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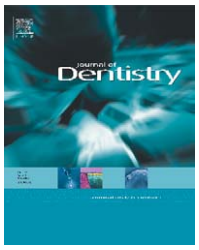

Assessment of the amount of remaining coronal dentine in root-treated teeth☆

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ABSTRACT

Objectives: There is currently no standardised technique to measure the amount of coronal dentine remaining in a root-treated tooth after crown preparation. The aim of this study was to develop a method of measuring remaining coronal dentine in root-treated teeth and to propose an index for grading tooth restorability.

Methods: The study recruited 20 patients who had completed molar endodontic treatment at the Eastman Dental Hospital and had been prescribed an amalgam coronal-radicular core with a full coverage cast restoration. Using a series of interlocking special trays and impressions, a method was devised to produce a cast of the amount of remaining dentine coronal to the finish line after crown preparation. This cast was scanned using a laser profilometer and the volume of remaining dentine was calculated. A tooth restorability index (TRI) was developed to assess the strategic value of the remaining dentine. The TRI allowed scores of 0–3 in each sextant with a maximum score of 18 per tooth.

Results: Twenty teeth were scored by three examiners and the TRI scores varied from 2 to 13. The volume of coronal dentine varied from 61.73 to 232.22 mm^3.

Conclusions: A tooth restorability index has been devised to assess the strategic value of remaining dentine. A Kappa statistic was calculated to produce values of 0.584, 0.688 and 0.720, giving moderate–good agreement between the examiners.

1. Introduction

Restoration of the root-treated tooth is complicated by the fact that much or all of the coronal tooth structure that would normally be used in retention of a restoration has been destroyed by caries, previous restorations, trauma and the endodontic access preparation itself. If insufficient dentine remains it may be necessary to use a post and core or coronal-radicular core in order to retain a restoration.

The importance of preserving intact tooth tissue when restoring non-vital teeth is widely reported.[1–4] It is generally agreed that a ferrule design providing coronal dentine above the finish line will increase fracture resistance of root-treated teeth.[5] The amount of additional dentine gained by the extent of the ferrule is also important.[6–8]

It is assumed that root-filled teeth contain less coronal dentine than their vital counterparts. The increased failure rate of non-vital teeth when used as bridge abutments may therefore reflect their compromised structure[9,10] but has also been attributed to an elevated mean pain threshold.[11]

Few studies have assessed the amount of residual tooth structure. Residual dentine thickness after preparation for

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Cerec crowns in vital posterior teeth has been reported.[12] They concluded that the mean residual dentine thickness between the axial wall and pulp chamber varied between 0.47 and 0.7 mm in posterior teeth.

The thickness of remaining dentine following various preparations on a maxillary second premolar with an endodontic access and a moderate sized amalgam restoration has been reported.[13] Following preparation for a ceramo-metal or all-ceramic crown the thinnest section of remaining tooth structure (cut in the occlusal plane) was 0.8 mm and >0.3 mm, respectively.

Malferrari et al.[14] evaluated 205 quartz fibre posts placed in root canals during a 30-month period. As part of their pre-op assessment they classified the remaining tooth structure as complete (i.e. 66–100% remaining), partial (33–66% remaining) or absent (0–32% remaining). Three posts failed, one of these occurred in a tooth with partial tooth structure and two in teeth with absent remaining tooth structure.

One recent prospective study[15] found that the amount of dentine height after preparation influenced longevity of a post and core restoration. Teeth were assessed to have either substantial or minimal dentine height. In the former group a dentine collar of 1–2 mm could be achieved but was not possible in the later group.

In non-vital teeth, the residual coronal dentine must be assessed before a decision can be made regarding its suitability for restoration with either a post and core or a plastic core. Nayyar et al. (1980)[16] described a technique where amalgam was used as a core material in the pulp chamber and the coronal 2–4 mm of the root canal system to gain additional retention and resistance-form. Christensen (1996)[17] recommended that if more than half the coronal tooth structure was remaining a post and core restoration was probably not required.

Many studies evaluating root-treated teeth have been retrospective in nature and have therefore not included information on residual dentine.[3,9,10] We therefore have little prospective data which can provide an evidence-base and allow guidelines for the restoration of the root-treated tooth to be developed. The aim of this study was to develop a method of measuring remaining coronal dentine in root-treated teeth and to propose an index for grading tooth restorability.

2. Materials and method

Patients who had molar root-treatments provided at the Eastman Dental Hospital and were suitable for restoration with an amalgam core and full coverage, extra-coronal cast restoration were included in the study. The first 20 patients who presented within the study period were recruited, 9 had conventional root canal treatments and 11 had non-surgical re-root canal treatments. Study protocols were discussed with the patient and consent was obtained. One operator prepared and fitted all cast restorations but the amalgam cores were placed by an endodontic postgraduate. Ethical approval was not required at the time of the study as no extra clinical procedures were required to complete the treatment.

A patient history was taken followed by intra-oral and extra-oral examinations. The periodontal status was recorded using the basic periodontal examination (BPE) index. A dental chart of teeth present was recorded and the occlusion was analysed clinically in intercuspal position, retruded contact position and excursive movements. Study casts were mounted on a Dénar semi-adjustable articulator (Teledyne Water Pik, Fort Collins, CO, USA) using a facebow transfer, occlusal record and type II Snow White plaster (Kerr, Peterborough, UK). A diagnostic wax-up was carried out of the molar intended for a cast restoration, and a President® putty index was taken.

One of two types of amalgam core was placed by the endodontist; the first was the Nayyar core where amalgam was placed 2–4 mm into each root canal, in the second 1–2 mm of Intermediate Restorative Material (IRM®) (Dentsply, Surrey, UK) was placed over the canal orifices and amalgam condensed into the remainder of the pulp chamber. Prior to amalgam core placement a polyvinyl siloxane addition cured silicone impression (President®, Coltene, W. Sussex, UK) was taken of the internal and external form of the tooth, adjacent teeth and soft tissues using a sectional impression tray. After 5 min the tray was removed and poured using type IV Silky Rock stone (Whip Mix Corporation, Kentucky, USA). An Automatrix® band (Dentsply, Surrey, UK) was placed and Tytin® (Kerr, Peterborough, UK) amalgam was condensed into the cavity.

The patient was recalled for the crown preparation. The putty index was sectioned and used as a guide to provide adequate even occlusal reduction of 1.5 mm on the functional cusps and 1 mm elsewhere. A provisional crown was made by relining the putty matrix with Trim® (Harry Bosworth Company, Sokokie, IL, USA). A full-arch impression was made using President® light and heavy body material in a stock tray and if any planned adjustments were made to the opposing tooth a new alginate impression was taken of the opposing arch.

The President® impression was silver plated and then poured using Duralay® and type IV Silky Rock stone. The crown was subsequently waxed up, invested, cast and polished. The crown was examined on the preparation intra-orally, contact points, marginal integrity and occlusion were checked prior to cementation with zinc phosphate. The patient was then discharged back to the referring dental practitioner for maintenance and regular check-ups.

2.1. *Coronal dentine analysis*

In order to ascertain the amount of coronal dentine remaining after crown preparation the internal aspect of cast A (the cast of the molar prior to amalgam core placement) was combined with the external aspect of cast B (the cast of the molar after crown preparation). This will be referred to as a combined cast which represents the amount of remaining coronal dentine (cast C).

Firstly, buccal and lingual special trays were made on cast A using Triad® acrylic (Dentsply, Surrey, UK). The trays extended up to the level of the occlusal plane of the adjacent teeth. V-shaped retention slots were placed along the occlusal aspect of these two trays to locate a third impression tray as seen in Fig. 1.

A third special tray made on cast A recorded the occlusal detail of the abutment teeth and care was taken to ensure that no Triad® entered the access cavity as this would prevent correct seating of this tray onto cast B. This technique enabled all three trays to be separated and linked together using the retention slots.

Fig. 1 – Buccal and lingual impressions of cast A.

The occlusal special tray from cast A was transferred to cast B and new buccal and lingual special trays and impressions were taken of cast B (Fig. 2). This impression provided the external axial contour of the final crown preparation (Fig. 3).

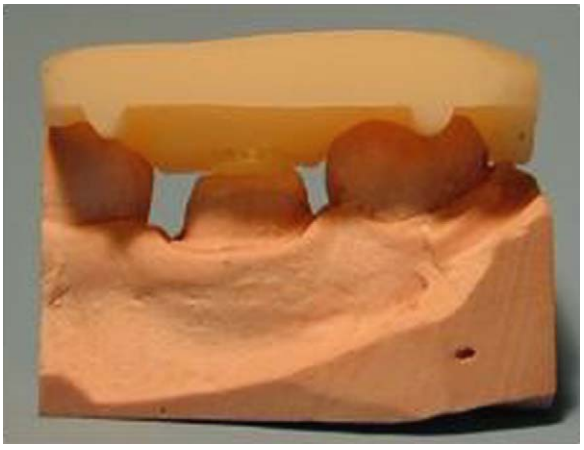

Fig. 2 – Transfer of occlusal impression from cast A to cast B.

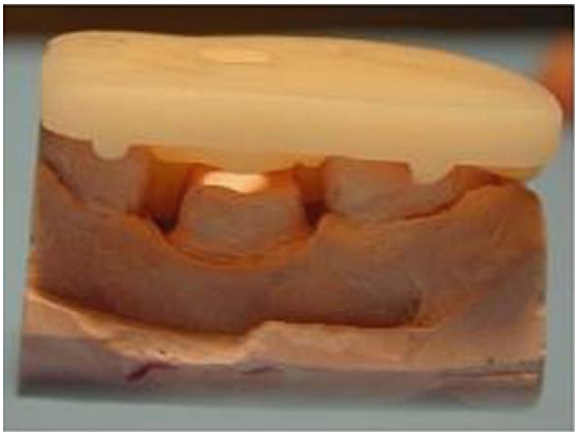

Fig. 3 – Buccal impression taken of cast B linked to the occlusal tray transferred from cast A.

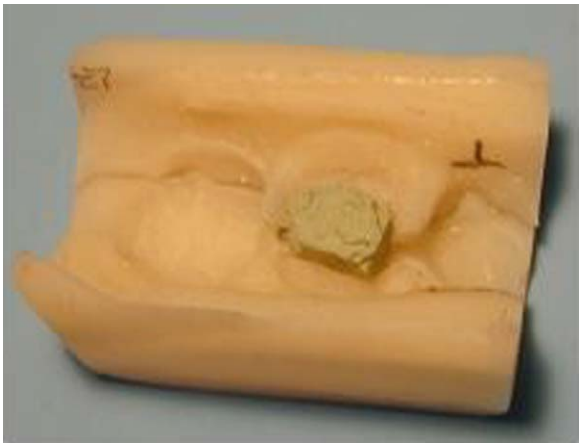

Fig. 4 – Buccal and lingual impressions of cast B combined with occlusal and internal aspect of cast A.

The next stage involved making an impression of the internal aspect of cast A. The occlusal tray was returned to cast A with the original buccal and lingual trays from cast A. Medium body President® impression material was syringed into the internal cavity on cast A and was recorded on the occlusal tray. The buccal and lingual trays were used to contain the impression material. The occlusal impression of the internal aspect of cast A was linked by slots to the buccal and lingual impressions from cast B (i.e. the external form of the crown). Together this information provided a complete impression of the remaining coronal dentine (Fig. 4) and was poured in Silky Rock stone.

2.2. *Laser profilometer*

The combined cast of the remaining coronal dentine was trimmed under a microscope to the crown margin so that the margin was clearly identified. The die was scanned bythe laser profilometer in order to record the remaining tooth structure. Undercuts within the internal aspect of the die were blocked out using President® impression material, as these areas could not be recorded by the profilometer. In order to account for the volume discrepancy caused by blocking out of undercuts, the section of impression material used to block out the undercut was weighed, volume calculated and subtracted from the volume reading for coronal dentine.

The profilometer measured the cross-sectional height of the tooth at 0.05 mm intervals in a mesio-distal and bucco-lingual plane along the finish line of the preparation. This gave approximately 200 readings in each plane and a total of 40,000 recorded measurements per tooth. These points were used to produce a three-dimensional image of the tooth. The data was transferred to a Microsoft Excel® spreadsheet and each point was represented by a numerical value. This enabled line graphs to be drawn which related to the cross-sectional outline for each tooth. Within each line graph the crown margin was identified and points below the crown margin were deleted. In this way 20 line graphs were produced for each tooth clearly showing the crown margin and cross-sectional outline in various planes. A program was run in Excel

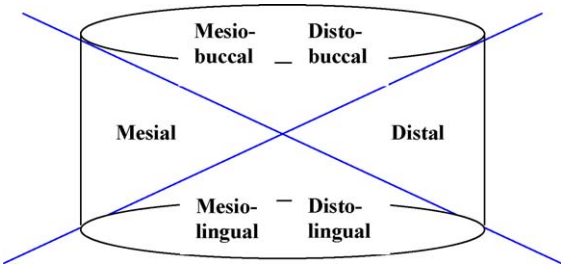

Fig. 5 – Occlusal diagram to illustrate sextants for tooth restorability index.

that joined the two opposing points of the crown margin together to create an imaginary line that was used to calculate the area of the section from this line to the tooth surface. The area was then multiplied by 0.5 mm (the width of each section) to give the volume. This was repeated 20 times for each tooth to obtain the total area and volume for the tooth.

This technique was verified by trimming three of the combined casts to their finish lines. These casts were then weighed and the volume calculated by dividing the mass by the density of the stone (where volume = mass/density).

2.3. *Tooth restorability index (TRI)*

In order to ascertain if the coronal dentine had any structural value to crown retention and resistance, a tooth restorability index was devised. This was intended to provide a numerical value as to whether tooth sections or the whole tooth was deemed to be predictably restorable. The tooth was divided into six equal sections encompassing two proximal, two buccal and two lingual areas (Fig. 5).

For each sextant, the coronal dentine's contribution to retention and resistance (i.e. above the finishing line of the preparation) was reviewed and the following scores assigned. If in doubt, the lower score was assigned.

The clinicians who analysed the teeth were advised to use their clinical judgement and were given the following guidelines.

A scoring system of 0–3 was allocated to each section:

- 0—None. Throughout two thirds or more of the sextant under consideration there is no axial wall of dentine (i.e. a box or missing cusp) or any dentine present above the finishing line is so lacking in height as to be unable to contribute to retention and resistance of a core or crown. This score is appropriate where a margin is visible just apical to the limit of a missing wall but there is only a small bevel or chamfer comprising the preparation dentine.
- 1—Inadequate. Coronal dentine is present in the sextant but in terms of thickness, height or distribution (example: an undermining undercut) is in the operator's clinical opinion insufficient to make any predictable contribution to retention and resistance. Dentine walls that are less than 1.5 mm thick (a turbine bur shank is 1.6 mm) or more than twice as high as their thinnest part would be included in this category.
- 2—Questionable. More dentine is present than in 1, but in one's clinical opinion it is not possible to be confident whether or not it will make a predictable contribution to retention and resistance. This score should only be assigned where the operator finds it impossible to determine whether a score of 1 or 3 is more appropriate. Do *not* use it as a default category.
- 3—Adequate. There is sufficient coronal dentine in terms of height, thickness and distribution for the operator to feel confident that this sextant will contribute fully to retention and resistance of the core and final restoration.

Thus a maximum of 18 could be scored for each tooth.

Each of the 20 teeth were analysed by the author and two experienced consultants. A mean was taken of all three scores and an assignment of tooth restorability given to each tooth. The examiners used the combined cast of remaining coronal dentine to score the tooth restorability index for each tooth. Kappa statistic was calculated.

3. Results

Three casts were made of each tooth, a cast of the tooth prior to the amalgam placement, a cast of the tooth once the core had been placed and the crown had been prepared, and a cast of the overall remaining dentine. Casts of tooth number 4 are presented as a series of photographs (Fig. 6a–c). All photographs were taken from the disto-buccal or disto-lingual aspect. Table 1 describes the teeth that had amalgam extending into the root canals (Nayyar core) and those which had an IRM base covering the canal orifices.

The casts were scanned by the laser profilometer to produce a three-dimensional image as shown in Fig. 7. This image was transported to Microsoft Excel® to produce a line graph of each 0.05 mm cross-section of the tooth as shown in Fig. 8. The results for the volume of each tooth obtained from the laser profilometer are shown in Table 2. These results indicate that volume of remaining dentine varies from 61.73 to 232.22 mm^3 and are represented graphically in Fig. 9. Table 3 illustrates the results of weighing three trimmed casts to verify the coronal dentine volumes obtained from the laser profilometer.

Table 1 – Type of coronal-radicular cores

Type of amalgam core	Tooth number	Total
Extending into root canals	1, 2, 4, 5, 7, 10, 13, 14, 15, 17, 19, 20	12
Remaining within the pulp chamber	3, 6, 8, 9, 11, 12, 16, 18	8

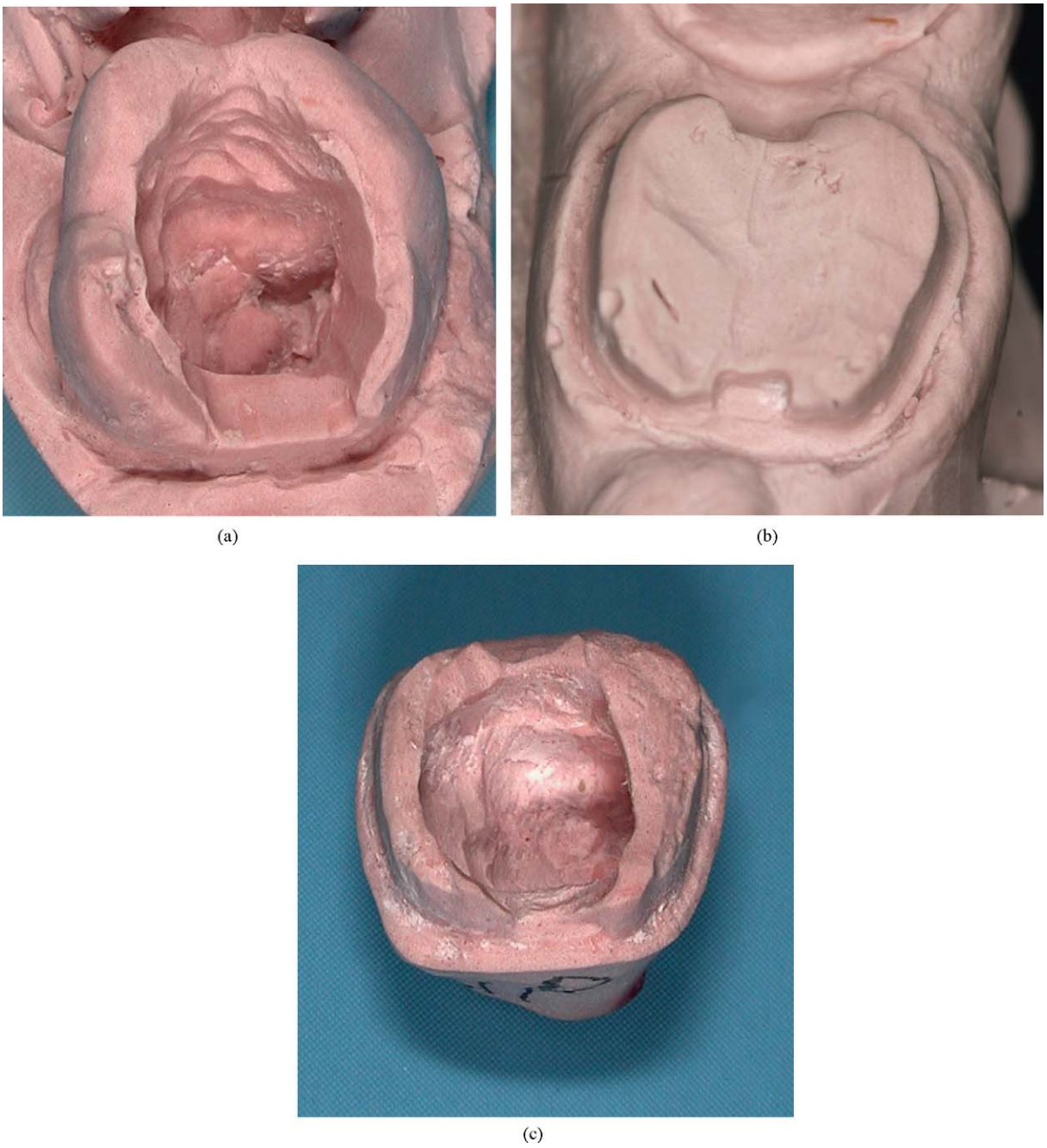

Fig. 6 – Photographs of casts: (a) tooth 4: prior to amalgam placement; (b) tooth 4: after crown preparation; (c) tooth 4: remaining coronal dentine or combined cast.

3.1. *Tooth restorability index*

Table 4 shows the tooth restorability index for each tooth scored by all three examiners in sextants with the total score per tooth.

The mean of the tooth restorability index was calculated from the total score of each tooth as devised by the three examiners (Table 4). The mean score is presented in Table 2. Discrepancies between the three examiners can be seen in Table 5. A Kappa statistic was calculated and results can be seen in Table 6. A Kappa value of 0.720 was obtained between examiners 1 and 2, a value of 0.688 between examiners 2 and 3, and 0.584 between examiners 1 and 3.

4. Discussion

Random allocation of patients into this study was intended to reduce the potential for bias. It is generally accepted that root-treated posterior teeth should be restored to include cuspal coverage.[18] Nineteen of the 20 teeth prepared were restored with full gold crowns. One tooth was restored with a porcelain

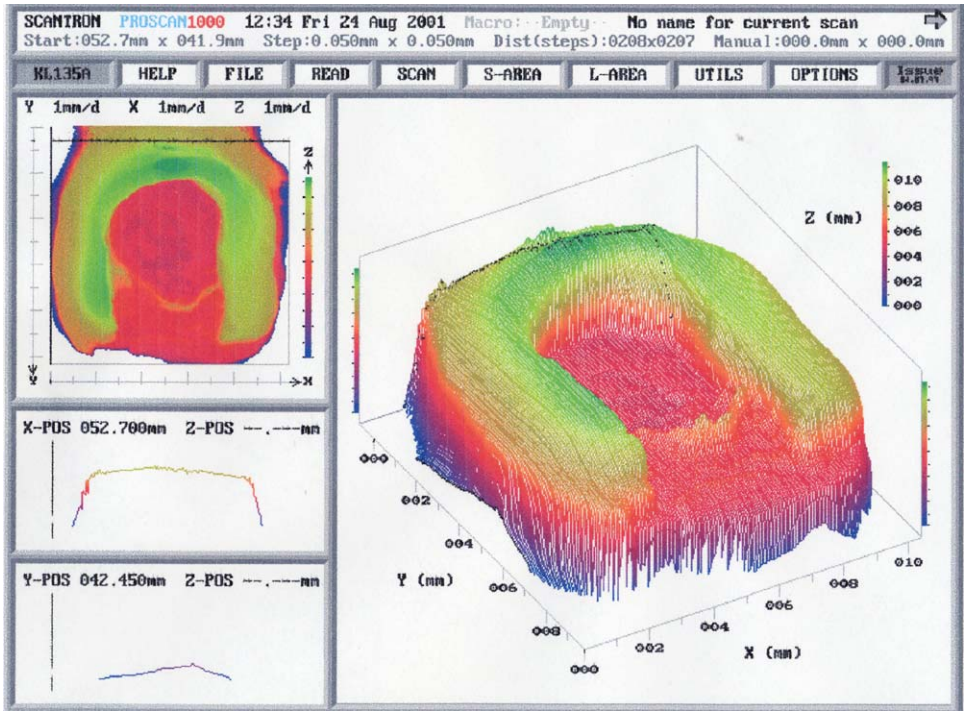

Fig. 7 – Laser profilometer three-dimensional image of combined cast.

fused to metal (PFM) restoration as it had previously been restored with a crown of this design.

Endodontic postgraduates placed two different amalgam core types. The decision regarding the type of core was based on the depth of the pulp chamber and the volume of dentine that would remain after preparation to retain the core. Controversy exists as to whether increased retention of the amalgam core is gained when the core is extended into the root canal system. It has been reported that the depth of pulp chamber may be an important factor in determining whether the root canal system is incorporated into the coronal-radicular restoration.[19] In another study it was demonstrated that extension of the core material into the coronal root canal system did not increase the fracture resistance to compressive loading.[20] However other forces are also encountered intra-orally. In this study 60% of the teeth were restored with the Nayyar core restoration and 40% with the modified technique. Both cores require identical coronal preparation and therefore the amount of coronal dentine present was unaffected by the core type chosen. Prospectively these data may prove useful in evaluating whether the core type is significant to the longevity of the restoration.

The laser profilometer was unable to record undercuts and these were recorded by syringing impression material into these areas and subsequently weighing it to determine its volume. The results show that there was considerable

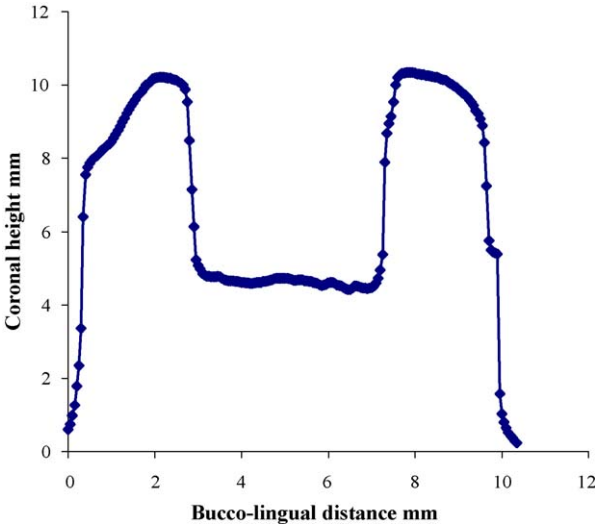

Fig. 8 – Line graph of cross-section of combined cast.

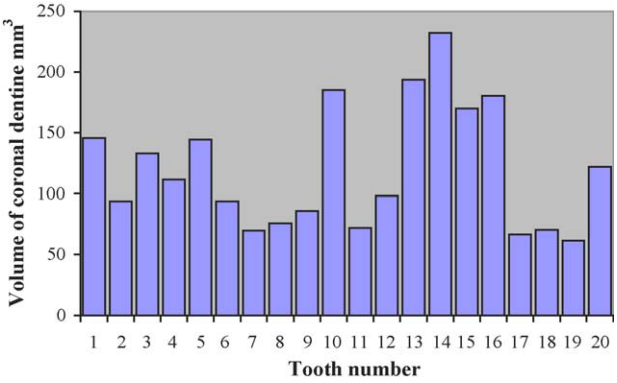

Fig. 9 – Column chart of total volume of coronal dentine.

Table 2 – Volume of coronal dentine scanned by laser profilometer and TRI score

Tooth number	Scanned volume (mm^3)	Impression material volume (mm^3)	Total volume (scanned – impression material) (mm^3)	Mean TRI score
1	145.73		145.73	10
2	93.70		93.70	6.66
3	132.95		132.95	10
4	114.24	2.57	111.67	10
5	154.11	9.66	144.45	12
6	114.31	20.30	94.01	4
7	69.85		69.85	8
8	75.77		75.77	8
9	85.95		85.95	9.66
10	185.18		185.18	10.33
11	72.03		72.03	4.66
12	105.96	7.49	98.47	4.66
13	193.52		193.52	12.33
14	232.22		232.22	9.66
15	175.00	5.23	169.77	6
16	180.36		180.36	10
17	66.81		66.81	8
18	70.44		70.44	9
19	61.73		61.73	4
20	121.94		121.94	7.33

Table 3 – Verification of remaining dentine volume measured

Tooth number	Mass of stone (g)	Volume (mm^3)	Scanned volume (mm^3)
1	0.257	138.2	145.73
13	0.336	180.6	193.52
16	0.305	163.9	180.36

Table 4 – Tooth restorability index teeth 1–20

Tooth	Examiner	Tooth surface						
		D	DL	ML	M	MB	DB	Total
1	1	1	3	3	0	2	1	10
	2	2	3	3	0	1	1	10
	3	1	3	3	0	2	1	10
2	1	0	0	1	0	2	3	6
	2	0	0	1	0	2	3	6
	3	0	1	1	1	2	3	8
3	1	1	3	2	1	2	2	11
	2	1	3	2	1	2	2	11
	3	1	2	2	1	1	1	8
4	1	0	3	3	1	3	3	13
	2	0	1	1	1	3	3	9
	3	0	1	2	1	3	1	8
5	1	0	3	3	0	3	3	12
	2	0	3	3	0	3	3	12
	3	0	3	3	0	3	3	12
6	1	0	1	1	0	1	1	4
	2	0	1	1	0	1	1	4
	3	0	1	1	0	1	1	4
7	1	1	2	3	2	1	1	10
	2	1	2	2	1	1	1	8
	3	1	1	1	1	1	1	6
8	1	0	3	3	0	1	1	8

Table 4 (*Continued*)

Tooth	Examiner	Tooth surface						
		D	DL	ML	M	MB	DB	Total
	2	0	3	3	0	1	1	8
	3	0	3	3	0	1	1	8
9	1	0	1	2	1	3	2	9
	2	0	2	2	1	3	2	10
	3	0	2	2	1	3	2	10
10	1	0	3	3	0	3	2	11
	2	0	3	3	0	2	2	10
	3	0	3	3	0	2	2	10
11	1	2	0	0	0	1	1	4
	2	1	1	1	0	1	1	5
	3	0	1	1	1	1	1	5
12	1	0	2	2	0	1	1	6
	2	0	1	1	0	1	1	4
	3	0	1	1	0	1	1	4
13	1	3	3	3	0	2	2	13
	2	2	3	3	0	2	2	12
	3	2	3	3	0	2	2	12
14	1	0	1	3	0	3	3	10
	2	0	1	3	0	3	3	10
	3	0	1	3	0	3	2	9
15	1	0	0	0	0	3	3	6
	2	0	0	0	0	3	3	6
	3	0	0	0	0	3	3	6
16	1	1	1	1	3	3	3	12
	2	0	1	1	2	3	3	10
	3	0	0	1	3	3	1	8
17	1	1	1	1	0	3	3	9
	2	1	1	1	0	2	2	7
	3	0	1	1	0	3	3	8
18	1	1	2	2	2	2	2	11
	2	1	2	1	1	2	2	9
	3	0	1	1	1	2	2	7
19	1	0	1	1	0	2	2	6
	2	0	1	1	0	1	1	4
	3	0	0	0	0	1	1	2
20	1	1	2	2	2	1	1	9
	2	1	2	1	1	1	2	8
	3	1	1	1	1	0	1	5

D: distal DL: disto-lingual ML: mesio-lingual M: mesial; MB: mesio-buccal DB: disto-buccal.

Table 5 – Tooth restorability index scores as determined by the three examiners

Discrepancy of TRI between examiners	Tooth number	Total number of teeth
0	1, 5, 6, 8, 15	5
1	9, 10, 11, 13, 14	5
2	2, 12, 17	3
3	3	1
4	7, 16, 18, 19, 20	5
5	4	1

variation in the remaining dentine present, i.e. from 61.73 to 232.22 mm^3. This figure represents the amount of residual dentine but does not indicate the distribution or strategic value of the amount of remaining tooth tissue.

An index was devised by the authors to provide a representation of the distribution and quality of remaining dentine in specific areas, as well as a total score for the whole tooth. The tooth restorability index scores for the 20 teeth varied from 2 to 13. The results showed moderate agreement between examiners 1 and 3 and good agreement between examiners 1 and 2, 2 and 3. These strengths of agreement follow the original guidelines of Landis and Koch (1977)[21] as adapted by Altman.[22] The main area of discrepancy occurred when the height to width ratio of dentine was large. This is

Table 6 – Kappa values

Paired examiner	Value of *K*	Strength of agreement	95% confidence interval
Examiner 1 and 2	0.72	Good	0.622–0.818
Examiner 1 and 3	0.584	Moderate	0.472–0.695
Examiner 2 and 3	0.688	Good	0.584–0.791

well illustrated by the mesio-lingual area of tooth 4 (Table 4, Fig. 6). Good inter-examiner reliability was obtained in teeth that had a particularly large or small amount of residual coronal dentine. As with all subjective scoring systems, some variation occurred due to different clinical opinion and experience.

Of the 20 teeth in this study, 13 teeth had a TRI score of less than 10, which in the subjective opinion of the examiners was becoming less suitable for a plastic core. However the total TRI scores must be used with caution and would ideally, in the author's view, be comprised of scores of 2 or 3. The effect of reduced coronal dentine can only be evaluated in a long-term prospective study.

The examiners were particularly consistent in their scoring of the approximal areas of teeth where the amount of residual dentine present was usually very little. Of the 40 approximal surfaces only 2 surfaces scored 2 or more by the examiners; distal surface of tooth 13 and mesial surface of tooth 16 (Table 4). This reflects the incidence of caries in approximal sites. Scores of 1 and 0 made up approximately 62% of the overall scores and reflects the absence of dentine in the majority of sites.

Many authors have examined the effect of the height of coronal dentine on either strength or success of the final restoration.[5,6] These in vitro studies appear to indicate that maintenance of 2 mm of coronal dentine height has a beneficial effect. A recent prospective study found that post and core restorations made as single units with substantial dentine height performed significantly better than those on teeth with less remaining tooth structure. The required thickness and strategic placement of dentine is at present unknown.

5. Conclusions

The study aimed to devise a method of recording and assessing the remaining coronal dentine after crown preparation. As such the sample number is relatively small. The results from the assessment with the tooth restorability index must be interpreted with caution as they are based on an evaluation by three examiners.

Within the limitations of this clinical study it can be concluded that:

1. A method has been established to record and assess the remaining coronal dentine present following core placement and preparation for a cast restoration.
2. A tooth restorability index has been devised to assess the strategic value of remaining dentine.
3. There was moderate to good agreement between examiners using the tooth restorability index.

Additional conclusions

1. The volume of residual dentine lying coronal to the finish line after crown preparation was 61.73–232.22 mm^3.

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