that they offer more resistance to heat, fracture, and other unfavorable conditions.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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