Digital Image Correlation and Strain Gauges to Map and Compare Strain in Teeth with Different Quantity and Quality of Remaining Tooth Structure

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Purpose: To evaluate strain in teeth with differing quality and quantity of tooth surface loss by utilizing surface displacement field measured using digital image correlation (DIC) and strain gauges (SG). Materials and Methods: A total of 80 mesio-occlusodistal preparations were carried out in human maxillary premolars. Ten sound premolars served as a control group, and treated samples were divided into two groups of 40 each according to the composition of the prepared walls (composed of either enamel and dentin [E + De] or dentin only [De]). Each group was then divided into four subgroups of 10 each according to the selected cusp height-to-width ratio (A = 2:1 mm; B = 3:1 mm; C = 3:1.5 mm; D = 4.5:1.5 mm). The samples were uni-axially loaded to 130 N, and strain was recorded using DIC and SG. Results: With SG testing, control samples recorded the lowest strain values and were significantly different from all test groups. However, DIC failed to detect strain in control samples, as it was too low. With DIC, group D showed the lowest strain readings among all the dimension groups and was significantly different from groups A and B, but the composition of the remaining tooth structure did not show any significant effects. With SG testing, remaining wall dimension and composition both had significant effects: Group A scored the highest strain at all compositions, and E + De had better resistance to load stresses than De only. Conclusion: For both testing methodologies, height (≥ 3 mm) and width (1 to 1.5 mm) of the remaining tooth structure had an effect on strain. Tooth compositions of E + De resisted strain better than De counterparts at all dimensions.


Tooth fracture is a frequent restorative problem. A tooth’s ability to resist fracture may be the result of a combination of clinical factors, including quality, quantity, and age of remaining tooth structure; cavity preparation; choice of restorative material; and tooth loading. Caries, erosion, attrition, and trauma commonly remove tooth structure, which in turn decreases the fracture resistance of the tooth and affects stress distribution within the tooth. Stresses within tooth structure in combination with strength properties are important for fracture resistance.

The generation of stresses within teeth is complicated by the nonhomogenous nature of tooth structure and the irregularity of its contours. Tooth structure is composed of different materials with widely varying properties, including enamel, dentin, pulp, cementum, and supporting tissues of periodontium and bone. This complex structure is subject to large variations in both the magnitude and direction of chewing forces.
Load application to an object causes stress concentration and structural strain. The ultrastructural integrity of the body is not greatly affected when this occurs within the elastic limit, but stress concentration beyond this limit may result in crack formation and propagation, which will eventually cause fracture and structural failure.6

As the fracture resistance of restored teeth is lower than sound teeth, the dental practitioner is challenged by the design of the cavity preparation.7–9 One study showed that 92% of fractured teeth had previously undergone restoration.10 The presence of wide and/or deep restorations may be considered the highest risk for tooth fracture,11 and cavity preparation typically exaggerates the height of the remaining cusps, rendering them unsupported. When unsupported cusps are loaded they may deflect, rotate, or fracture.1,9,12 Where fracture does not occur, the tooth-restoration interface may open as a result of deflection or torsion of a weakened cusp. This may subsequently result in marginal leakage, secondary caries formation, and possibly tooth fracture.8,13

The anatomy of posterior teeth (ie, cusps and fossae) predisposes them to deflection of cusps under stress,14 while the form and height of the cusps influence the direction of this stress. To reduce tooth fracture, it appears to be important to maintain the marginal ridge integrity.15–18 In intact teeth, strength is gained from marginal ridges forming a continuous band of tooth structure.

Bassir et al3 showed that the fracture resistance of sound teeth was significantly reduced with mesio-occlusal (MO) and mesio-occlusodistal (MOD) cavity preparations. When nondestructive occlusal loading was applied, Pereira et al6 observed that MOD cavities presented significantly higher stress values than MO, occlusal (O), or intact teeth. To assess remaining tooth structure, both remaining wall height and width should be examined. In the literature, few studies have assessed the amount of residual tooth structure in intact teeth. Residual dentin thickness in vital posterior teeth after all-ceramic crown preparation has been reported, and the mean thickness between the axial wall and pulpal chamber in posterior teeth varied between 0.47 and 0.7 mm.19 Another study by Seow et al20 reported the thickness of remaining dentin on a maxillary second premolar following various preparations for a metal-ceramic or all-ceramic crown. The thinnest section of remaining tooth structure was the palatal wall, with only 0.8 mm and < 0.3 mm remaining for each restoration, respectively.

Many in vitro studies on endodontically treated teeth have examined the effect of the preserved coronal dentin height on the success of the final restoration. Maintenance of a height of at least 2 mm of coronal dentin has a favorable effect.21–23 It has also been suggested that preserving 2 mm of coronal dentin thickness improves resistance to fracture.24–26

Clinical evaluation of remaining coronal dentin is essential in restorative decision-making. A tooth restorability index (TRI) was devised to allow the mapping of remaining tooth structure.21,27 This index allows assessment of tooth restorability by allocating numeric values to tooth sections that sum to a total value for the whole tooth. After all existing restorations and unsupported tooth structure have been removed, each molar tooth was divided into equal sextants: two proximal, two buccal, and two lingual areas. A scoring system of 0–3 was allocated to each coronal dentin sextant (0 = none, 1 = inadequate, 2 = questionable, 3 = adequate) contributing to retention and resistance form. Thus, a maximum score of 18 could be given for each tooth, and the topography of the remaining tooth could be recorded.

In their in vivo investigation to assess the remaining coronal tooth structure in teeth prepared for complete and partial coverage restorations, Murphy et al26 used three-dimensional (3D) scanning and the TRI to assess tooth preparations for full and partial coverage restorations. They found there was a strong correlation between mean TRI and the scanned volume of tooth structure. They also confirmed that partial coverage preparations removed less tooth structure than full coverage when provided for the same teeth.

Evaluation of remaining tooth structure should focus on both the quality and quantity of the remaining tooth structure and the available restorative options. Different types of restorations are recommended for different amounts of remaining tooth structure. In situations of minimal or no retention, adhesive restorations have a major advantage of bonding to both enamel and dentin.28 Bonding to enamel is stable over time, but in vivo19,30 and in vitro31 studies have revealed the limited durability of resin-dentin bonds.32 Frassetto et al33 carried out a review on the durability of resin-bonded interfaces and their degradation with aging and concluded that although most currently used dental adhesive systems show favorable immediate results reflected in good retention and sealing, dentin-bonded interfaces may not withstand aging and may show long-term degradation.34 Clinical trials evaluating adhesive systems have found dramatically variable bonding qualities between tested materials35 and substrate.36,37 Given that the dentin-adhesive bond varies among different conditions and deteriorates with time, relying only on adhesion may not be ideal.

Based on the aforementioned literature, it has been shown that loss of tooth structure within the coronal aspect of a tooth can alter stress distribution within the tooth. It has been well demonstrated that the fracture resistance of a restored tooth is lower than a sound tooth. The combined effect of the quality and quantity of the remaining coronal tooth structure, together with its exact dimension recommendations, still needs further evaluation. Therefore, the purpose of this research
was to map and evaluate tooth strain in teeth with different amounts and areas of remaining tooth structure and tooth surface loss utilizing two techniques: the surface displacement field measured using digital image correlation (DIC), and strain gauges (SG). The null hypotheses tested in this study were that: (1) There would be no significant difference in strain measured using the two different techniques.

Table 1 Sample Preparation Dimensions (mm)

<table>
<thead>
<tr>
<th>Wall width</th>
<th>H:W 2:1</th>
<th>H:W 3:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2:1 (A)</td>
<td>3:1 (B)</td>
</tr>
<tr>
<td>1.5</td>
<td>3:1.5 (C)</td>
<td>4:5:1.5 (D)</td>
</tr>
</tbody>
</table>

H = height of prepared wall; W = width of prepared wall.

MATERIALS AND METHODS

Sample Preparation

A total of 50 extracted, intact, noncarious human maxillary premolars were collected following consent (NHS REC Ethical approval no. 11LO/0939). Teeth were cleansed of soft tissue debris and stored in 0.2% thymol solution at 4°C until testing. The selection of teeth was based on regular crown anatomy, intact cusps, and lack of wear. The inclination angles formed were determined by digital caliper to verify they were within the following means ± standard deviations (SD): 8.2 ± 0.1 mm (buccolingual) and 6.4 ± 0.1 mm (mesiodistal). Each tooth was dried and mounted vertically in the center of a nylon mounting mold of 2.5-cm height with clear epoxy resin (Specifix-20; Struers), used according to the manufacturer’s recommendations. Each root was positioned centrally with the long axis of the tooth aligned parallel to the mold walls. A 1-mm height of the roots was left exposed below the cementoenamel junction (CEJ) to simulate the alveolar bone level. The epoxy resin was allowed to polymerize for 24 hours at room temperature before the mold was opened. The resin base was machined with water-cooled silicon carbide discs (220-grit) (LaboPol-5; Struers) to expose some of the root structure at the bottom of the base.

Ten sound premolars served as the control group. A total of 40 premolars served as the test group, and each molar was prepared into two samples (buccal and lingual walls; n = 80). The samples were divided into two subgroups of 40 each according to the composition of the prepared walls. One group was prepared to have both enamel and dentin elements in the remaining walls (E + De), while the other was prepared to have dentin only (De). Each subgroup was further divided into four sets of dimensions according to the preparation height-to-width ratio of the two remaining cusps (n = 10 each). The dimensions of 1 mm and 1.5 mm were selected to represent the width for 2:1 and 3:1 height to width (H:W) ratios, respectively, generating four preparation dimensions (A, B, C, D), as shown in Table 1.

Tooth preparation started as an MOD cavity, then cuspal walls were reduced in thickness at both the outer and inner aspects following the outer contour of the tooth to the test dimensions (Table 1) with a high-speed handpiece and constant water irrigation at 40 mL/minute flow rate. A digital caliper was used constantly to check dimensions along six approximate points on the prepared wall (mesial, central, and distal points at both the incisal and cervical ends of each prepared wall). For initial preparation, the FG 765X Coarse chamfer diamond bur (Kerr Blu White Coarse Diamond Bur, Henry Schein Europe) was used, followed by FG SF2 fine chamfer diamond bur (Kerr Blu White Diamond Bur FG Yellow, Henry Schein Europe) and finally with a tungsten carbide finishing bur (T/C Fine Finish 30 Blade, Henry Schein Europe). The base of each prepared sample wall was considered to be 1 mm above the CEJ. Teeth were lightly prepared as a slice preparation with no cervical finish line. The external walls were cut to be parallel with a maximum wall inclination of 6 to 14 degrees on the buccal, lingual, and proximal aspects, creating a total occlusal convergence (TOC) of 10 to 20 degrees. The inclination angles formed were determined by direct viewing of the preparation from all aspects (buccal, lingual, and proximal). A dimple (1-mm diameter and 0.5-mm depth) was prepared on the top of each wall to allow a point of loading at the center of the wall (Fig 1).

All preparations were made by one operator to ensure standardization (M.M.A.). Teeth were subjected to gradual nondestructive occlusal loading within the physiologic limit for human teeth followed by unloading to try to mimic a clinically relevant loading pattern. Teeth were prepared according to four sets of dimensions involving different H:W ratios. The resulting walls followed the natural convexity of the buccal and palatal tooth surfaces. To standardize...
A speckle pattern was painted onto the specimens using a black-ink spray, as higher quality DIC measurements could be obtained using this patterning method (Fig 2). The imaged face of the samples was kept dry for the duration of the test. Images were analyzed, and a displacement field was determined.

Vertical displacement was measured in an area directly below the point of loading on the buccal and palatal areas of each specimen. These data were averaged over a small width on either side of the center line, and this was plotted against a vertical position within the specimens. Strain was recorded when it was constant at areas where an appreciable linear relationship between displacement and vertical position were observed.

The buccal/palatal surfaces of the specimen were imaged using a macro lens that had a field of view of approximately 3 × 2 mm in a circular area caused by an internal vignette of the image (Fig 2). At this magnification, this corresponded to approximately 1,800 pixels per mm, or 1.8 pixels = 1 micrometer. Images were captured at peak load (130 N) and final unload (5 N) and were used to measure displacement. The displacement field was processed in several ways to calculate strain over appropriate fields of view, either a representative area of long narrow width or a shorter vertical height where linear strain behavior was observed.

Experimental Setup for SG Testing
SGs (Micro-Measurements Group UK) attached to copper leads with a resistance of 120 Ω (type C2A-06062LW-120) and a gauge factor of 2.15 were attached to prepared samples. The surface of each tooth was prepared by etching with 37% phosphoric acid (Heraeus, i Bond Etch 35 Gel). Enamel was etched for 30 seconds...
followed by a 15-second dentin etch. The surface was washed with water for 20 seconds and dried with a stream of air for 10 seconds. The backing of the SGs was bonded to the prepared buccal and lingual walls of premolars with a thin layer of cyanoacrylate adhesive (M-Bond 200 Adhesive; Micro-Measurements Group UK). Care was taken to align the gauges vertically along the long axis of the tooth so that they were parallel to the direction of loading. After the adhesive had set, the gauges were covered with a thin layer of a silicone rubber protective coat (M-COAT C, Micro-Measurements Group UK). All test and control samples received SGs, and an extra control tooth received a dummy gauge that was subjected to the same environmental conditions but without loading.

The resin block containing the specimen (Fig 3) was screwed into a brass receptacle within a servohydraulic testing machine (Dartec series HC10, Darte) with a 1.0-kN load cell. The loading program was initially set in the test machine, and the subsequent loading cycles were controlled by the testing machine software (Workshop 96. Dartec HC10; Zwick). Samples were subjected to the same gradual loading and unloading cycles as previously described for the DIC testing, and strain values were recorded at peak load (130 N).

Statistical Analyses
The goal of the analysis was to determine the influence of the two factors involved in this study: tooth composition and dimensions of the remaining tooth structure. Two tooth compositions (E + De and De) and four H:W ratio dimensions (A = 2:1 mm; B = 3:1 mm; C = 3:1.5 mm; D = 4.5:1.5 mm) were tested. Data of tested strain under gradual loading and unloading were analyzed using two-way analysis of variance (ANOVA).

Bonferroni post hoc test was applied. Groups were considered statistically significantly different at $\alpha = .05$.

RESULTS

Digital Image Correlation
A typical image from a measurement is shown in Fig 2. Here, the position of the loading ball can be seen at the top of the image. The speckle pattern is clearly visible. The area at the bottom of the image is partially embedded in resin and behaved differently under load than the bulk of the specimen.

The area used for the measurement is demarcated as a red box in Fig 2. The data were averaged over a small width on either side of the center line, and this was plotted out against the vertical position within the specimen. For many specimens, there were appreciable areas where a linear relationship between displacement and vertical position was observed, and the strain was constant within these areas and was recorded. A displacement field in micrometers is shown as an example in Fig 4. This was generated by using the relative movement between two images to measure in-plane displacements of one image against another. The images used for this were fully loaded with subsequent unloading.

The two-way ANOVA indicated a statistically significant difference in the mean strains between the different preparation dimensions (A, B, C, D) ($P < .05$), but not between the compositions (De, E + De) (Table 2). Dimension A showed significantly higher strain than C and D, while Dimension D showed significantly lower strain than A and B. No significance was detected between dimensions B and C or between C and D. Displacement in control samples was too low to be recorded by the DIC system.

**Table 2** Digital Image Correlation Testing with Strain as Dependent Variable

<table>
<thead>
<tr>
<th>Source</th>
<th>Wald chi-square</th>
<th>Degrees of freedom</th>
<th>$P$</th>
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<td>Dimension</td>
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<td>.000</td>
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<tr>
<td>Composition</td>
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<tr>
<td>Dimension*composition</td>
<td>0.559</td>
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<td>.906</td>
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</table>

**Table 3** Strain Gauges Testing with Strain as Dependent Variable

<table>
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<th>Source</th>
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<th>Degrees of freedom</th>
<th>$P$</th>
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<tr>
<td>Composition</td>
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<tr>
<td>Dimension*composition</td>
<td>26.801</td>
<td>3</td>
<td>.000</td>
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</tbody>
</table>

**Fig 5** Mean strain values ± standard deviations for all groups ($n = 10$ each) with digital image correlation testing. E + De = enamel + dentin; De = dentin only; $A = \text{height to width ratio (H:W) of 2:1 mm}; B = \text{H:W of 3:1 mm}; C = \text{H:W of 3:1.5 mm}; D = \text{H:W of 4.5:1.5 mm}$. *$P < .05$. 

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Comparison between the estimated mean strain values and their associated SDs for all groups (A, B, C, D) and both De and E + De compositions are shown in Fig 5.

**Strain Gauges**

The two-way ANOVA indicated a statistically significant difference in the mean strains both between the different preparation dimensions (A, B, C, D) \( (P < .05) \) and between the two composition groups (De, E + De) (Table 3). For both composition groups, all dimensions were statistically significantly higher than control. Dimension A showed significantly higher strain than all other dimensions, while both dimensions B and C had significantly lower strain than A and higher than D \( (P < .05 \text{ for all}) \).

Comparison between the estimated mean strain values and their associated SDs for all groups (A, B, C, D) for both compositions are shown in Fig 6. Comparisons of the mean strain values between De and E + De for all groups with SG testing are shown in Fig 7.

**DISCUSSION**

DIC is an innovative noncontact optical methodology to measure strain and displacement that uses the relative movement between two images to measure in-plane displacements. The effect of the size of the tooth specimen under load was incorporated by calculating a bulk modulus for each sample from the zone where linear strain behavior was recorded. This was done to overcome the inevitable size variations expected to occur between samples, as they were hand-prepared, not machined.

Some areas of the image appear noisy (Fig 4) due to the out-of-focus areas and spatial variations in the speckle pattern. The central area across the image was chosen to overcome the noise and maximize the area for the measurement that was in focus (Fig 2). DIC can measure displacements at a resolution down to about 1/20th of a pixel, or, in this case, about 10 nanometers. However, the primary limitation of the optical system can be seen in the very limited depth of field and the areas away from the center of the image that are out of focus and less suitable for DIC measurements. This may explain the failure of the system to detect the very low displacement expressed by control samples, and for this reason they were excluded from testing.

Fabrication of indirect restorations usually includes tooth preparation to reshape the remaining tooth structure. There are little published data on the optimal thickness of remaining dentin in preparation walls,\(^43\) Different heights (0 to 5 mm) and widths (0.5 to 4 mm) of remaining coronal walls have been tested in both vital and nonvital teeth,\(^45\)–\(^49\)

Many studies have been carried out to examine coronal dentin height, without consideration of width,\(^40\)\(^45\)\(^46\)\(^50\) root dentin thickness,\(^47\)\(^51\)\(^52\) remaining coronal tooth structure location,\(^26\)\(^46\)\(^53\) or a combination of these.\(^34\)

The aforementioned studies had different designs, looked at different parameters, and lacked a common standardization, with most being carried out in vitro and little work being undertaken in vivo. So far, there have been no controlled studies that define specific recommendations on H:W dimensions and locations of remaining tooth structure to best withstand stresses and resist fracture. To the authors’ knowledge, this study is the first to evaluate remaining tooth walls with a specific H:W ratio.

Seow et al\(^20\) found that following tooth preparation for a ceramic inlay and onlay, the width of 2.0 to 2.5 mm...
of buccal and palatal tooth structure was remaining, while following preparation for a metal-ceramic crown, approximately 1 mm of tooth structure was left buccally and between 1.6 and 1.8 mm palatally. On the other hand, preparation for an all-ceramic crown retained 1.0 to 1.2 mm of tooth structure surrounding the endodontic access cavity. The effect of these varying dimensions is unknown. Another study by Davis et al.55 developed a method to measure local dentin thickness using x-ray microtomography scans. Scans were made on extracted maxillary central incisors before and after preparation for metal-ceramic crowns. Their results revealed multiple thicknesses of residual dentin along different prepared crown areas, ranging between 0.5 mm (the thinnest) and 1 to 1.5 mm (the thickest). Following the aforementioned studies as a guide and considering the size of human posterior teeth and the space occupied by the pulp, the thicknesses of 1 mm and 1.5 mm were selected to represent the most common range. To assess the possible influence of height and width combinations, these dimensions of remaining wall thicknesses were prepared against multiple wall heights to produce the H:W ratios of 2:1 and 3:1.

In the present study, tooth preparation was started as an MOD cavity to create buccal and lingual samples in each premolar. To standardize dimensions, the depth of the mesial and distal cavities was positioned 2 mm coronal to the CEJ. The height of the buccal and lingual walls (samples) was measured coronal to an imaginary line positioned 1 mm above the CEJ (equivalent to the position of the gingival margin), as Bandlish et al.21 used the gingival finish line to assess the remaining tooth structure coronal to this level. This was designed in order to prevent pulpal exposure and to simulate a clinical approach to avoid encroaching on the biologic width.

Different dimensions and qualities of remaining tooth structures were investigated, and no attempt was made to restore the teeth to their original form. The influence of the use of either direct or indirect restorations with or without dentin bonding systems was not investigated in this part of the study. The combination of dentin adhesive systems and resin luting cements have shown the ability to strengthen the restored tooth units.56–59 Bonding intracoronal restorations offers cusp splinting and decreases cuspal flexure, thus strengthening the remaining tooth unit.59,60

Samples in this study were tested as independent walls of remaining tooth structure without the incorporation of a finish line or investigation of the effect of ferrule if these teeth were restored. The incorporation of the ferrule concept is considered one of the foundations of the restoration of vital and endodontically treated teeth.53,61 Adhesion to the prepared walls or overlaying of the cusps would have altered the results of this study, but this study was designed to examine the effects of remaining type and dimensions of tooth structure alone.

Destructive mechanical tests can be used in situations of high-intensity load application to determine fracture resistance and analyze tooth behavior. However, these tests show limitations in obtaining the valuable internal behavior of the tooth-restoration complex. For a more reliable response, a combination of nondestructive methodologies has been implemented.17,62,63 The implementation of these nondestructive testing methods allows sequential and repeated measurements on the same tooth, taking into consideration the individual differences among teeth, which further minimizes the effects of the natural variation between teeth.38

Based on these results, the null hypothesis that there would be no significant difference in tooth strain with different structural loss can be rejected. The results of both the DIC and SG testing methodologies showed significant differences in strain values between some of the geometries tested (A, B, C, and D). When tested with SGs, the E + De group showed generally lower strain values than De at all dimensions. This is most likely due to the stiffening effect enamel has on dentin, albeit its minimal dimension in the E + De group when compared to the presence of dentin only in the De group. However, significant differences between the two compositions could be detected only when SGs were used. This could be attributed to the reliability and accuracy of the strain gauges mounted directly on the tooth structure in measuring relative stress/strain. The role of enamel in resisting and dissipating strain may be particularly important to patients who have lost enamel due to attrition, aging, or trauma.

Since both testing methodologies gave similar result patterns, the null hypothesis that there would be no difference in strain measured using the two techniques can be partially accepted. In both methodologies, group A possessed the smallest height and width (2:1 mm), showed the highest strain, and was significantly different from both groups C and D (3:1.5 mm and 4:5:1.5 mm, respectively). These results suggest the importance of the H:W ratio in the preparation, and that lower strain is achieved by preserving a minimum height of 3 mm and a width between 1 and 1.5 mm.

This study's findings with regard to remaining tooth width agree with the results of Shahrabf et al.,64 who found that fracture resistance of endodontically treated teeth with composite restorations could be reduced by preserving mesial marginal ridge thicknesses of 2, 1.5, and 1 mm. However, preserving a 0.5-mm thickness of the mesial marginal ridge did not provide fracture resistance at the level of intact teeth, although it did confer higher strength than teeth with no marginal ridge at all.

The results are also in accordance with earlier observations by AL-Omiri and AL-Wahadni,65 who investigated the effect of different heights of remaining coronal...
dentin on the fracture resistance of root canal–treated teeth restored with composite cores. Although results were not statistically significant, greater fracture resistance was achieved with greater retained dentin height. However, the fracture pattern of teeth was not related to the height of retained dentin when the height was > 2 mm. The positive influence of maintaining 3 mm of tooth structure was also confirmed by Al-Wahadni and Gutteridge.45

Magne15 and Magne et al66 have tested the responses of both anterior and posterior teeth under different loading configurations. The authors concluded that progressive loss of tooth substance (MO to MOD to endodontic access) produced a progressive loss of cuspal stiffness. They also confirmed that linear axial loading of posterior teeth did not generate harmful concentrations of stress compared to lateral loading. However, the behavior of posterior teeth must be differentiated from the behavior of anterior teeth due to shape and occlusal loading patterns. Stress distribution within an incisor was not significantly affected when the tooth material was removed proximally, whereas a significant increase in stress concentration and flexibility occurred when facial and palatal tooth material was removed.57,68 As this was an in vitro study, it cannot replicate the clinical situation, although it was designed to replicate the clinical environment as closely as possible.

CONCLUSIONS

Within the limitations of this study, it was concluded that the preservation of a remaining minimum tooth height of 3 mm and a width of 1 to 1.5 mm produced lower strain on loading than 2-mm tooth height. Remaining tooth structure comprised of both enamel and dentin resisted strain under load better than dentin-only counterparts at all test dimensions when evaluated with SGs. The results obtained with SGs and DIC showed similar trends. DIC is a relatively simple optical methodology that allows measurement of strain and displacement without the need for physical attachment to the object. This study has examined the effect of different remaining tooth structure dimensions (multiple H:W combinations) under axial static loading. The effect of tooth loading with and without the presence of a restoration (either bonded or cemented) should be further studied.

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REFERENCES

Fundamental Research


