Fracture Behavior of Human Mandibular Incisors Following Endodontic Treatment and Porcelain Veneer Restoration

Henry H. W. Ho, BDS, MSc, DGDP[a]
Frederick C. S. Chu, BDS(Hons), MSc, FRACDS, MRDRCS[b]
Alastair N. Stokes, BDS, MSc[c]

Purpose: Because of existing controversy, the present study investigated the individual and combined effects of endodontic treatment and porcelain veneer restoration on the fracture behavior of human mandibular incisors. **Materials and Methods:** Forty extracted intact human mandibular incisors were assigned to four groups of ten with a similar range of labiolingual widths at the cementoenamel junctions. Group A consisted of intact teeth; group B consisted of endodontically treated teeth; group C teeth were restored with labial porcelain veneers; and those of group D were endodontically treated and had labial porcelain veneers. All teeth were subjected to a slow continuous loading test at 30 degrees to the long axis of the teeth and 1 mm below the incisal edge on the labial side. **Results:** Fracture forces were 415 ± 220 N, 370 ± 89 N, 420 ± 128 N, and 448 ± 156 N for groups A, B, C, and D, respectively. Root fracture was the most common mode of failure. There were no statistically significant differences between the groups in terms of fracture forces and modes of failure. **Conclusion:** Human mandibular incisors with endodontic treatment and/or porcelain veneer restorations were able to withstand the same magnitude of oblique loading as intact teeth. Endodontic treatment and/or porcelain veneer restoration did not affect the mode of failure of mandibular incisors. *Int J Prosthodont 2001;14:260–264.*

Mandibular incisors are generally the smallest teeth in the adult dentition, with relatively small thicknesses of enamel and dentin. It follows that restorative and endodontic techniques appropriate to larger teeth may compromise mandibular incisors.[1] Little has been done to evaluate the effects of restorative treatment on the mechanical properties of mandibular incisors. Previous reports concentrate on the mechanical aspects of intact, restored, and endodontically treated human maxillary incisors,[2–6] premolars,[7–10] and molars.[11,12] Preparation for complete-coverage ceramometal crowns may put vital mandibular incisors at risk of pulpal exposure as well as fracture, leading at worst to the use of a post in the root canal. This can cause both lateral perforation and disturbance of the apical seal.[13,14] Adhesive restorative techniques with resin composite or porcelain have been used as alternatives to complete crowns for both vital and root-filled mandibular incisors. Porcelain laminate veneers are popular for the restoration of vital and endodontically treated mandibular incisors because tooth preparation is more conservative and limited to the labial surface and incisal edge. However, it has been reported that porcelain veneers constructed on root-treated teeth have a poorer prognosis than those on vital teeth.[15]

The purpose of this study was to investigate fracture behavior in terms of fracture force and mode of failure with respect to the individual and combined effects of endodontic treatment and porcelain laminate veneer placement on human mandibular incisors.

[a]*Private Practice; and Lecturer, Faculty of Dentistry, The University of Hong Kong, Prince Philip Dental Hospital, Hong Kong, China.*
[b]*Assistant Professor, Faculty of Dentistry, The University of Hong Kong, Prince Philip Dental Hospital, Hong Kong, China.*
[c]*Senior Lecturer, Eastman Dental Institute for Oral Health Care Sciences, University of London, United Kingdom.*

Reprint requests: *Dr Frederick C. S. Chu, Faculty of Dentistry, The University of Hong Kong, Prince Philip Dental Hospital, 34 Hospital Road, Hong Kong, China. Fax: + (852) 25470164. e-mail:cschu@hkucc.hku.hk*

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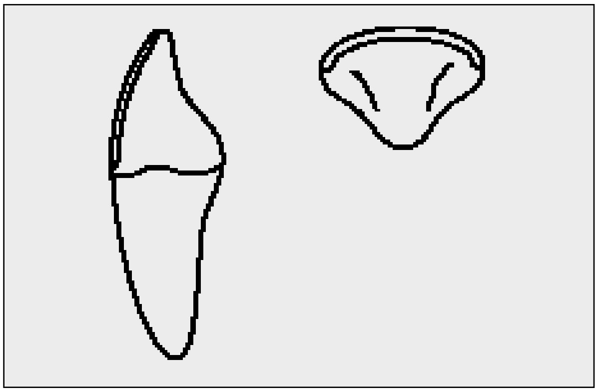

Fig 1 Relationship between a mandibular incisor and porcelain veneer in longitudinal and coronal sections.

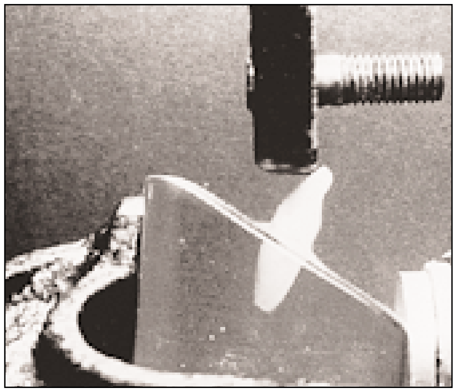

Fig 2 Loading test setup.

Materials and Methods

Selection of Mandibular Incisors

Human mandibular incisors were collected from the oral surgery unit of a teaching hospital 2 weeks before the study. All teeth were stored in sterile saline at room temperature. Forty intact teeth were selected under fiberoptic light and 20× magnification after removal of stain, calculus, and periodontal ligaments using ultrasonic scaling and rotary polishing. Proximal radiographs showed that all selected teeth had only one canal. These teeth were assigned to four groups according to their labiolingual widths measured at the cementoenamel junctions. The range, mean, and standard deviation of labiolingual widths of each group were similar (group A = 5.9 ± 0.46 mm; group B = 5.9 ± 0.42 mm; group C = 5.9 ± 0.40 mm; and group D = 5.9 ± 0.41 mm). Group A was control; group B had endodontic treatment; group C had labial porcelain veneers; and group D had both endodontic treatment and porcelain veneers.

Endodontic Treatment

Instrumentation of the root canals of groups B and D was performed after minimal access cavities were prepared on the lingual surfaces using tapered diamond burs and a high-speed turbine handpiece.[16] A standard step-down technique,[17] using Hedstroem files (Kerr) and a 3% sodium hypochlorite irrigant (Sainsbury's Bleach, Sainsbury), was employed to create an apical stop of size 30 at 0.5 mm from the radiographic apex. All canals were enlarged up to size 45 at 1.5 mm coronal to the apical stop, and they were obturated with laterally condensed gutta percha points (Kerr) and Roth Canal Cement (Roth International). Excess coronal gutta percha was removed with a hot plastic instrument to create an access cavity of 2-mm depth. The access cavities were restored with resin composite (XRV Herculite, Kerr) following acid etching for 15 seconds (Esticid, Heraeus Kulzer) and application of a primer (XR Prime, Kerr) and a dentin bonding agent (XR Bond, Kerr).

Porcelain Veneer Restorations

Preoperative silicone matrices (President, Coltène) were taken and sectioned longitudinally to evaluate the amount of tooth reduction for specimens of groups C and D. Intraenamel tooth preparation was carried out by the first author using diamond burs (#120, Two Striper, Premier). The gingival chamfer margins were prepared 1 mm coronal to the cementogingival junction. The labial surfaces, with proximal tooth preparation not exceeding half of the labiolingual widths of the teeth, were reduced by 0.5 mm. A feather-edge incisal preparation was selected, and there was no reduction of the original tooth length (Fig 1). At the end of tooth preparation, a self-curing resin was used with an intact silicone index to construct resin veneers, which were measured to monitor the amount of tooth reduction.

The prepared teeth were used as working dies, and platinum foils (20 µm thick) were adapted to the prepared tooth surfaces with a burnisher.[18] Vitadur Alpha porcelain (Vita) was applied in three increments. Shade A3 dentin porcelain was used first, and A1 enamel porcelain was used for the second and third increments. Firing of each increment was carried out in a vacuum furnace (Multimat MC II, Dentsply) at 940°C for 2 minutes. The veneers were adjusted according to the silicone matrices using fine diamond burs in an electric handpiece. A final glaze was placed and air fired in the furnace at 960°C for 1.5 minutes. The platinum foils were subsequently detached from the veneers.

The fitting surfaces of veneers were air abraded using 50-µm glass beads at 23 psi (1.5 bar) for 5 seconds and acid etched for 60 seconds with a 5% hydrofluoric acid (Vita Ceramics Etch). The acid was rinsed away under running water. A silane coupling agent (Kerr Silane Primer) was applied onto the fitting surfaces of veneers and left to dry at room temperature. Veneers were bonded to the teeth using the dual-curing Nexus Universal Luting system (Kerr) according to the manufacturer's instructions.

Loading Test

The prepared specimens were mounted for the loading test by embedding the roots in self-cured clear denture acrylic (RR Self-Cure Repair Material, Dentsply). There was a 2-mm distance between the cementoenamel junction and the acrylic resin. The specimens were stored in water at room temperature for 7 days before testing.

The assembly was mounted in a universal load-testing machine (Hounsfield H25K). Each tooth was placed at a 30-degree inclination to the long axis of the loading force (Fig 2), and the specimens were loaded at a rate of 5 mm/min until fracture. The loading jig was a half-round steel rod 22 mm in diameter, and it was attached to a 2.5-kN load cell through a cast metal cylinder. The jig was placed 1 mm below the incisal edge on the labial surface. The applied force was generated by the load cell and displayed on a chart recorder (PL3XY/t, JJ Lloyd Instruments) at a chart speed of 20 mm/min. The forces at which fracture of tooth or porcelain veneer first occurred were recorded. Tooth and veneer fragments were collected for analysis of modes of failure.

Prism 2.0 statistics software (Graphpad Software) was used for data analysis. Gaussian distributions of the fracture forces were confirmed by normality testing for each group before using one-way analysis of variance (ANOVA).

Results

The means and standard deviations of fracture forces of the intact control, endodontically treated, veneered, and veneered and endodontically treated teeth were 415 ± 220 N, 370 ± 89 N, 420 ± 128 N, and 448 ± 156 N, respectively. One-way ANOVA showed that there were no statistically significant differences between the forces required to fracture the specimens of each group ($P > .05$).

Root fracture was the most common mode of tooth failure for all four groups, while crown-root fractures were the least common (Figs 3 to 6). There were no statistically significant differences between the tooth fracture patterns of each group. For the veneers of groups C and D, half of them fractured in the same path of tooth fracture, but the debonded veneer fragments were not always associated with the tooth fracture paths (Table 1).

Discussion

Endodontic treatment and porcelain veneer restoration, alone or together, may have a role in the restoration of mandibular incisors, but it was unclear if these procedures would jeopardize the final strength of the teeth. Although it is impossible to extrapolate the results of in vitro loading tests to clinical conditions, the results of fracture load and mode of failure testing deserve consideration in the prosthodontic literature because they give us useful information for objective evaluation of restorative procedures and materials.

The use of natural teeth for fracture behavior testing provided a more realistic range of variations not only in tooth size and shape, but also in the quality and thickness of enamel. Although artificial teeth may allow a better standardization in tooth size and physical properties, it is difficult to simulate on them the effects of endodontic treatment and veneer bonding to various amounts of enamel and exposed dentin. In this study, the teeth were assigned into one of four groups according to their labiolingual widths at the cementoenamel junctions to give a similar distribution of tooth sizes encountered clinically.

It is agreed that a horizontal force will be generated on the palatal surfaces of maxillary incisors during mandibular protrusion,[4–6] and a vertical force will be generated against both maxillary and mandibular incisal edges when they articulate in the intercuspal or edge-to-edge positions.[19] The resultant horizontal force and vertically compressive force will bring the labial surfaces of mandibular incisors into tension. To apply both horizontal and vertical forces on the mandibular incisors, the specimens were oriented at 30 degrees to the loading jig with a labial point of application. Oblique force placed palatally at 30 degrees to the long axis of maxillary central incisors was also employed in another study.[3]

Large deviations of fracture load were found in all four groups. Although not completely comparable, large standard deviations were also found in the results of other studies.[20,21] In addition to the influence of minor morphologic differences, this finding may be explained by the variations in human material tested, especially in terms of anisotrophy, enamel quality, thickness, and age.

Our study confirmed that endodontic treatment with conservative access cavities restored with resin composite would not jeopardize the fracture resistance of a mandibular incisor when compared with the intact

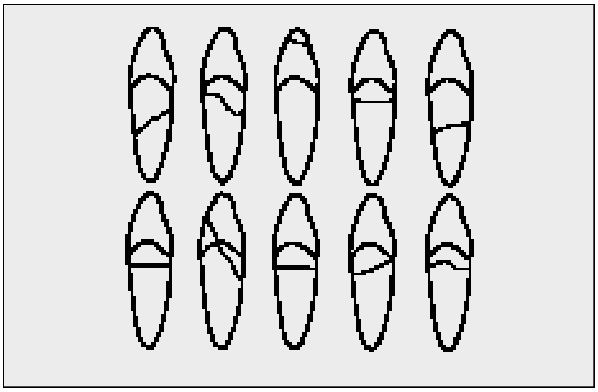

Fig 3 Modes of failure of specimens in group A (control teeth).

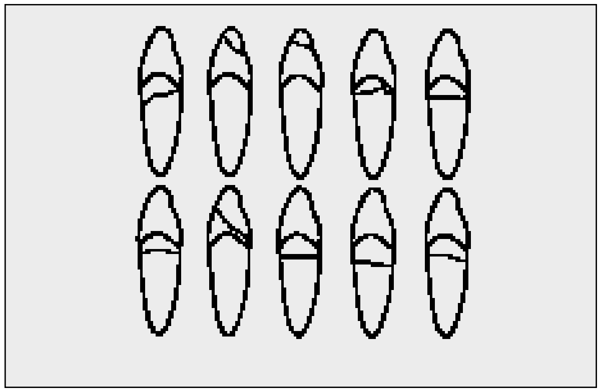

Fig 4 Modes of failure of specimens in group B (endodontically treated teeth).

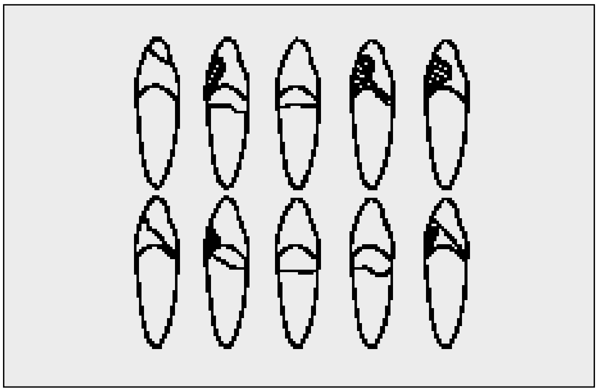

Fig 5 Modes of failure of specimens in group C (porcelain-veneered teeth). (Shaded areas represent the debonded veneers.)

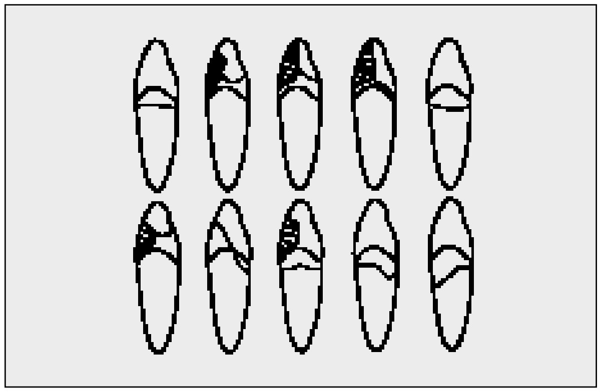

Fig 6 Modes of failure of specimens in group D (endodontically treated teeth with porcelain veneers). (Shaded areas represent the debonded veneers.)

Table 1 Distribution of Mode of Failure (No. of Teeth)

Group	Crown fracture	Crown-root fracture	Root fracture	Veneer fracture	Veneer debond	Veneer crazing
A	1	1	8	—	—	—
B	3	0	7	—	—	—
C*	3	2	4	5	5	2
D	4	1	5	5	5	3

*One specimen had veneer debond only.

control. By measuring the impact fracture energy of intact and endodontically treated maxillary central incisors, the same finding was reported.[2,20] There are no differences between endodontically treated mandibular incisors with or without posts.[21] However, endodontic treatment could lead to significant increase in coronal flexure when the maxillary central incisors are under horizontal loading from the palatal side (1.55× the intact control). In the same study, it was also found that veneered and intact maxillary central incisors have the same amount of coronal flexure.[5] Differences between these studies may be explained by the variations in loading rates and directions as well as the measured parameters. A continuous load simulating the masticatory function was used in a flexure test.[5] This allowed minute strain measurement to be made. Unfortunately, the flexure test would not provide any information about modes of failure, which are useful for judging if an in vitro test could reproduce failure patterns observed clinically.

Our study was designed to allow both quantitative analyses of the fracture loads of mandibular incisors and qualitative comparisons of the modes of failure of teeth and veneers. Root fracture was the most common mode of failure, possibly reflecting that crack initiation would occur more readily on the root surface when the crown is loaded obliquely and the coronal dentin is "laminated" with enamel and porcelain veneer. On the other hand, the fracture paths were unpredictable, as the human dental structure allows energy dissipation by various paths of crack propagation.

Although there were no statistically significant differences between the modes of failure of the teeth between the groups, nor between the modes of failure of veneers of groups C and D, it is interesting to observe that some veneers were cervically debonded, as reported in a clinical study.[22] Some of these veneers were debonded together with the tooth fracture fragments, and some of the debonds were separated from the tooth/root fractures. Our results were different from a previous study, which reported no veneer debond when veneers with different incisal-edge designs bonded on artificial teeth were loaded at their incisal edges.[23] In addition to direct compression, we believe that the veneers debonded because there was a difference between the elastic modulus values of porcelain and tooth substances. Shear stresses would develop between them when the labial surfaces are subjected to flexure.[3]

Conclusions

Within the limits of this study, the following conclusions were drawn:

- Human mandibular incisors with endodontic treatment and/or porcelain veneer restorations were able to withstand the same magnitude of oblique loading as intact teeth.
- Endodontic treatment, porcelain veneer restoration, and the combination of both restorative techniques did not affect the mode of failure of mandibular incisors.

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