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Remaining Tooth Structure Associated With Various Preparation Designs for the Endodontically Treated Maxillary Second Premolar

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Abstract - *Existing literature suggests a relationship between the amount of remaining tooth structure and the fracture resistance of the restored endodontically treated tooth. This study investigated the amount of tooth structure remaining following various tooth preparations used in the restoration of the endodontically treated maxillary second premolar. Illustrations of the maxillary second premolar in buccopalatal, mesiodistal and occlusal sections were drawn to scale. Outlines of various intra- and extracoronal preparations were superimposed on the illustrations to reveal the amount of tooth tissue remaining in each case. Preparations for a ceramic inlay, inlay with palatal cusp coverage and onlay left 2.0–2.5mm of tooth structure buccally and palatally. Following preparation for a metal-ceramic crown, ≈ 1.0mm of tooth structure remained buccally, and between 1.6mm–1.8mm palatally. Preparation for an all-ceramic crown was observed to leave 1.0mm–1.2mm of tooth structure surrounding what remained of the endodontic access cavity. It was concluded that decisions as to the type of definitive restoration to restore the endodontically treated maxillary second premolar may be influenced, amongst other factors, by information on the amount of tooth tissue remaining following preparation.*

KEY WORDS: Endodontic treatment, remaining tooth structure, ceramic restorations.

INTRODUCTION

The restoration of teeth following root canal therapy continues to pose a challenge in everyday clinical practice. Various restorative approaches have been advocated, many of which can be successful if properly applied. Traditionally, the restoration of a tooth following root canal therapy has tended to consist of the insertion of a metal post to supposedly strengthen the tooth and a core build-up, or other form of foundation restoration, followed by a full coverage crown to protect the tooth from subsequent fracture[1].

The amount of sound tooth structure that will remain following root canal therapy and any subsequent preparation is an important factor in planning the restoration of endodontically treated teeth. Existing literature suggests a close relationship between the amount of remaining tooth structure and the fracture resistance of the restored endodontically treated tooth[2–4]. In their investigation on impact resistance, Trabert *et al.*[3] found that the use of a small diameter stainless steel post to restore endodontically treated teeth provided increased resistance to fracture in comparison to the use of a larger diameter stainless steel post. Howe and McKendry[4] reported that tooth preparation significantly decreased the resistance of endodontically treated teeth to coronoradicular fracture.

The preparation of a tooth needs to reflect the properties of the restorative materials to be used, in particular, the amount of space needed to accommodate a sufficient thickness of material for strength[5]. Tooth preparation for a definitive restoration can be both destructive and weakening to the already compromised tissues of endodontically treated teeth. It is therefore important, notwithstanding the patients' functional and aesthetic requirements, to preserve as much tooth structure as possible to guard against fracture in clinical service. Where appropriate, the use of minimal preparation techniques, and adhesively retained restorations should be considered.

The introduction of new ceramic systems, together with advances in dental adhesives and adhesive luting techniques, has increased the use of all-ceramic restorations. Bonding of all-ceramic restoration contributes greatly to the fracture resistance of restored tooth units[6].

The dentine-bonded crown has been defined as: "a full coverage restoration in which an all-ceramic crown is bonded to the underlying dentine (and any available enamel) using a resin composite luting material, with the bond being mediated by the use of a dentine bonding system and a micromechanically retentive ceramic surface"[6]. Clinical studies of dentine-bonded crowns have reported promising findings. For example, the work of Burke[7] on the fracture resistance of teeth restored with dentine-bonded crowns was followed by retrospective clinical evaluation of 60 dentine-bonded crowns. The clinical performance of the crowns was found to be favourable over a period of 3–5.5 (mean: 4.4 years)[8].

As patient demand for aesthetic restorations has increased, new ceramic inlay and onlay systems have been developed[9]. Inlays and onlays provided using these systems are widely considered to offer a durable and satisfactory alternatives to restorations of traditional materials, despite

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a recent systematic review of ceramic inlays having concluded that no strong evidence is available to confirm the clinical effectiveness of ceramic inlays in comparison to other posterior restorations. Notwithstanding the need for further clinical investigations, it is suggested that existing clinical findings indicate that the margins of porcelain inlays are very brittle and dependent on bonding to tooth structure to withstand the rigours of occlusal function. This requires adhesion of the luting material to both the porcelain inlay and the hard tissues for retention and a lute with a high resistance to chemical degradation[10].

The purpose of the present study was to investigate the amount of tooth structure which may remain following preparations for various all-ceramic restorations and a metal-ceramic crown as may be indicated clinically for an endodontically treated maxillary second premolar tooth.

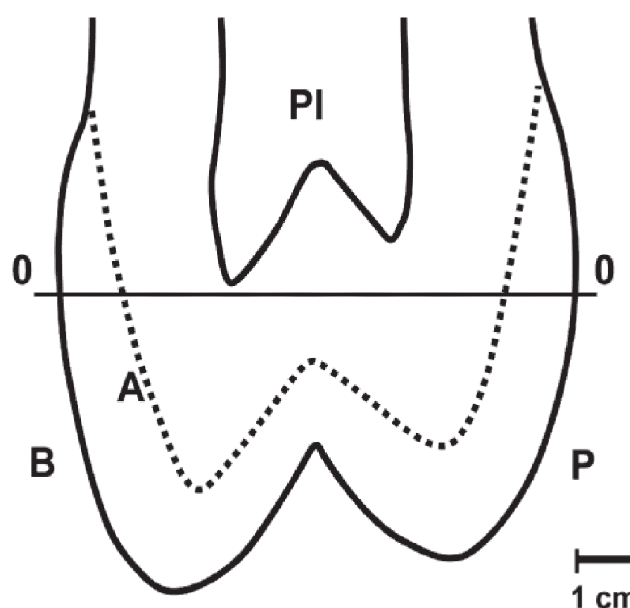


Figure 1. *Maxillary second premolar in buccopalatal section. A, amelodentinal junction; B, buccal; P, palatal; Pl, pulp space; O-O, plane where occlusal section was taken*

MATERIALS AND METHODS

Illustrations of a maxillary second premolar in buccopalatal (*Figure 1*), occlusal (*Figure 2*) and mesiodistal (*Figure 3*) sections were drawn to a x10 scale (1.0mm–1.0cm), according to the tooth dimensions given in Wheeler's Atlas of Tooth Form (*Table 1*)[11]. The plane where the cross sections were taken was indicated in *Figure 1* and *Figure 2*; B-P-buccopalatal section, M-D-mesiodistal section, O-O-occlusal section. The sections were taken at the thickest portion of the crown. The data on the thickness of enamel and dentine (*Table 2*) were taken from Shillingburg[12]. It was assumed that the tooth had a pre-existing, moderate-sized restoration of amalgam. An endodontic access cavity with straight line access, as determined by the outline of the pulp space, was superimposed on the illustrations to indicate the amount of tooth structure removed during endodontic treatment and, where appropriate, a core build up procedure was assumed to have been carried out prior to preparation.

The outlines of various preparations for intracoronal ceramic restorations and extracoronal full coverage crowns[13] were superimposed on the illustrations to investigate the amount of remaining tooth structure associated with different restorations. The intracoronal cavity preparations illustrated included preparations for an all-ceramic inlay, inlay with palatal cusp coverage and an onlay. The extracoronal preparations consist of a preparation for a metal-ceramic crown and a preparation for a dentine-bonded all-ceramic crown.

The outline form of an mesio-occluso-distal (MOD) ceramic inlay to restore an endodontically treated tooth will generally be governed by the size and outline form of pre-existing restorations, the extent of the endodontic access cavity and any other loss of tooth tissue as a consequence of caries, wear or trauma[14]. With an endodontic access cavity of average size (≈3.3mm in buccopalatal width), the isthmus width of a MOD ceramic inlay may be found to be approximately one-third of the buccopalatal cusp width. The illustrations, including the preparations for the inlay with palatal cusp coverage and onlay, were drawn with 2.0mm reduction of the functional cusps and 1.5mm reduction of the non-functional cusps[13].

For a metal-ceramic crown, occlusal reduction of 2.0mm was selected for the buccal cusp with the palatal cusp being reduced by 1.5mm. A buccal shoulder of 1.2mm and a palatal chamfer with 0.8mm axial reduction completed the preparation. The preparation for the dentine-bonded all-ceramic crown included 2.0mm occlusal reduction; with a deep chamfer at the cervical margin and 1.5mm axial reduction[13].

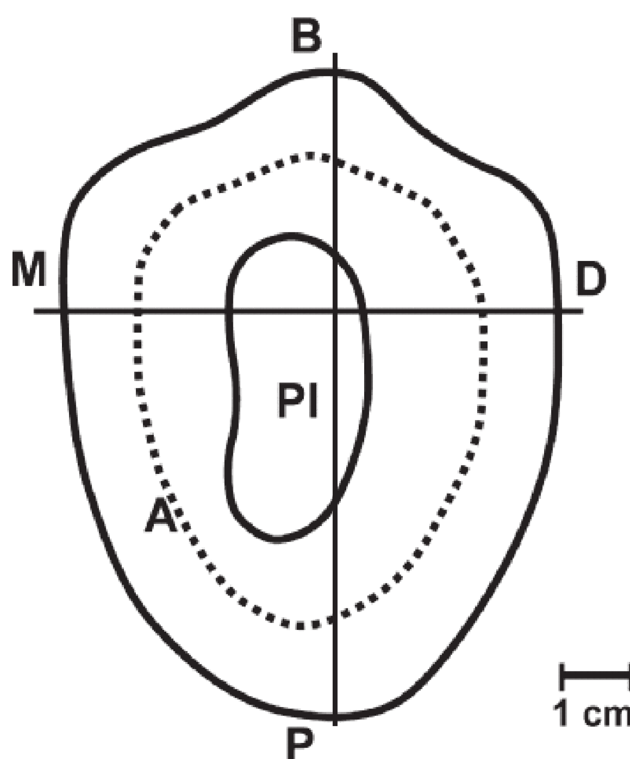


Figure 2. *Maxillary second premolar in occlusal section. A, amelodentinal junction; B, buccal; P, palatal; Pl, pulp space; M-D, plane where mesiodistal section was taken, B-P, plane where buccopalatal section was taken*

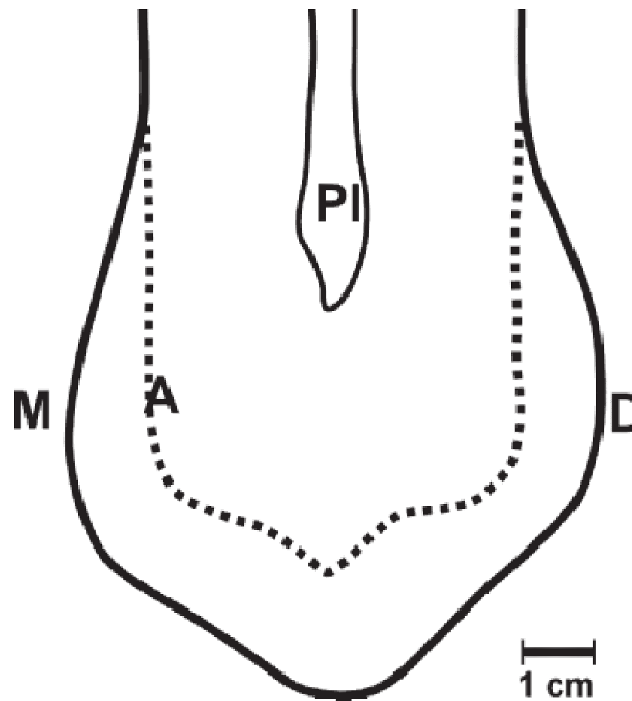


Figure 3. *Maxillary second premolar in mesiodistal section. A, amelodentinal junction; M, mesial; D, distal; Pl, pulp space*

Table 1. *Dimensions of a maxillary second premolar.*

	Dimension (mm)
Cervico-incisal length of crown	8.5
Bucco-palatal diameter of crown	9.0
Bucco-palatal diameter at cervix	8.0

Taken from Ash, M.M.[11]

Table 2. *Enamel and dentine thickness (mm) in a maxillary second premolar.*

	Thickness (mm)						
		Occlusal		*Midcrown*		*CEJ*	
	B Cusp	*Center Groove*	*L Cusp*	*B*	*L*	*B*	*L*
Enamel	1.7	1.3	1.7	1.3	1.4		
Dentine	3.3	3.2	3.4			2.2	2.3

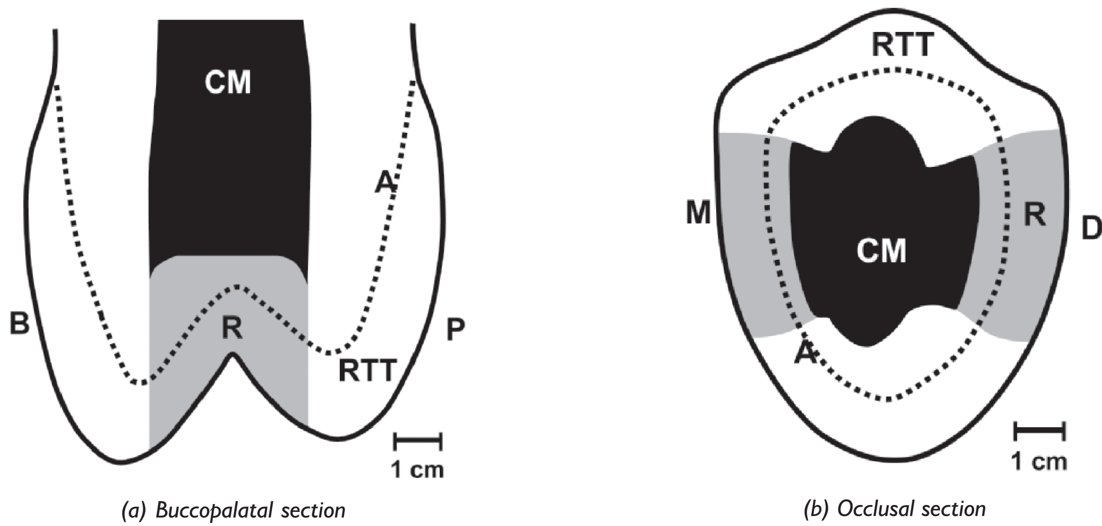
CEJ, cemento-enamel junction; B, buccal; L, lingual.
Taken from Shillingburg *et al.*[13]

The illustrations were drawn on a 1:10 scale (1.0mm–1.0cm). Measurements of the amount of tooth structure, which may be found to be remaining following the various preparations, were made using caliper and ruler. The measurements were made at the thickest and thinnest portion of the remaining tooth structure and repeated at least three times to obtain a consistent value to an accuracy of 0.1mm. For the purposes of illustration the drawings were computer scanned and reproduced electronically.

RESULTS

The inlay cavity preparation is illustrated in *Figure 4*. In both buccopalatal and occlusal section, 2.0–2.5mm of tooth structure was found to be left intact. The cavity preparations for the inlay with palatal cusp coverage and the onlay with both buccal and palatal cusps coverage are shown in *Figures 5* and *6*. The figures revealed that with these preparations the bulk of the buccal and palatal tooth structure should be found to be left intact both buccally and palatally.

The preparation for a full metal-ceramic crown in buccopalatal, mesiodistal and occlusal section is shown in *Figure 7*. In the buccopalatal section, ≈ 1.0mm of sound tooth structure was left intact buccally and 1.8mm palatally. In the mesiodistal section < 1.0mm of tooth structure was left intact both mesially and distally close to the contact areas. The occlusal section illustrated a semilunar portion of tooth structure remaining buccally, with a thickness of 0.8mm; 1.2mm of tooth structure remained palatally.



(a) Buccopalatal section *(b) Occlusal section*

Figure 4. *The endodontically treated maxillary second premolar prepared for an all-ceramic inlay. A, amelodentinal junction; B, buccal; P, palatal; R, restoration; CM, core material; RTT, remaining tooth tissue; M, mesial; D, distal*

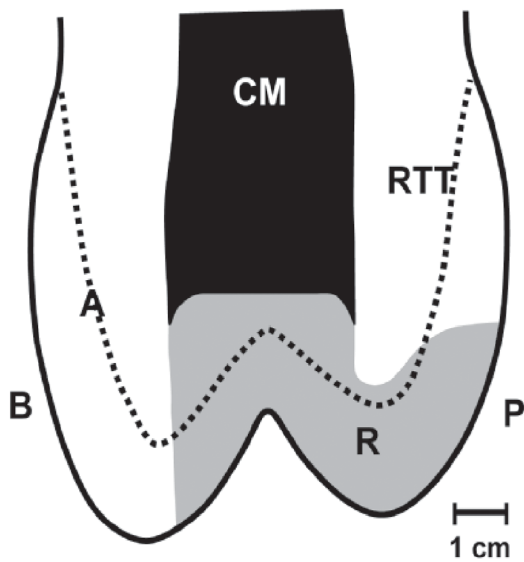


Figure 5. *Buccopalatal section of the endodontically treated maxillary second premolar prepared for an all-ceramic inlay with palatal cusp coverage. A, amelodentinal junction; B, buccal; P, palatal; R, restoration; CM, core material; RTT remaining tooth tissue*

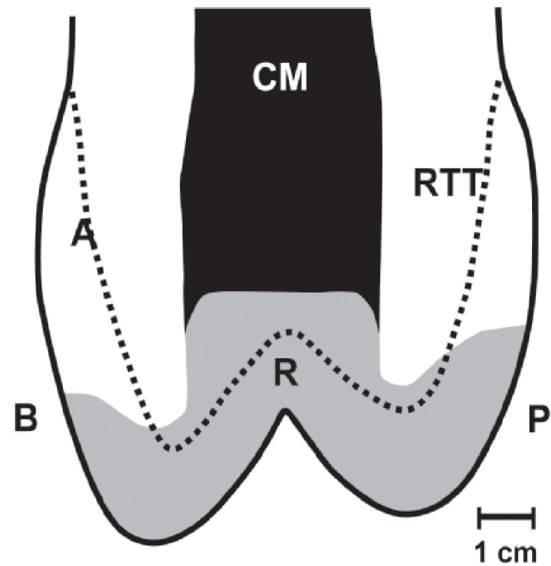
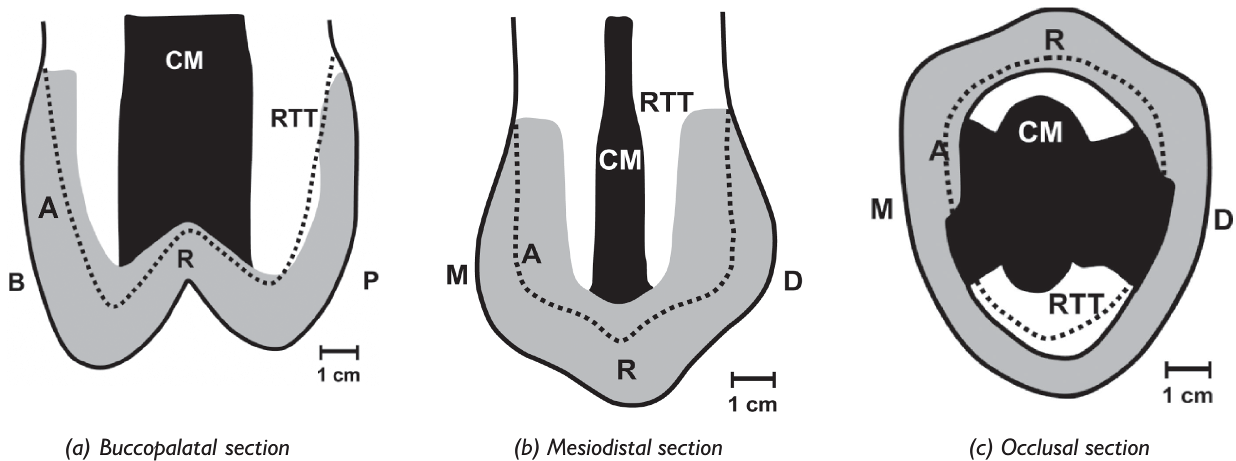
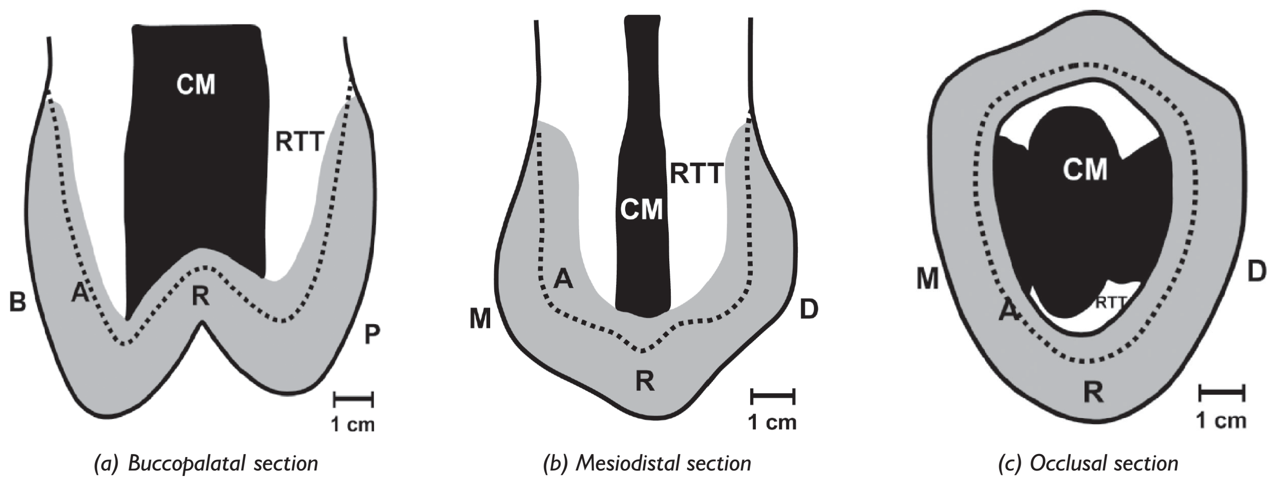


Figure 6. *Buccopalatal section of the endodontically treated maxillary second premolar prepared for an all-ceramic onlay. A, amelodentinal junction; B, buccal; P, palatal; R, restoration; CM, core material; RTT remaining tooth tissue*



(a) Buccopalatal section *(b) Mesiodistal section* *(c) Occlusal section*

Figure 7. *The endodontically treated maxillary second premolar prepared for a metal-ceramic crown. A, amelodentinal junction; B, buccal; P, palatal; R, restoration; CM, core material; RTT, remaining tooth tissue; M, mesial; D, distal*



(a) Buccopalatal section *(b) Mesiodistal section* *(c) Occlusal section*

Figure 8. *The endodontically treated maxillary second premolar prepared for an all-ceramic crown. A, amelodentinal junction; B, buccal; P, palatal; R, restoration; CM, core material; RTT, remaining tooth tissue; M, mesial; D, distal*

The appearance of the maxillary second premolar following root canal treatment and preparation for an all-ceramic crown is illustrated in *Figure 8*. In the bucco-palatal section, 1.0–1.2mm of tooth structure was found to be left buccally and palatally. The mesiodistal section revealed 1.0mm of tooth structure left both mesially and distally, close to the contact areas. A more telling picture of the preparation was seen in the occlusal view in which semilunar shaped fragments of tooth structure, ≈ 0.6mm thick buccally and < 0.3mm thick palatally, were apparent.

DISCUSSION

This study was undertaken to illustrate the amount of coronal tooth tissue remaining in a maxillary second premolar with a pre-existing MOD restoration, following root canal treatment and preparation to receive various forms of definitive restoration. It is acknowledged that there are substantial variations between teeth, preparations vary from tooth to tooth and that, as a consequence, the findings of the study suffer some limitations.

Furthermore, the study was limited to investigations of the maxillary second premolar – a tooth commonly restored using the approaches included in the present work. There is relatively little information, let alone general appreciation of the amount of tooth tissue remaining following the preparation of teeth to receive various forms of restorations, in particular, when there has been a pre-existing restoration and root canal therapy has been undertaken prior to the definitive restoration of the tooth. Indeed, it is suggested that certain illustrations in existing literature on preparations for various forms of restorations may be found to be misleading in that they are not necessarily a true representation of the form, let alone dimensions of teeth. More importantly, certain illustrations fail to reveal the limited amount of tooth tissue which may remain following completion of the preparation necessary for various forms of restorations.

Regarding the method employed in the present study, it was not intended to utilize sophisticated scanning techniques to illustrate the tooth in three dimensions nor to attempt to calculate remaining and lost tooth tissue volumetrically. The study was designed to reveal, in a simplistic way, the amount of sound tooth structure that may be left when a maxillary second premolar is subjected to various dental treatments, including root canal treatment in the process of restoring its form and function. The mesio-distal, bucco-palatal and occlusal sections of the tooth were all taken at the widest diameter of the maxillary second premolar. Although the bucco-palatal section was normal to the external surface of the tooth, it cut obliquely through the pulp chamber on the distal aspect and may over-estimate the amount of remaining tooth tissue. The short-coming will be addressed in the occlusal section which provide a view of the circumference of remaining tooth tissue.

The extent to which endodontic therapy contributes to a tooth's susceptibility to coronal-radicular fracture is uncertain[4]. Endodontically treated teeth have been referred to as having altered physical properties[15] and, as a consequence, more susceptible to fracture under loading than vital teeth. Carter and others[16] used a punch shear test and reported a 14% reduction in strength and toughness of dentine from endodontically treated teeth. They concluded that dentine from endodontically treated molars was both weaker and also more brittle compared with samples from teeth with pulp vitality. A decrease in moisture content was once postulated to be responsible for dentine brittleness. Helfer and others[17] in a study of dog's teeth reported 9% less moisture in the calcified tissue of pulpless teeth compared with the tissue of vital teeth. In contrast, Lewistein and Grajower[18] found that endodontic treatment did not affect the Vickers hardness number of human cervical root dentine, postulating that the increased fracture susceptibility of endodontically treated teeth may result primarily from additional loss of tooth structure critical to fracture resistance in access cavity preparation. This view is supported by Larson and others[19] who reported that an increase in the width of the occlusal portion of a preparation reduced the fracture resistance values but that extension of the preparation to include the marginal ridges and create a shallow proximal box did not weaken the tooth further.

Burke[14] found that the standard Class II inlay cavity has

an isthmus width of one third of the buccolingual cusp width and an interproximal box width of half the buccolingual cusp width. Similar dimensions were selected for the inlay preparation in the present study. Substantial bulk of tooth structure remained buccally and palatally following the inlay preparation and may aid in providing support for the restoration. Although Hood[20] has demonstrated that there is partial reinforcement of teeth in terms of increased stiffness when teeth were restored by means of acid etch retained, resin-bonded restorations, clinicians must be cautious in proper case selection. In a finite element study, ceramic inlays showed a high degree of interfacial tensile stress which may challenge the adhesive bond, whilst onlays exhibited almost pure compression stress at the interface[21].

The margins of porcelain inlays are very brittle and dependent on adequate bonding to the underlying tooth tissue to limit, in particular, marginal chipping in clinical service. This requires the luting material to adhere to both the porcelain inlay and the prepared tooth tissues for retention and resistance to chipping and fracture in clinical service[10]. Research has indicated that teeth restored with resin-bonded porcelain inlays have a cuspal stiffness equal to that of unprepared teeth[22]. Teeth restored in this way may be found to have decreased cuspal flexure, increased fracture resistance and reportly reduced microleakage because of the bond created between the tooth structure and the ceramic material[22,23].

According to Eakle *et al.*[24], the palatal cusps of maxillary premolars and permanent molars fracture more frequently than the buccal cusps of these teeth. Inlays with palatal cusp coverage may therefore serve a valuable purpose, providing protection to the functional cusp, while preserving the appearance of teeth buccally. However, if the buccal cusp is weakened and compromised, an onlay may be required to provide protection to the remaining tooth structure. The results of the present study indicate that cavity preparation for an all-ceramic inlay (*Figure 4*), inlay with palatal cusp coverage (*Figure 5*) and onlay (*Figure 6*) are relatively conservative; in that 2.0–2.5mm of tooth structure still remains both buccally and palatally, albeit that the cuspal coverage restorations require cuspal reduction, a loss of tooth tissue which in itself is not considered to reduce fracture resistance.

Metal-ceramic crowns remain in many countries the most frequently used full veneer restorations for posterior teeth[25]. These restorations require considerable reduction of tooth structure to accommodate the metal substructure and veneering porcelain. Shillingburg and others advocated occlusal reduction of 1.5mm–2.0mm and a facial shoulder of 1.3mm–1.5mm for a metal ceramic crown[13,26,27]. If porcelain is to be limited to the facial aspect, occlusal reduction may be limited to 1.0mm–1.5mm[13]. Following endodontic treatment and preparation of a maxillary second premolar for a metal-ceramic crown, 1.0mm of tooth structure may remain buccally and approximately 1.6—1.8mm palatally as shown in *Figure 7*. However, if the tooth had a pre-existing MOD restoration, which is believed to be a common occurrence clinically, the remaining tooth tissue is limited to a thin (≈ 0.8mm) fragment of semilunar shape tooth structure (*Figure 7*). Under such circumstances the completed crown will be supported largely by whatever foundation restoration has been placed, and the fracture resistance of the tooth may be compromised given the near absence of remaining tooth tissue.

All-ceramic restorations are capable of providing a cosmetically pleasing clinical outcome[25]. Ceramic, however, is a brittle material and in thin section, as occurs at the margins of dental restorations, may be found to be susceptible to fracture. The development of various technologies and reinforced dental porcelains in the 1990s resulted in a growing interest and, in many parts of the world, reliance on all-ceramic restorations. Because of the brittleness of ceramic restorations, aggressive tooth preparation designs and adhesive luting techniques have been recommended to improve the fracture resistance of teeth restored with all-ceramic restorations[28,29]. According to Rammelsberg and Eickemeyer[30], adhesive luting with resin-based material rather than cementing with either glass-ionomer or zinc phosphates cements increases substantially the fracture resistance of metal-free polymer crowns. Bernal *et al.*[28] reported that all-ceramic Dicor crowns were found to have significantly increased fracture resistance when luted with resin systems (1427N) compared with zinc phosphate (983N) and glass-ionomer (1048N) cements.

Dentine-bonded crowns have gained popularity with the increased demand for aesthetic restorations. Contemporary techniques of luting dentine-bonded crowns, using dentine bonding systems and resin luting cements, result in restored tooth units which function and transmit loads in a manner similar to an intact tooth. The luting procedure is, however, time consuming, moisture sensitive and potentially problematic when the crown margin is located subgingivally. A retrospective evaluation of 60 dentine-bonded crowns with an average time in service of 4.4 years, reported that the performance of the crowns was found to be favourable[8].

Findings regarding advantages of various cervical finishing lines and the extent of axial reduction for all-ceramic crowns have been varied. Meier and others[31] reported greater fracture resistance for In-Ceram crowns with chamfer finishing lines compared with a shoulder preparation. However, these workers found no difference in fracture resistance following axial reductions of 0.8mm and 1.2mm. Rammelsberg and Eickemeyer[30] reported that 0.5mm axial reduction combined with a chamfer finishing line provided the most favourable fracture resistance for ceramic crowns. In contrast, a laboratory study[32] of Dicor crowns revealed significantly higher fracture loads with a 1.2mm shoulder preparation compared with a 0.8mm chamfer finishing line. In a study using extracted human molars, Bernal *et al.*[28] found no effect of the finishing line on the fracture resistance of adhesively luted Dicor crowns.

In the present study, the preparation for the all-ceramic crown included, as advocated by Shillingburg[13], a deep chamfer margin with axial reduction of 1.5mm and occlusal reduction of 2.0mm. As illustrated (*Figure 8*), the occlusal section of the preparation revealed that a circa 1.0mm thick semilunar shaped remnant of tooth structure remained to support the core material and the crown, except mesiopalatally where only approximately 0.3mm of tooth structure remained. Clinically, when a maxillary

second premolar had a pre-existing MOD cavity and has had endodontic treatment prior to preparation for an all-ceramic crown, very small amounts of tooth structure may be found to be left intact. The clinician may not fully appreciate this situation at the crown preparation stage, as the tooth may have build-up using a tooth-coloured material, making it difficult, if not impossible, to assess the extent of remaining tooth tissue.

Despite the limitations of the present study, the illustrations emphasis the need to better understand the effects of various preparations on, in particular, previously prepared teeth in terms of remaining tooth tissues to support core build-up (foundation) restorations and in turn crowns. With the use of tooth-coloured core build-up materials, it may often escape the clinicians' notice that following preparation for the definite restoration there is very little tooth tissue remaining. Greater understanding and appreciation of such outcomes may, it is suggested, influence thinking in terms of tooth preparation prior to core buildup procedures and foundation restoration placement. In certain cases, it may be advantageous to remove what will become a thin, weak, possibly ineffectual section of remaining tooth tissue following preparation and to restore the lost retention and resistance form by means of additional slots, grooves and, in endodontically treated teeth, the use of the coronal portion of the pulp space.

Root-filled premolars may be successfully restored with direct-placement composite if substantial amount of good quality tooth structure remains following completion of root canal therapy. The choice between a direct-placement composite, which act as a transitional restoration and a crown is multifactorial. While a direct-composite may help to preserve tooth tissue, the aesthetic outcome and longevity may not be as favourable as with a crown.

CONCLUSIONS

A relatively large amount of tooth structure may be found to remain if a ceramic inlay or onlay is used to restore the endodontically treated maxillary second premolar. Extensive tooth preparation for metal-ceramic and all-ceramic crowns to restore the endodontically treated maxillary second premolar may leave very little tooth tissue to support the final restoration. Decisions as to the type of definitive restoration to be selected for the restoration of the endodontically treated maxillary second premolar may be found amongst other factors to be influenced by information on tooth tissue remaining following preparation.

ADDRESS FOR CORRESPONDENCE

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