Original Article

The quantification of percentage filling of gutta-percha in obturated root canal using image processing and analysis

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ABSTRACT

Aim: To quantify the percentage filling of the gutta-percha in obturated root canal cavity using image processing and analysis.

Methodology: The image processing and analysis using the X-ray radiographs is commonly being used by medical practitioners for easy and speedy diagnosis of patient health. But these methods are qualitative and assessment depends upon dentist's own experience and perception. Fifteen patients were randomly assigned to fifteen Dentists to perform the root canal treatment using warm vertical condensation. X-ray radiographs of pre and post obturation were obtained to carry image processing and analysis. Image enhancement, low pass filtering, k-means clustering algorithm and edge detection technique were applied to get results. Percentage filling of the obturated root canal using X-ray radiography (Dentist's prediction) and proposed algorithm results of the present study were compared. Out of fifteen Dentists, the prediction of twelve Dentists were close in range of percentage filling quantified using proposed algorithm of the present study. When investigated it was found that three discrepancies found due to lack of sufficient experience of the respective Dentist. The proposed algorithm not only helps to overcome this false assessment but also helps to quantify accurate percentage filling of gutta-percha and outlines unfilled cavity gap of root canal.

Results: The proposed algorithm of present study provides accurate percentage filling of gutta-percha in the obturated root canal up to two decimal points. The present study used gutta-percha as obturation material but the study can be implemented for any obturation material.

Conclusion: The proposed algorithm of present study accurately quantified the percentage filling of root canal cavity using image processing. It also locates and outlines the unfilled root canal cavity.

1. Introduction

In the field of the endodontics, the quantification of the percentage filling of the gutta-percha in obturated root canal is of prime importance for correct assessment of the root canal obturation. Nowadays, this is done using the various qualitative techniques such as micro-computed tomography, radiography, computed tomography scans, cone beam computed tomography or scanning electron microscope investigation having the various technological limitations and requires broad experience of Dentist for accurate assessment (Pravin R. Lokhande et al., 2018).¹ The Dentists currently using root canal treatment and it's qualitative assessment procedure is shown in Fig. 1. In order to provide the accurate quantification of the obturated root canal, image processing and analysis can be effectively used. It can quantify the percentage filling obturation materials in the obturated root canal by scanning the radiographic report. The prime objective of

the present study is to quantify the percentage filling of gutta-percha in obturated root canal using MATLAB pixel program written in MATLAB Image Processing Toolbox. The patient's X-ray radiograph of the obturated root canal taken to perform the image analysis by differentiating the white and black colours, where white colour square represents the filling of the root canal and black squares represents unfilled root canal cavity. Apart from the qualitative technique, there are quantitative techniques such as fluid filtration technique, bacterial microleakage, dye penetration test. But the results of these quantitative techniques are challengeable (Pravin R. Lokhande et al., 2019).² The proposed algorithm of the present study avoids such drawbacks (see Fig. 2).

Image analysis refers to the extraction of the statistical data from the fundamental components that includes searching shapes, finding edges, eliminating noise, counting objects, measurement of regions and images based properties evaluation (Pravin R. Lokhande et al., 2019).³ In the present study image enhancement, region analysis and supervised

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Fig. 1. Root canal treatment and its qualitative assessment procedure.

Fig. 2. Flowchart of the proposed algorithm of the present study.

machine learning algorithm are used. Image enhancement helps to eliminate the noise and region analysis extracts the statistical data from enhanced image of the obturated root canal radiograph.

2. Literature review

Medical image processing and analysis plays vital role during diagnosis

of the patient's health. In the image analysis process, there exist the several objects overlapping selected image for analysis. The proximity of adjacent image pixel may also lead to difficulties in diagnosis task. The morphological transform method helps to cope with such problems and enhanced the quality of medical images selected for study (Hamid Hassanpour et al., 2015).⁴ The rotation of the human lungs is measured by line histogram technique in range of 0° to 180° angle (K. C. Santosh et al., 2015).⁵ The bad quality X-ray image can be filtered with the help of computer aided screening diagnosis. The screening approach outperformed the state of art methods by giving least processing time (K. C. Santosh et al., 2018).⁶ Template free geometric signature technique proposed for labelling the region of interest (K. C. Santosh et al., 2016).⁷ The past endodontic studies performed qualitative assessment of obturated root canal (Amir moineza-deha et al., 2015; Nicola maria grande et al., 2015; Pravin R. Lokhande et al., 2020).^{8–10} But the assessment depends on Dentist's experience and perception. Therefore, there is need of quantitative assessment of percentage filling of obturation material in obturated root canal.

3. Materials and methods

The present study used MATLAB pixel program written in MATLAB Image Processing Toolbox to quantify the percentage filling of gutta-percha in obturated root canals of fifteen patients selected for study. The warm vertical condensation was used to perform obturation on selected patients. The post-obturation X-ray radiograph of each patient scanned in JPEG image file format and then imported to the MATLAB to perform image processing.

3.1. Basic idea of pixel program

The basic idea of pixel program can be expressed using equation (i) and (ii). X-ray radiograph image imported to the MATLAB is divided into number of small squares. Using pixel program the number of white (W) and black (B) squares along root canal are counted. White squares along the obturated root canal indicates that portion of root canal is filled with gutta-percha on the other hand, black squares shows unfilled root canal portion.

$$\text{Percentage filling of the root canal cavity using gutta - percha} = \frac{W}{W+B} \times 100 \quad (\text{i})$$

$$\text{Percentage un - filling of the root canal cavity using gutta - percha} = 1 - \frac{W}{W+B} \times 100 \quad (\text{ii})$$

where,

W= Number of the white squares along obturated root canal cavity

B= Number of the black squares along obturated root canal cavity

W+ B= Total number of the squares along obturated root canal cavity

The Pixel program written in the MATLAB used image enhancement, region analysis, K-means, edge detection and supervised machine learning algorithm. Image enhancement is used to edit X ray radiograph image and adjust it for further processing. Image enhancement converted the true colour RGB image into the gray scale using `rgb2gray` function by removing hue saturation information to retain luminance.

The proposed segmentation algorithm combines Smoothing Operator and Laplace Operator to give birth to new template that is noise free. The Laplace operator is used because it strongly respond to isolated pixels than lines or edges. The Laplace Operator is isotropic with rotational invariance that constrained with edges positions. It located and outlined unfilled root canal portion. The Laplace Operator in two dimension is represented by Equation (iii).

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \quad (\text{iii})$$

K-means algorithm used for clustering the image. The algorithm is simple, fast, efficient, applicable to large scale data and linear with time. Fig. 3 shows the K-means algorithm steps for clustering the obturated root canal images.

3.2. Root canal treatment details

The warm vertical condensation obturation method was used to perform the obturation on fifteen selected patients for this study. The DENTSPLY plugger of working diameter of 0.5 mm, 0.7 mm and 0.9 mm were used with master gutta-percha cones of 6% taper. The Kerr pulp sealer was used warm vertical condensation, extended the working time. Kerr 5004 Touch N Heat device (shown in Fig. 4) was used working length of 3.5–4.2 mm was used for performing obturation on fifteen patients. The sample Pre and Post obturated X-ray radiographs selected for study are shown in Fig. 5.

The present study used gutta-percha as obturation material using warm vertical condensation obturation technique. But the program is applicable to any obturation material and obturation technique.

Fig. 4. Kerr heat N touch obturator.³

Fig. 5. Pre and Post Obturated X-ray radiographs selected for the present study: A) Obturated root canal example 1 B) Un-obturated but prepared root canal example 1 C) Un-obturated but prepared root canal example 2 D) Obturated root canal example 2.

Fig. 3. K-Means clustering algorithm.

Table 1
Percentage filling of gutta-percha using qualitative assessment method (Dentist's prediction) and proposed algorithm of present study.

Patient No.	Percentage filling of obturation material		
	Using qualitative assessment method (Dentist's prediction) (in '%')	Using proposed algorithm of present study (in '%')	Experience of the Dentists selected for study (in 'years')
01	90–95	91.23	17
02	75–80	78.99	13
03	80–85	83.99	14.5
04	75–80	78.11	12
05	80–85	83.71	11.5
06	75–80	72.72	12.5
07	90–95	93.01	13
08	90–95	88.32	7
09	75–80	73.33	13
10	70–75	72.01	10
11	80–85	80.08	10
12	75–80	71.79	4
13	90–95	94.26	15
14	80–85	86.10	3
15	75–80	78.99	18

4. Results and discussion

The proposed algorithm quantified the percentage filling of obturation material based on the post-obturation X ray radiograph image for the fifteen selected patients (Shown in Table 1). The study used image processing techniques to quantify the percentage filling of gutta-percha in obturated root canal and to locate and outline the unfilled root canal. The reports of image processing are shown in Fig. 7. To quantify the most accurate percentage filling quantity the image was divided into smallest square. The white colour square along the root canal indicates the presence of the obturation material (gutta-percha) and on the other hand black square along the root canal shows unfilled root canal cavity. The percentage filling of gutta-percha in the obturated root canal is quantified for Patient No. 6 by using Equation (i) and (ii). The image processing and analysis result for Patient No.6 is shown in Fig. 6.

A)

B)

C)

D)

E)

F)

(caption on next page)

Fig. 6. Region of interest: showing number of white and black squares along root canal cavity.

Fig. 7. Image processing reports: **A)** Image enhancement and low pass filtering applied on pre-obturation radiograph image **B)** Enhanced pre-obturation image divided into squares **C)** Patient number 6 pre-obturation radiograph image **D)** Patient number 6 post-obturation report showing the percentage filling of gutta-percha using proposed algorithm of the present study **E)** Patient number 3 post-obturation image showing the percentage filling of gutta-percha using proposed algorithm of the present study **F)** Pre-obturation image showing 0% filling of gutta-percha using proposed algorithm of the present study.

$$\begin{aligned}\text{Percentage filling of the root canal cavity} &= \frac{W}{W+B} \times 100 \\ &= \frac{16}{16+6} \times 100 = 72.72\%\end{aligned}$$

$$\begin{aligned}\text{Percentage un-filling of the root canal cavity} &= 1 - \frac{W}{W+B} \times 100 \\ &= 1 - 0.7272 \times 100 = 27.28\%\end{aligned}$$

Based on the results of the quantification of percentage filling of the obturated root canal of fifteen patients, it is observed that the proposed algorithm of present study gives accurate percentage filling quantity of gutta-percha up to two decimal point (shown in Table 1). Qualitative assessment of the obturated root canal using X-ray radiograph is old method but the results are dependent of Dentist's experience and perception. It gives the percentage filling with 5–10% tolerance if having broader experience.

In the present study fifteen Dentists were randomly selected to assess the filling quality of obturation of fifteen patients with 5% tolerance. Out of fifteen patients, we found twelve cases matching when results of assessment of Dentists prediction compared to proposed algorithm of present study. Three cases found not matching and when investigated thoroughly we found that handling Dentists had less experience.

The proposed algorithm can be effectively used for all types of qualitative reports provided that report to be tested must contain dual colour image pattern. The Laplace operator and the smoothing operator effectively generated new template. The Laplace operator avoided the blurring of the image. The K-means segmentation based clustering algorithm is fast, simple, efficient, linear with respect to time and applicable for large scale data sets. Edge detection locates and outlines the unfilled root canal cavity along the obturated root canal.

Even though root canal obturation is done using robust technique, shrinkage and porosity of the obturation material causes gaps in between obturation material and root canal wall that leads to leakage in obturated root canal. Based on X-ray radiograph report, if Dentist fails to locate gaps and porosity, further leads to failure of root canal treatment. The proposed algorithm of present study accurately quantified the percentage filling of the obturation material in obturated root canal. It also locates and outlines the gaps and porosity in obturated root canal.

5. Conclusions

The present study concludes following points:

1. The proposed algorithm gives the accurate quantification of the percentage filling of the gutta-percha in obturated root canal cavity. It also locate and outline the unfilled root canal cavity.
2. The proposed algorithm is quantitative method and does not require the experience of Dentist for assessment. Thus it helps to avoid the false assessment that get occurred using qualitative assessment methods.
3. The present study performed is based on the X-ray radiograph report, for other types of reports also the study can be applied.
4. Image enhancement, Laplace operator, K-means clustering algorithm and edge detection segmentation proved to be effective tool of the image analysis for quantification of percentage filling of obturated root canal. K-means is easy, fast and simple algorithm.
5. The present study is in-vivo type and can be implemented to large scale.

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Declaration of competing interest

None.

References

1. Lokhande Pravin R, Deenadayalan, Ghorpade Ratnakar R, Srinidhi SR. A review of contemporary research on root canal obturation and related quality assessment techniques. *Lect Note Mech Eng.* 2018;511–515.
2. Lokhande Pravin R, Balaguru S, Deenadayalan. A comparative micro leakage assessment in root canals obturated by three obturation techniques using fluid filtration system. *Biomed Pharmacol J.* 2019;12:1–8.
3. Lokhande Pravin R, Balaguru S, Deenadayalan G, Ghorpade Ratnakar R. A review of contemporary researches on biomedical image analysis. *Commun Comput Inform Sci.* 2019;1036:1–3.
4. Hassanpour Hamid, Samadiani Najmeh, Mahdi Salehi SM. Using morphological transforms to enhance the contrast of medical images. *Egyptian J Radiol. Nucl. Med.* 2015;46:481–489.
5. Santosh KC, Candemir S, Jaeger S, et al. Automatically detecting rotation in chest radiographs using principal rib-orientation measure for quality control. *Int J Pattern Recogn Artif Intell.* 2015;29:1557–1.
6. Santosh KC, Wendling Laurent. Angular relational signature-based chest radiograph image view classification. *Med Biol Eng Comput.* 2018;56:1447–1448.
7. Santosh KC, Wendling Laurent, Antani Sameer, Thoma G. Overlaid arrow detection for labelling regions of interest in biomedical images. *IEEE Intell Syst.* 2016;31:66–5.
8. Moizadeh Amir T, Zerbst Wilhelm, Boutsoukis Christos, Shemesh Hagay, Zaslansky Paul. Porosity distribution in root canals filled with gutta percha and calcium silicate cement. *Dent Mater.* 2015;31:1100–1108.
9. Grande Nicola Maria, Plotino Gianluca, Sinibaldi Raffaele, Gambarini Gianluca, Somma Francesco. The impact of endodontic anatomy on clinical practice: a micro-CT study and tribute to Prof. Francesco Riitano. *G Ital Endod.* 2015;29:30–36.
10. Lokhande PR, Balaguru S. A mathematical model for root canal preparation using Endodontic file. *J Oral Biol Craniofac Res.* 2020;10(1):396–400. <https://doi.org/10.1016/j.jobcr.2019.09.002>.