Indian Journal of Forensic Medicine and Toxicology
Volume 16 No. 4, October-December 2022

Quick Response (QR) Codes In Dentistry: A Review

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How to cite this article: Durbakula Karteek, Shakil Moidin, Spoorti Kulkarni. Quick Response (QR) Codes In Dentistry: A Review. Indian Journal of Forensic Medicine and Toxicology 2022;16(4).

Abstract

Quick Response (QR) codes are the two dimensional barcodes which store a large amount of data in the form of black square modules (dots). They connect physical objects with digital world by providing links to videos, websites and maps. Use of QR codes saves time, energy, paper and enhances the learning process. The purpose of this review is to provide information about structure, types and applications of QR codes in dentistry.

Key Words: QR code, Barcode, Scanner, Dentistry, Mobile, Education

Introduction

Quick Response (QR) code is a two dimensional barcodewith enhanced data storage capacity than traditional (1D) barcode. It was invented in 1994 by the Denso Wave (Toyota Motors subsidiary) to track vehicles and parts during the manufacturing process. The QR code consists of black square dots (modules) arranged in a square grid on a white background. The data/information encoded may contain numeric, alphanumeric, byte / binary, Kanji orthrough supported extensions (URLs).[1]

The amount of data that can be stored in QR code depends on mode, version anderror correction level. The maximum data that can be stored in a typical barcode is 20 digits in a horizontal direction while a QR code can hold great amount of information in both horizontal and vertical directions. The maximum data capacity for QR code depends on the type of data like Numeric[7089 characters (0,1,2,3,4,5,6,7,8,9)], Alphanumeric [4296 characters (0-9, A-Z, space, $, %,*,+)], Binary/Byte [2953 characters (8-bit bytes)] and Japanese Kanji (1817 characters).[2]

The version of the QR code indicates itssize which relates to the number of black square dots (modules) present in the QR code. There are about 40 versions; higher version means more modules, bigger size and more information. Version 1 has the minimum size 21 x 21 modules while version 40 has the maximum size of 177 x 177 modules.The QR code increases in size by four modules for each increment in its version.[3]

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QR code has a unique capability that it is possible to read it even after damage or distortion to some extent. The error correction level indicates the percentage of symbol area that can be restored. There are four error correction levels for QR codes, Low(7%), Medium(15%),Quality (25%) and High(30%). The data storing capacity decreases as the error correction level of the QR code increases. The error correction level has to be selected while creating the QR code based on the damage that can occur in the environment in which it will used.[4]

Structure Of QR Code

QR code consists of two regions, (1) Function patterns and (2) Encoding region. Function patterns include position patterns, alignment patterns andtiming patterns. Encoding region consists of data and error correction zones. QR code also consists of separators, format information and quiet zone (Figure 1).

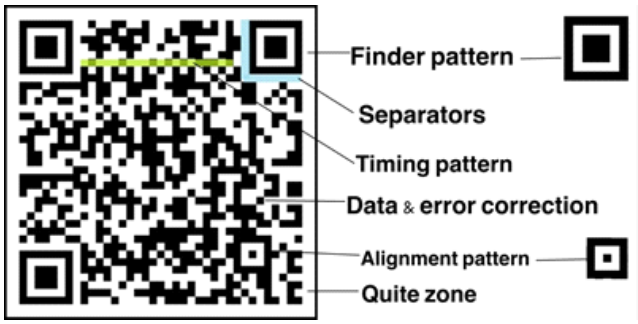

Figure 1: Structure of QR code

Position/FinderPatterns: These are three identical patterns located in three cornersof the QR code.These help in identifying the position, size and orientation (angle) of the QR code. Any alterations in these patterns can prevent decoders from reading the code.

Alignment Pattern: If the QR code is distorted, the alignment patterns help the scanners to decode the code by identifying the central coordinate. No alignment pattern is available in version 1 of QR codes while Version 2 contains onealignment pattern. As we move to higher versions, the size of QR code increases and so is the number of alignment patterns.

Timing Pattern: In this pattern, white and black modules are alternately arranged to determine the coordinate. The timing pattern is placed between two position patterns in a QR code.

Encoded data: Data is first converted into a stream of binary numbers of 0 and 1 and then converted into black and white modules. It consists of Reed-Solomon codes to provide error correction function.

Error Correction: These are 8-bit code-words (binary) stored in the error correction section which help in reading the damaged QR codes.

Separators: These are used to separate the position patterns from the actual data and thus improve the visibility of the position patterns.

Format Information: The error correction level of the QR code and the masking pattern(distribution of black and white modules) are the information stored in this section.

Quite zone: It is the white margin surrounding the QR code which helps in better detection of the QR code.

QR codes can be easily generated using free online or offline QR code generator software. These can be printed on a normal paper with an ordinary printer and can be attached to any surface. A QR code is read by an imaging device, such as a mobile phone camera, BarcodeScanner and QR Scanner. These scanners can read and decode data from a QR code. Previously, QR code scanner software applications (Apps) have to be installed in mobile phones to read the QR codes but now most of the mobile phones are coming with inbuilt QR code scanner software making it easier to read QR codes.

Types Of QR Codes:

Micro QR Code:

It has only one position pattern to achieve more efficient data encoding in smaller size (Figure 2a). It is suitable for small data/space applications. The largest version of Micro QR code is M4 (17 x 17 modules) with a maximum storage of 40 numerals.

SQRC (Security QR Code):

QR Code is currently being used in many applications and the information encoded in them includes personal information of the users. As these QR codes can be read anywhere and anytime using a

mobile phone, there is threat for the loss of personal data from QR codes. So, DENSO WAVE developed a "Security QR Code (SQRC)", which has the ability to prevent the data from being disclosed to the public.

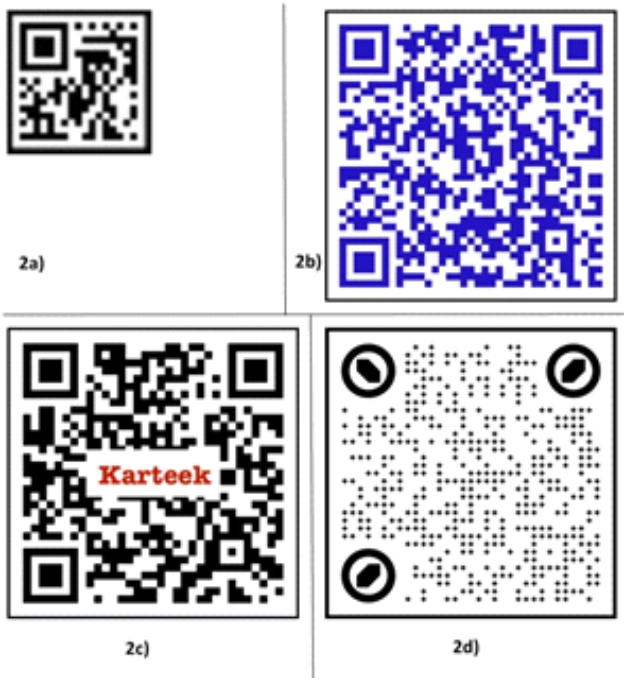

Figure 2a: Micro QR code

Figure 2b: Colored QR code

Figure 2c: Frame QR code

Figure 2d: Custom QR code

iQR Code:

It has features like High Density (store more informationwith same size of QR code). It can be square or rectangle in shape. The maximum storage capacity is with version 61 (422 x 422 modules) which stores up to 40000 numerals.

Colored QR code:

A typical QR code consists of square modules in black color over a white background. Colored QR code consists of colored modules (red, blue, green, yellow) over white background (Figure 2b). Inverted QR code contains white modules over black background. It is important to maintain proper contrast between the color of the modules and the background for the scanner to detect the QR code.

Frame QR code:

It is a QR code with a canvas area which can incorporate letters or images in it (Figure 2c). This helps in product promotion and shows authenticity of the product when brand logo is used in canvas area.

Custom QR code:

The QR code can be customized by changing the shapes of the position patterns and data modules. Position pattern can be square, round, rhomboid and grooved. Data modules can be square, round or star shaped. Different colors and photo can be incorporated like colored frame QR code (Figure 2d).

Other Two Dimensional Bar codes:

Two dimensional bar codes include Datamatrix code, PDF417 and AZTEC codes other than QR codes.

Datamatrix codes:

Datamatrix codes are small sized and can store up to 2335 alphanumeric characters. They have two solid black adjacent borders in 'L' shape (finder pattern) and other two borders contain alternating black and white modules (Figure 3a).

PDF417:

PDF417 are used when there is huge amount of information to be stored. It consists of quiet zone, start pattern, left row indicator, data code words, right row indicator and stop pattern (Figure 3b).

AZTEC codes:

AZTEC codes are used in transportation industry over airlines tickets and train tickets. It consists of a central finder pattern surrounded by data in black and white modules (Figure 3c).

Figure 3a: Data matrix code

Figure 3b: PDF417

Figure 3c: AZTEC code

Applications Of QR Code:

QR codes are used to maintain the repair and maintenance records for buildings and equipment.

They are used to describe about the equipment components of complex systems. QR codes on business cards provide information like address, phone number and even website. QR codes on broachers will provide URLs or links to YouTube videos giving description about the product or building in the broacher. QR code on books will guide the users to book reviews and additional resources.

QR codes containing bank account information can be used for online payments of bills, booking of train, airlines & movie tickets and money transfer through wallets. AADHAR card or The Unique Identification Cards (UID) issued by Government of India to its citizens has a QR code printed on it which contains the basic information of the cardholder.

QR codes on groceries, food packages and fruits & vegetables provide information like ingredients, expiry date and cooking recipes. QR codes on jewelry tags provide information about name, weight and production date.QR codes on biological specimens provide links to photographs, maps, ecosystem notes and citations.[5]

In medical hospitals, QR Codes are used for patient identification by printing it on patient's wrist band which contains information like patient's name, identification number, date of birth, sex, ward and bed numbers.[6] In pathological diagnostic labs, QR codes are attached to the test tubes during testing with automated counting machines. Physiotherapists give QR codes to the patient containing information about the postoperative physical exercises and links to multimedia sources on the internet showing video demonstrations of the exercises.[7]

QR Code Applications In Dentistry:

QR codes can be used in various departments of Dentistry to help patients, doctors and undergraduate students. The protocol for the usage of these QR codes is

Step 1: Data to be encoded in the QR code is prepared, like case history, radiographic interpretation, treatment plan, patient details, equipment information and material manipulation.

Step 2:QR code of size 1x1 cm is generated after incorporating data in it by using an offline or online QR code generator software.

Step 3: QR code is laminated to prevent its damage or distortion from moisture, dust and acrylic materials.

Step 4: QR code is attached to the object like radiographic cover, model, appliance or medical equipment.

Step 5: QR code is read or scanned using a mobile phone camera or a QR code scanner.

Step 6: QR code can be stored in a computer or over a paper for documentation or can be sent to the patient through e-mail or mobile.

Prosthodontics:

A laminated QR code encoding patient details is generated. Then it is placed in the recess created in the widest part of the prosthetic appliance (removable partial/complete denture) and covered with clear auto-polymerizing resin (Figure 4a). This QR code can also be attached over the models. These help in identifying the dentures in senior citizen centers and models in prosthetic labs.[8]

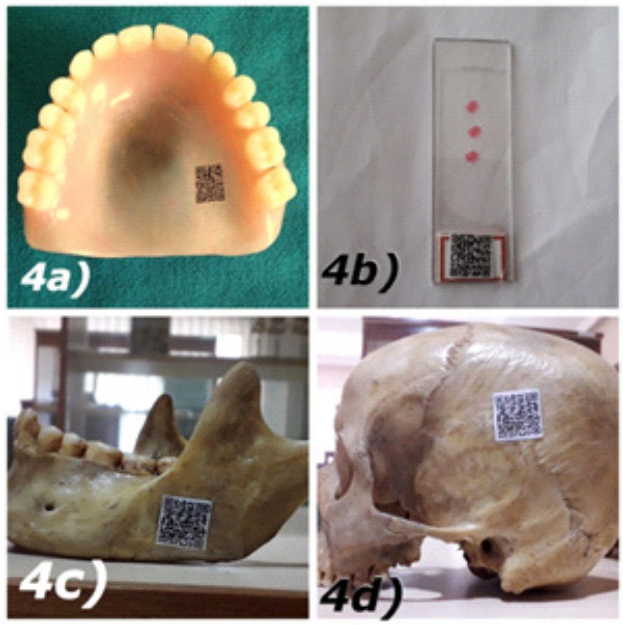

Figure 4a: Complete Denture with QR code

Figure 4b: Histopathological slide with QR code

Figure 4c: Mandible with QR code

Figure 4d: Skull with QR code.

QR codes are printed on ceramic crowns (palatal/ lingual surface) and implant abutments using laser

markers. These withstand high temperatures without undergoing distortion/damage. Micro QR code or Data matrix code are used for these.[9,10]

Orthodontics:

QR code encoding for case history, radiographic interpretation (cephalometrics) and treatment plan is generated and laminated. This QR code is incorporated into orthodontic appliance in its widest part or attached to the study models and radiographs. QR codes help in patient's subsequent visits, retrospective studies and to study the tooth movement patterns.[11]

Oral Pathology:

QR code encoding for the case history is generated and laminated. Then it is attached to the case history form, specimen bottle, cassettes containing the grossed specimen, embedded block and to the slide after staining. A second QR code is generated encoding for biopsy report and attached to the reverse side of the slide (Figure 4b). First QR code helps in identification of the specimen and block during retrospective studies while the slide containing both first & second QR codes provides both case history and histopathological report of that particular slide.[12] These QR codes may contain URL leading to a website where the digital histopathological picture of the slide is available.

Pedodontics:

The information like case history, radiographic interpretation and treatment plan are encoded in a QR code. This QR code is printed and laminated and attached to the radiographic cover or incorporated into the pedodontic appliances like habit breaking appliances or space maintainers. Tooth eruption sequences can also be encoded in the QR codes.[13]

Oral Radiology:

Radiographs like Intra Oral Peri-Apical radiograph (IOPA), Orthopantomogram (OPG) & Lateral Cephalogram are taken and interpreted. QR code encoding for the patient details and radiographic interpretation are generated. These are laminated and attached to the radiographic covers in IOPA (adult/pediatric) and to the x-ray film in case of OPG & Lateral Cephalogram. These help in retrieving the patient's information during subsequent visits and in retrospective studies.[14]

Dental Education:

QR codes can enhance the dental education by connecting the paper based teaching methods with digital sources making it *m*-learning (mobile learning). Students can use QR codes containing video links and journal articles to get detailed information of the seminar or lecture they have attended from an online source. QR codes can also be used for online surveys, self assessment tests for students and feedback for faculty.[15]

QR codes encoding for video links and images can be attached to skull, mandible which will provide information like the anatomical landmarks and muscle attachments making the anatomy learning more interesting (Figure 4c, 4d). QR codes attached to the instruments like Sphygmomanometer and Neubauer's chamber will provide information regarding experimental procedure, normal values.

QR codes encoding for histological features can be attached to the ground sections and histological slides. QR codes attached to the mixed dentition models will help the students in identifying the correct age and eruption sequence of the patient. QR codes containing information about dental material composition, material manipulation and stepwise procedures for impression takingcan be given to the students. QR codes containing information about indications, contraindications and fabrication procedure can be incorporated in various appliances like Prosthodontic, Orthodontic and Pedodontic appliances.

Oral Medicine:

Patient's case history, investigations and treatment were planned. Recording these details electronically using QR codes will save paper and energy as they are easy to retrieve during subsequent visits or for retrospective studies.

Community Dentistry:

Patient details attending community health programs, dental health awareness camps, mass screening of oral diseases are usually saved on the paper. Recording these details electronically using

QR codes will save paper, energy and time as it easy to access the details during subsequent visits of the patients.

Forensic Odontology:

Identifying the person becomes difficult during accidents like air plane crashes and train accidents. If QR codes are used to mark the dentures, crowns and implants then the identification of the person becomes easy as these can withstand high temperatures (370^0C), concentrated acids without undergoing any damage. These QR codes can be read even if they are placed at varying depths in the acrylic materials.[16]

In dental clinic, these QR codes help the dental assistant in providing information regarding tray set up for procedures like impaction, flap surgery, root canal and implant placement. Patients can use these QR codes to get information about dental procedures, post operative instructions,for booking appointments and review of the clinic. QR codes can also be used to set up a digital museum.

Inter-departmental confusion may arise while using QR codes in a dental college. This may be avoided by using colored frame QR code specific for each department. Each department will be given a specific color and logo in the frame QR code will be the short form of the department name. Eg: Blue color and letters 'OP' in logo of QRcode for the Department of Oral Pathology.

Advantages:

QR codes are easy to create, less expensive, small in size and can store large amount of data. High speed 360 degree scan and ability to read even if it is damaged by error correction adds to it benefits.Use of QR codes saves paper, time and energy during retrospective studies. It is very economical method of labeling the dentures and appliances. It turns the classroom learning into digital *m*-learning.

Limitations:

Lack of technical familiarity in creating and scanning of the QR codes is the main limitation in their usage. Privacy and confidentiality is the other limitation as the information encoded in them includes personal details, banking information, case history, diagnoses and treatment plans.Other drawbacks like inclusion of histopathologic picture, radiographic image in the QR code limits its usage. Malicious links can be present in the QR codes leading to websites hacking user mobile phones and retrieving their details.

QR codes incorporated in appliances made from acrylic materials cannot withstand temperatures above 500^0C. The presence of porosity in the acrylic material overlying QR code might hinder its scanning. Fracture of the appliances during major accidents might limit QR code's readability depending on the amount of distortion occurred to it.

Future Scope:

Technical advancement might help in inclusion of images in QR codes and also createsfamiliarity of QR codes which will ultimately increase their usage.Privacy and confidentiality of the users can be preserved by the development of highly advanced versions of QR codes with password protection.

Conclusion

QR codes act as a bridge between physical objects and digital world.They store information electronically which can be easily accessed from anywhere in the world. They revolutionize the learning process by augmenting the textbook method with *m*-learning. Technology is advancing at a rapid pace, making the usage of QR codes in modern dentistry as the need of the hour.

Ethical clearance: As it is a review paper, ethical clearance has not been taken.

Source of funding: Self

Conflict of Interest: Nil

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