Estimation of remaining dentine thickness below deep lesions of caries

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RESEARCH

IN BRIEF

- Stepwise excavation is an accepted technique for restoring deep caries lesions.
- The remaining dentine thickness influences pulp vitality and the outcome of certain restorative procedures.
- Reliable measurement of tooth dimensions from an intra-oral conventional or digital radiograph was not achievable.
- The general trend for the radiographic images was to over-estimate the remaining dentine thickness.

Objective The objective of this study was to investigate agreement between the estimated remaining dentine thickness (RDT) under lesions of caries, measured from a conventional *in vivo* periapical radiograph, compared directly to the measured RDT of the tooth. Additional investigation was to be made for agreement between *in vitro* digital radiographs and conventional radiographs. **Design and setting** This was a cross-sectional, single centre study at Leeds Dental Institute, United Kingdom, in 2009. **Subjects, materials and methods** Twenty-five carious teeth with occlusal or proximal lesions were collected from patients aged 19 to 82 years attending the Oral Surgery Department. Each patient had a pre-extraction *in vivo* periapical radiograph of the tooth demonstrating an intact layer of dentine below the lesions of caries. Post-extraction *in vitro* digital and conventional radiographs were taken. **Main outcome measures** Agreement of the RDT was analysed using Bland-Altman plots. **Results** A trend for the radiographic images to over-estimate the RDT compared to the tooth was found. Greater over-estimation of the RDT by conventional radiographs both *in vivo* and *in vitro* was shown compared to the *in vitro* digital images in the majority of cases. **Conclusion** This analysis has demonstrated it is not possible to estimate the dimension of the RDT from a periapical radiograph.

INTRODUCTION

The conventional approach to the treatment of lesions of caries is being increasingly questioned by the dental profession. The need to remove dentine in deep lesions to the point of being hard and stain-free while risking pulpal exposure if the tooth has been symptom-free is no longer necessary.[1]

Alternative techniques, such as atraumatic restorative treatment[2] and stepwise excavation,[3] appear to be very successful in maintaining pulpal health and vitality. In conventional treatment of deep lesions of caries, 40% of treated teeth had pulpal exposures compared to 17.5% with the stepwise approach.[4]

A number of methods have been explored to assess the remaining dentine thickness beneath lesions of caries. These include electrical resistance[5] and the Prepometer.[6] However, the radiograph is the most readily available method to the dental practitioner. It is important to understand how reliable intra-oral radiography is for the estimation of any tooth dimension and it is commonly accepted that radiographs underestimate the depth of carious lesions by as much as 1 mm.[7]

The depth of remaining dentine may give an indication of likely pulp vitality.[8] If it were possible to accurately measure the depth of the remaining dentine thickness and, therefore, the proximity of the pulp to the base of a lesion, excavation could be terminated before exposing the pulp.

The amount of remaining dentine thickness can influence treatment outcomes:

- 1 mm of residual root dentine[9] following post preparation is claimed to reduce the risk of root fracture
- Pulpal toxicity of certain materials (eg zinc oxide eugenol[10]) reduces with increasing dentine thickness
- Bond strength of resin-based adhesive systems reduces as the dentine thickness reduces.[11] Resin-modified glass-ionomer adhesive is similarly affected[12]
- Hydraulic conductance of radicular dentine decreases with increasing distance from the pulp[13]
- Heat-induced pulpal injury following curing[14] of composite material with light-emitting diode units or from burs during caries removal is more likely with reduced dentine thickness.

Pulp vitality is influenced by the remaining dentine thickness.[8,15] The number of odontoblasts reduces as the remaining dentine thickness reduces. Severe pulpal inflammation appears to be influenced by the remaining dentine thickness,[16] allowing the effects of bacteria to reach the pulp more readily when reduced. Previous studies have suggested a remaining dentine thickness of 2 mm for protection of the pulp,[17] others suggest 1 mm[18] but a minimum of 0.5 mm is now accepted.[8] When the lesion reaches within 0.25 mm-0.3 mm of the pulp, inflammatory reactions of pulpitis and hyperaemia are initiated.[19]

The greatest deposits of reactionary dentine occur with a remaining dentine thickness of 0.25 mm-0.5 mm and the presence of bacteria can exacerbate this.[15] A remaining dentine thickness of less than

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0.25 mm can injure the odontoblasts, hindering their secretion abilities. At 0.5 mm and below, odontoblast numbers are reduced by 33.7%, whereas a reduction of 13.6% is observed at a thickness of 0.25 mm-0.5 mm.[8]

The success rate of stepwise excavation after 36-45 months is 88%.[20] Direct pulp-capping has a success rate of 37% at five years and a failure rate of 80% after ten years, following a carious exposure.[21]

The aim of this project was to ascertain if it was possible to conveniently measure the depth of remaining dentine thickness under lesions of caries from a radiograph, by demonstrating agreement between measurements taken from a radiograph and excavation of the tooth.

Digital images are increasing in popularity and an *in vitro* digital image and conventional radiograph were compared to the tooth measurements to assess agreement of remaining dentine thickness.

METHOD

This was a cross-sectional, single-centre study at Leeds Dental Institute, United Kingdom, in 2009. Ethical approval was gained from Leeds West Ethics Committee for collection of 25 teeth with corresponding *in vivo* radiographs.

Adult patients aged 19-82 years, attending Leeds Dental Institute for the removal of a posterior tooth (ie a premolar or molar) who had an accompanying periapical (PA) radiograph (Fig. 1a) demonstrating remaining dentine beneath a lesion of caries, were invited to take part. Written, informed consent was obtained from all subjects following a verbal explanation about the purpose of the study and the methods to be used. An explanatory leaflet was provided for each patient.

Each tooth collected was placed in a 20 ml plastic vial (Sterilin UK) with ice.

In vivo periapical films (Kodak Insight, F-speed, Size 2, Claudius Ash, Potters Bar, Herts, UK) were taken in the course of normal treatment, before removal of the tooth. Rinn Film Holders (Claudius Ash, Potters Bar, Herts, UK) were used with a Focus Intra X-ray Unit (7 ma, 0.25 sec, 70 Kv, posterior setting, focal spot to skin surface distance 320 mm, GE Health Care Dental, Tuusula, Finland) and were developed with a Velopex Automatic Processor (Velopex, Harlseden, London, UK).

Table 1 Data collection table

Tooth	Arch/ Lesion	Gender/ Age(yrs)	In vitro tooth RDT (mm)		In vivo radiograph RDT (mm)		In vitro radiograph RDT (mm)		In vitro Digora RDT (mm)	
				IA		IA		IA		IA
1	Max/P	M/33	0.5		1.0		1.5		1.0	
2	Man/O	M/34	2.0		2.0		2.0		2.0	
3	Man/P	M/22	2.5		3.0		2.5		3.0	
4	Max/O	F/22	0.5		1.5		1.0		1.0	
5	Max/P	M/29	1.0	1.0	2.0	2.0	2.0	1.5	1.5	1.5
6	Man/P	M/77	1.0		2.0		2.0		1.0	
7	Man/O	M/40	1.0		2.0		2.0		2.0	
8	Max/P	M/81	0.5		1.0		1.0		1.0	
9	Man/O	F/35	1.0		1.0		0.5		0.5	
10	Man/P	F/53	1.0	1.0	2.0	2.0	2.0	2.0	1.5	2.0
11	Max/P	M/27	1.0		2.0		3.0		2.0	
12	Man/P	M/30	1.0		1.5		0.5		1.0	
13	Man/O	M/76	3.5		3.5		3.0		3.0	
14	Max/O	M/47	1.0		3.0		3.0		3.0	
15	Man/P	M/28	0.5		0.5		1.5		1.0	
16	Max/P	F/41	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0
17	Max/P	M/41	1.0		2.0		1.0		1.0	
18	Max/P	M/35	2.5		3.0		2.0		1.5	
19	Max/P	F/19	3.0		3.0		3.0		3.0	
20	Man/P	M/48	1.0	1.0	2.0	2.5	2.0	2.0	2.0	2.0
21	Max/P	M/65	2.0		2.5		1.5		1.5	
22	Max/P	F/29	1.5		1.5		1.0		1.0	
23	Man/P	F/29	0.5		1.0		1.0		1.5	
24	Max/P	M/37	1.0		1.5		2.0		1.5	
25	Max/P	F/30	1.0	1.0	2.0	2.0	1.0	1.0	1.0	2.0

Key:
Max = maxilla; Man = mandible; O = occlusal; P = proximal; RDT = remaining dentine thickness;
IA = intra-agreement; mm = millimeter; M = male; F = female

The *in vitro* radiograph was taken with the tooth placed directly on a radiographic film (Kodak Insight, F-speed, Size 2, Claudius Ash, Potters Bar, Herts, UK) with the Prostyle Intra Machine (Planmeca, 70 Kv, focal spot to skin surface distance 315 mm, Claudius Ash, Potters Bar, Herts, UK) set to the recommended anatomical exposures. The radiographic cone was placed in a lead-lined box at the same depth for each film. The Kodak films were processed with the Velopex Automatic Processor. The remaining dentine thickness was measured on the periapical radiograph in a darkened room, on a viewing box, with a viewing area the size of the film cut out of black card. No magnification was used.

The digital image (Fig. 1c) was taken on Digora Optime Imaging Plates (Size 2, Soredex, Tuusula, Finland) in the same way as the *in vitro* radiograph. The Digora Plates were processed with the Digora Optime (Soredex, Tuusula, Finland). This was linked to a Dell Computer and Screen and used the programme Digora for Windows 2.5 Rev 1, Soredex, 1993-2005. The screen size was 17 inches,

with 1,024 × 768 pixels, 32 bit colour-depth and 96 dpi resolution. The programme allowed direct digital measurement of the required dimensions.

The tooth was sectioned in the mesio-distal plane within the hour. A silicone rubber-headed 50 mm hand-clamp (B&Q, Leeds, UK) held the tooth for sectioning and was attached with G-clamps (B&Q, Leeds, UK) to a laminated wooden frame secured with G-clamps (B&Q, Leeds, UK) to a phantom-head.

The diamond cutting disc (Skillbond, High Wycombe, UK, Sintered Diamond Disc, size 400, 1/10 mm set 638R1) was used in a Kavo EWL K9 hand-piece (Kavo Dental Ltd, Amersham, Bucks, UK). This was replaced after every fifth section. Water from the 3-in-1 syringe was used as a coolant.

The portion of the tooth with visually the deepest lesion was hand-excavated, using small and medium excavators (Henry Schein, Kent, UK) to the point of clinical acceptance of remaining dentine, ie the dentine was firm to the application of moderate excavation force. The remaining dentine thickness following hand-excavation (Fig. 1d) was measured directly on the tooth using a clear plastic ruler.[22] Measurements were taken from the thinnest point of remaining dentine on the floor of the lesion to the pulp dentine border[8] to the nearest 0.5 mm.

Thus, a total of four measurements were taken:

- *In vivo* conventional PA
- *In vitro* conventional PA
- *In vitro* Digora digital image
- Post hand-excavation.

Repeat measurements to assess intra-operator agreement were made on 20% of the samples selected at random (Table 1).

Statistical analysis

Statistical analysis was by graphical technique using Bland-Altman plots to demonstrate agreement of the continuous variables.[23] This utilises the difference between two measurements and their mean. The mean of the differences is shown as the bias line and the standard deviation (SD) of the differences demonstrates the 95% limits of agreement. This was carried out using SPSS 14.

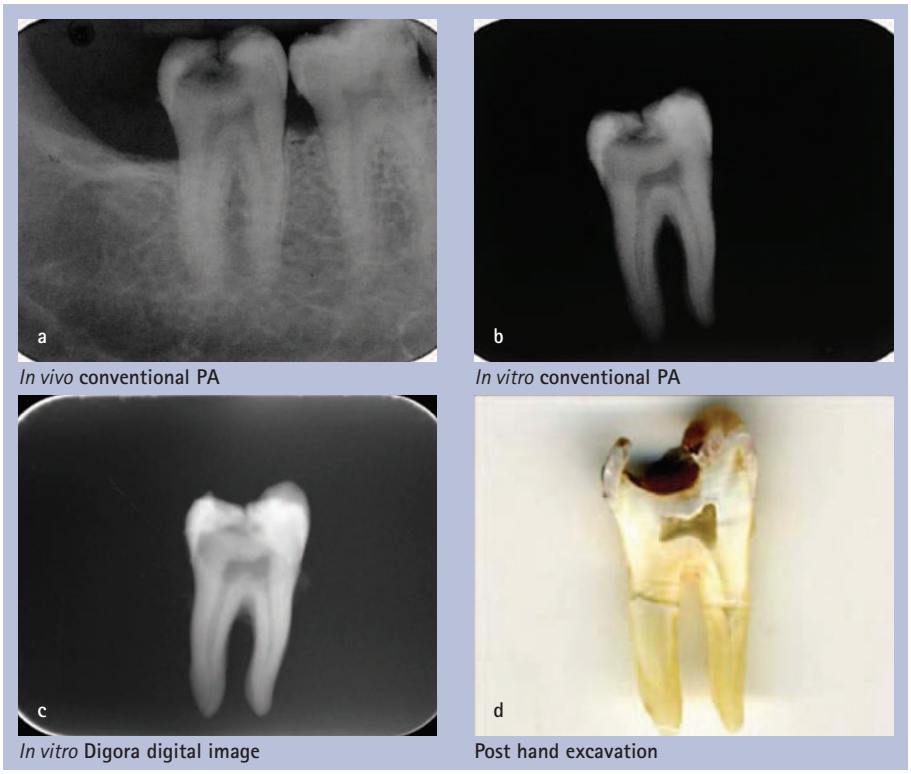

Fig. 1 A sample of each image taken

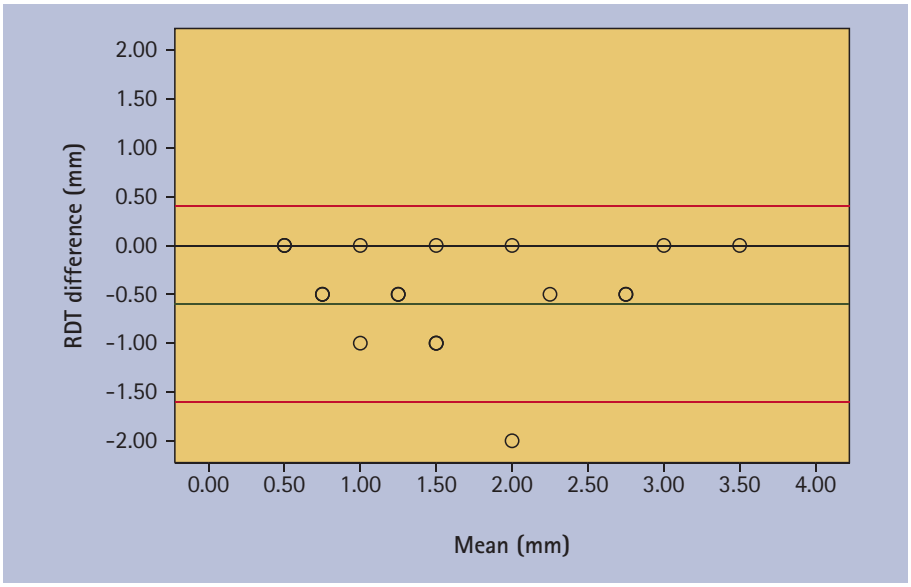

Fig. 2 Bland-Altman plot of remaining dentine thickness of *in vitro* tooth and *in vivo* radiograph

RESULTS

Subject data

This study consisted of 17 males and 8 females aged between 19 and 82 years, with a mean age of 40.3 years, SD 17.5.

The Bland-Altman plot of remaining dentine thickness of the *in vitro* tooth and the *in vivo* radiograph (Fig. 2) demonstrates agreement does occur in over a quarter of cases (7/25) and the *in vivo* periapical value is always equal to, or greater than, the tooth value, indicating a trend for the radiograph to over-estimate the RDT.

Figure 3 demonstrates the agreement between *in vitro* tooth and *in vitro* periapical radiograph, where there is agreement in a fifth of the sample (5/25) and there is over- and under-estimation of the dimensions radiographically.

Figure 4 represents the agreement between the *in vitro* tooth and *in vitro* Digora digital image, where there is agreement for just under a quarter of the sample (6/25). As with the conventional radiographs, the majority of samples

(20/25) digitally equal or over-estimate the dimensions.

Very good agreement between the *in vivo* and *in vitro* radiographs was demonstrated with a bias line of 0.16 mm, and between the *in vitro* radiograph and digital image at 0.14 mm.

DISCUSSION

Measurements of the teeth and the radiographs were taken by means of a clear plastic ruler. This method has been used in other studies for measuring tooth dimensions, for example enamel.[22] It may be argued that this may magnify the measurements but this will be the case for all measurements. This basic method of measurement was chosen as it can be replicated easily in an unmodified practice setting. It is a simple, fast and readily available method carried out at the chair-side.

The decision to measure to the nearest 0.5 mm was based on the premise that this is the minimum depth of remaining dentine acceptable before there is evidence of pulpal injury.[8]

The actual measurements taken were from the thinnest point of remaining dentine on the floor of the lesion and the pulp dentine border.[8] This proved very difficult at times due to the variation of mineral dissolution of the margins of the carious lesion. There will, inevitably, be an element of human error in the transfer from one image to another in maintaining the identical point to be measured compared to the tooth.

All measurements were taken by one examiner. The accessibility to two examiners for the measurements of the actual tooth was, unfortunately, logistically impossible within the hour of collection. As agreement was being investigated between the tooth and the radiographs, having only one examiner for the tooth measurements and two for the radiographs, would not have added to the validity of the results. Observer variability is a major factor in diagnostic performance and is rarely controllable.[24] Intra-examiner agreement measurements were taken for 20% of the samples to determine examiner reliability, which was good.

The radiographic and digital images of the teeth were taken, stored and read at a separate time to the measurements of the teeth. The radiographs were read in a quiet, darkened room on a viewer.[25] No magnification was used.

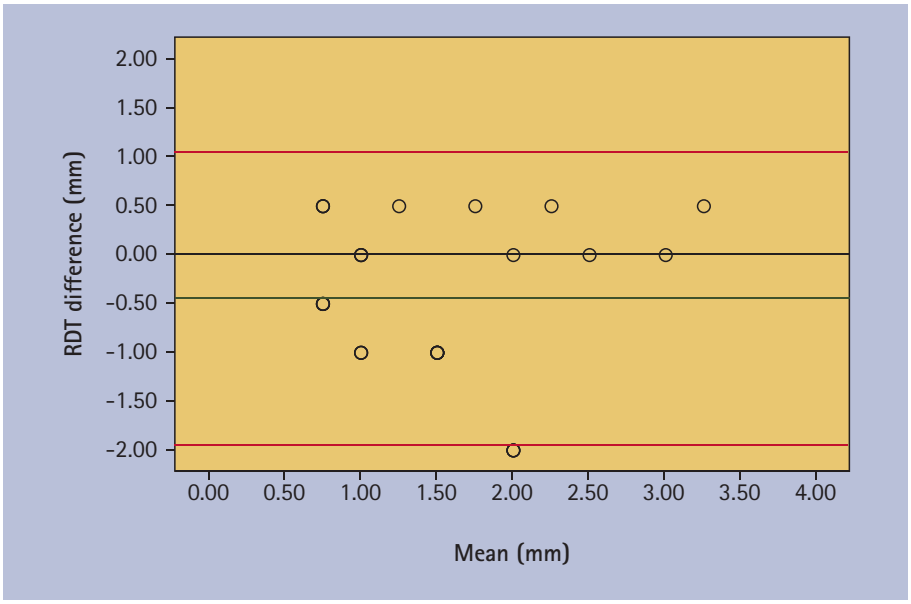

Fig. 3 Bland–Altman plot of remaining dentine thickness of *in vitro* tooth and *in vitro* radiograph

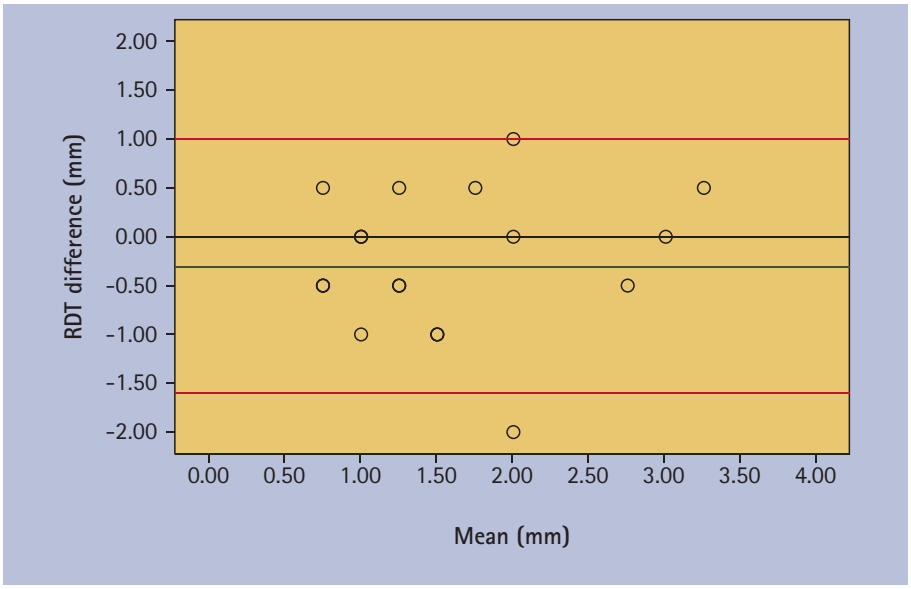

Fig. 4 Bland–Altman plot of remaining dentine thickness of *in vitro* tooth and *in vitro* Digora image

All studies have limitations and the ideal radiograph for caries detection is the bitewing[26] but it was not clinically justifiable to take a bitewing radiograph for this study. The peri-apical images were taken using film holders, and the projection geometry in relation to the crown of the tooth and the magnification is likely to be similar to a bitewing image.

The *in vitro* images may be made more consistent by the use of a device to hold the teeth and film in a standardised position[27] and to attempt to replicate the soft tissues[28] by the use of plasticine or a similar material. Svanæs *et al.*[29] utilised a method of simultaneous exposure for the digital and conventional image receptors to obtain geometric accuracy.

All images will be susceptible to magnification and some level of distortion as perfect geometry is unlikely. This is reduced by the use of film holders intra-orally to allow comparison with similar intra-oral films. However, in reality even this clinical application will not be totally reproducible, but it does minimise the level of distortion and magnification between images. The positioning of the teeth directly on the films *in vitro* is unlikely to replicate the film positioning *in vivo* perfectly but the results in this case demonstrated very good agreement between the *in vivo* and *in vitro*

radiographs (bias line 0.16 mm). Very good replication between the *in vitro* images was also demonstrated (bias line 0.14 mm). The dilemma continues as to how to consistently reduce such discrepancies clinically.

CONCLUSIONS

From the above analysis, the following conclusions may be drawn:

1. It is not possible to accurately determine the dimension of the remaining dentine thickness from a periapical radiograph
2. The *in vivo* radiographs over-estimate the amount of remaining dentine thickness under lesions of caries in the majority of cases. No underestimation was found
3. The Digora Optime digital image generally over-estimates the remaining dentine thickness
4. The *in vivo* and *in vitro* radiographs generally over-estimate the remaining dentine thickness by a greater degree than the Digora Optime digital image.

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