Original Research Article

Evaluation of fracture resistance of mandibular incisors before and after endodontic treatment and metal ceramic crown placement

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Abstract

Background: Mandibular incisors are the smallest among the permanent dentition, with thin enamel and dentin. Intact teeth do not fracture easily while mastication.

Objectives: To evaluate the fracture resistance of mandibular incisors after endodontic treatment and metal ceramic crown placement.

Materials and methods: Eighty recently extracted intact mandibular incisors were divided into four groups of twenty each based on root canal treatment and crowns, intact natural tooth without RCT and crown preparation was used as control group. Each tooth was mounted separately in acrylic block and subjected to loading in universal load testing machine until fracture, results were analyzed by one-way ANOVA and Turkey's multiple post hoc procedures.

Results: The results showed that Fracture resistance of teeth restored with metal ceramic crowns was very high when compared to the teeth without crowns ($p<0.05$).There was no statistically significant difference between intact and endodontically treated teeth ($p>0.05$).
Conclusion: The study concluded that endodontic treatment and tooth preparation followed by metal ceramic restoration increased the fracture resistance of mandibular incisors.

Key words

Fracture resistance, Endodontic treated teeth, Ceramic crown, Mandibular incisors.

Introduction

Mandibular incisors are the smallest among the permanent dentition, with thin enamel and dentin. Intact teeth do not fracture easily while mastication. However, fracture can occur in teeth weakened by dental caries, large cavity preparations and erosion or abrasion. Usually large teeth can withstand the extensive preparations involved in endodontic treatment and tooth preparation for full coverage crowns better than the smaller mandibular incisors.

Strength of decayed and root treated teeth is reduced and they fracture more easily than vital intact teeth, due to loss of tooth structure [1, 2]. Therefore, preservation of tooth structure to provide strength and fracture resistance is important when restoring endodontically treated teeth. Some studies showed significant reduction in rigidity and flexural strength of teeth after access cavity and post preparations [3, 4].

Endodontically treated teeth have been considered to have altered physical properties when compared with intact vital teeth. This difference was initially thought to be due to dentin dehydration causing an increased brittleness in endodontically treated teeth [5], but this was opposed by some authors based on their studies [6].

Endodontically treated anterior tooth need not always be restored with complete coverage crown [7, 8]. If the tooth is intact and loading is less, as the anterior teeth are away from the fulcrum, restoration of access cavity is sufficient [7, 8]. However, this is yet to be confirmed by further studies.

The materials of choice for the restoration of endodontically treated teeth are Ni-Cr alloy, gold alloy, porcelain fused to metal (PFM) and all ceramic [8]. Even in this advanced era of metal free restorations, in developing countries, metal-ceramic restorations are widely used. Metal ceramic restorations serve the purpose of esthetics and also strength [8, 9].

Before going for a restoration, the effect of endodontic treatment on the strength of the tooth should be assessed and known. The strength of the tooth prior to and after the endodontic treatment should be calculated. The restoration should be done so that the strength of the tooth is restored i.e. the restoration should not only restore the form but also the function.

So far many studies were done to investigate the mechanical properties of maxillary incisors, premolars and molars, but very little has been done in case of mandibular incisors. Extensive restorations and endodontic treatment may compromise the smaller mandibular incisors [10].

The purpose of this study was to evaluate the effect of endodontic treatment and metal ceramic crown placement on the fracture resistance of mandibular incisors.

Materials and methods

Eighty freshly extracted mandibular incisors free of caries, fractures, previous restorations and

open apices were selected and all were stored in artificial saliva (Wet Mouth, ICPA). Scaling of all the teeth to remove the external debris was done using an ultrasonic scaler (Satelec, France). The teeth were divided into four groups – group A, group B, group C and group D of twenty teeth each **Table - 1**.

Among the four groups, teeth from only two groups i.e. group B and group D were treated endodontically. Pulp extirpation of the teeth from group B and group D was done using barbed broaches (Mani, India). Biomechanical preparation was done using K- files (Mani, India) by step- back procedure and the canals were sequentially enlarged from 15 to 50 size K file, 0.5 mm short of the apex. Then a step back preparation was done up to 70 size K file. Canals were irrigated using 5.2% sodium hypochlorite (Biolab Diagnostics) and normal saline (Parenteral Drugs, India) and dried with absorbent paper points (Dentsply, Germany). Then they were obturated using gutta percha points (Dentsply, Germany) and sealer (Ah plus, Dentsply, Germany) by lateral condensation technique.

Putty indices for teeth were prepared and teeth from group C and group D. The uniformity and the extent of tooth preparation were checked with the putty index which was prepared prior to the tooth preparation.

Fabrication of metal ceramic crowns

Wax patterns were fabricated directly on the prepared teeth. The pattern was carved into a coping of 0.4 mm uniform thickness using PK Thomas wax carving instruments (Delta, India). The thickness of the wax was measured with a wax caliper (API, India). The wax patterns were sprued with preformed wax sprue of 2.5 mm diameter (Bego, Gemany). A ring less casting system was used for casting the patterns. The length of the sprue was adjusted so that the distance between top of the ring and free end of the pattern was 6 mm. All the patterns were sprued in the same manner.

All the patterns were invested in a phosphate bonded investment (Bellavest SH and Begosol, Bego, Germany) within 30 minutes of fabrication. The invested patterns were allowed to set for 20 min according to the manufacturer's instructions.

After wax elimination the hot investment was transferred to the induction casting machine (Fornax T, BEGO, Germany). Nickel - chromium alloy (Girobond – cbs, Amanngirbach, Germany) was used for casting. Sufficient number of pellets of alloy was placed in a ceramic crucible and heated sufficiently and when it reached the molten state, the piston of the casting machine was released for the flow of molten metal from the crucible into the mold space. Then the metal copings were finished using metal trimmers in a heavy duty micromotor (Marathon, Saeyang). The finished metal copings were then sandblasted using 110μm alumina (Cobra, Renfert, Germany) in a micro sandblaster (Delta, India).The metal ceramic crowns were finished and glazed at a temperature of 920°C, finished metal ceramic crowns were cemented using Type 1 Glass ionomer cement

Placement of teeth in acrylic blocks

For making acrylic blocks, a silicone mold of the acrylic block was fabricated with polyvinyl siloxane impression material – putty consistency (Aquasil, Dentsply LOT 1302000273). The size of the block was 15 mm in height, 14 mm breadth and 14 mm width. Auto polymerizing acrylic resin (DPI, India) was mixed in a ceramic jar according to manufacturer's instructions and poured into the silicone mold space. The tooth was positioned at the centre of the mold space and aligned perpendicular to the floor with the help of a surveyor (Marathon, Saeyang Company). This was done to simulate the tooth position of mandibular incisors in the mandible (90°) [12]. Tooth position was adjusted so that the prepared margin was 2 mm above the acrylic block. Same procedure was followed to prepare all the samples (**Figure – 1 to 8**).

Figure – 1: Extracted mandibular incisors.

Figure – 2: Customised plaster mould.

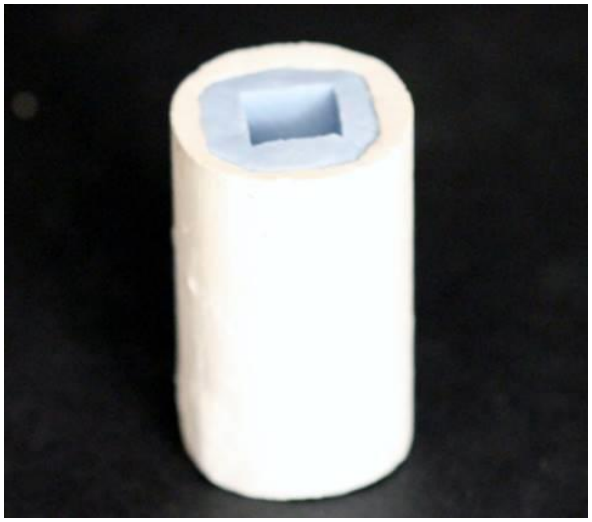

Figure – 3: Radiograph showing endodontically treated teeth.

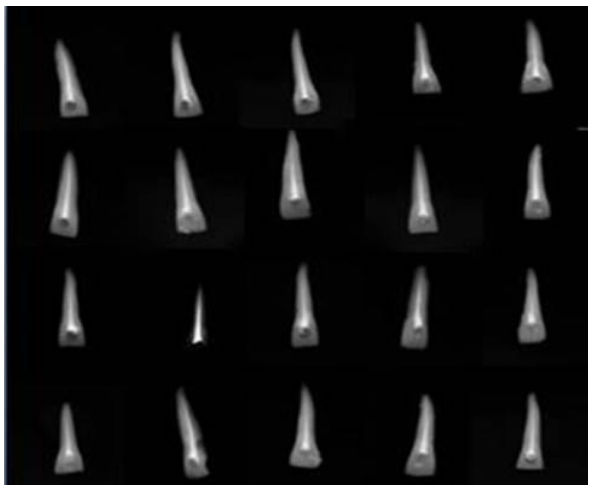

Figure – 4: Fracture resistance testing machine.

Figure - 5: Checking the tooth preparation using putty index.

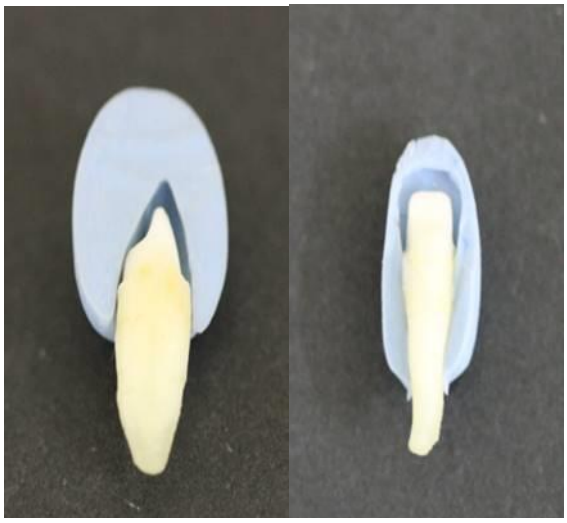

Figure - 6: Ceramic build up.

Figure - 7: Placing the tooth in acrylic block using a surveyor.

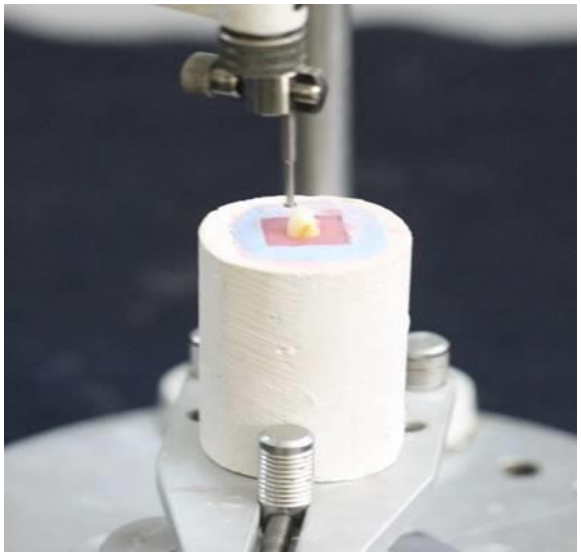

Figure - 8: Testing the sample under universal Testing machine.

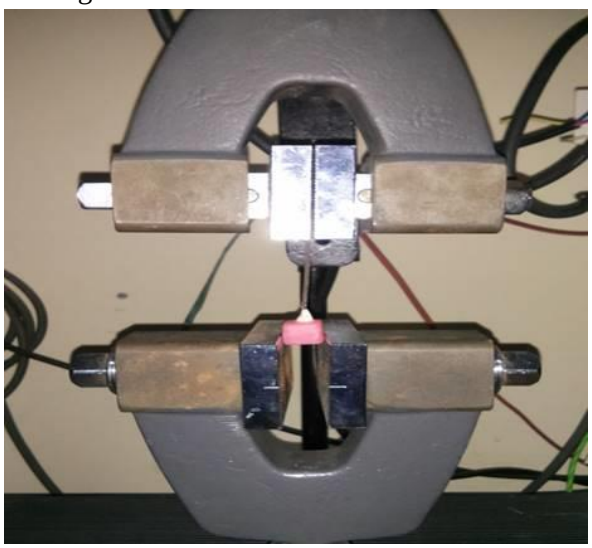

Table – 1: Grouping of Samples.

GROUP A	Mandibular incisors without RCT and crown (Control group)
GROUP B	Mandibular incisors with RCT only
GROUP C	Mandibular incisors with metal ceramic crown only
GROUP D	Mandibular incisors with both RCT and crown

Results

Testing samples for fracture resistance

The fracture resistance of samples of all the groups was tested under a static load using a Universal testing machine. The tooth mounted in resin block was attached to the lower member and the metal plate which was used to fracture the teeth was attached to the upper member of the testing machine using screws. The floor of the acrylic block was positioned parallel to the floor so that the tooth was perpendicular to the floor. The metal plate was positioned in such a way that the force applied on the tooth would be parallel to the long axis of the tooth.

A compressive force was applied on the tooth at a crosshead speed of 1 mm/min until fracture occurred. The maximum fracture loads were recorded in Newtons. The same procedure was repeated for all the samples of groups A, B, C and D.

All the readings were recorded. The variable of interest was the load at failure measured in Newtons. The statistical analyses used included 1-way analysis of variance (ANOVA) to detect the presence of group differences, and pairwise comparisons between groups with the Tukey adjustment for multiple comparisons using an overall Type I error (a=0.05).

The results of the study showed that the specimens of Group B (endodontically treated teeth) had least fracture resistance, the mean value as being 472.52N (**Table – 3**), followed by Group A (intact teeth) with 518.85N, then by Group D (endodontically treated teeth with metal ceramic crown) with 1021.36N. Group C (teeth with metal ceramic crown alone) had highest fracture resistance, with a mean fracture resistance value of 1151.43N (**Table - 2**).

Discussion

Popular belief (hypothesis) was that extensive preparations involved in endodontic treatment and tooth preparation would jeopardize the fracture strength of the mandibular incisors. This in vitro study on eighty mandibular incisors aimed at this hypothesis.

Table – 2: Fracture loads of all the samples measured in Newtons.

Sample No	Group A	Group B	Group C	Group D
1	556.250N	431.750N	1028.50N	911.500N
2	511.875N	381.875N	1120.50N	1023.75N
3	512.000N	434.750N	976.750N	807.750N
4	523.750N	396.250N	1125.50N	811.875N
5	497.500N	511.875N	956.750N	1019.75N
6	601.500N	426.250N	1102.50N	1089.00N
7	545.500N	447.000N	1128.75N	1017.50N
8	511.800N	512.750N	1203.00N	1045.00N
9	510.850N	482.750N	1047.50N	811.875N
10	475.750N	445.250N	911.875N	822.125N
11	493.660N	440.670N	1241.25N	804.500N
12	566.750N	510.675N	913.750N	1061.25N
13	485.590N	416.000N	1261.75N	933.750N
14	511.875N	388.500N	1171.50N	1023.75N
15	523.500N	519.000N	1023.75N	852.500N
16	475.670N	395.750N	1171.50N	1008.85N
17	550.600N	508.450N	1061.75N	1022.25N
18	455.235N	402.500N	994.500N	922.150N
19	511.870N	460.000N	1110.50N	1003.65N
20	545.500N	444.500N	976.750N	954.500N

Table – 3: Mean, SD and SE of each group.

Groups	N	Mean	SD	SE
Group A	20	568.85	204.52	45.73
Group B	20	472.53	170.01	38.02
Group C	20	1151.43	357.58	79.96
Group D	20	1021.36	484.33	108.30

Table – 4: One way Anova.

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F-value	P-value
Between groups	3	6092394.60	2030798.20	20.5074	0.00001*
Within groups	76	398725.799	5246.3921		
Total	79	6491120.40			

Many studies had shown that the non-vital and extracted teeth became brittle due to dehydration [2, 12]. To prevent dehydration, the extracted teeth were sent to loading test within 72 hours after extraction. For this period, the teeth were stored in artificial saliva to simulate the oral condition. The other storage media for extracted teeth were sodium hypochlorite, formalin and hydrogen peroxide [13]. Though these storage media also acted as disinfectants, they caused enamel porosity by deproteinization and alter dentin structure, by removing or modifying the proteic matrix, which could invalidate the use of teeth stored in this solution [8, 14, 18].

Table – 5: Pair wise comparisons by Tukey's multiple post hoc procedures.

Groups	Group A	Group B	Group C	Group D
Mean	568.8513	472.5273	1151.4313	1021.3638
SD	204.5217	170.0099	357.5807	484.3325
Group A	-			
Group B	P=0.7913	-		
Group C	P=0.0001*	P=0.0001*	-	
Group D	P=0.0004*	P=0.0002*	P=0.5974	-

*p<0.05

The material of choice for restoring the teeth in this study was metal ceramic. In spite of improved esthetics of all ceramics, metal ceramics are still used extensively, because of their better physical (mechanical) properties and acceptable esthetics [9. 16]. Also many studies revealed that porcelain-fused-to-metal (PFM) crowns had been used extensively in fixed prosthodontics to restore endodontically treated teeth [8, 14, 18].

Paphangkorakit, et al. proved that a vertical force will be generated against mandibular incisal edges when they articulate in the inter-incisal or edge-to-edge positions [15]. To simulate this condition the samples were oriented parallel to the loading jig.

The least fracture resistance values of endodontically treated teeth may be due to dentin dehydration [5] or due to decreased residual dentin and loss of tooth structure [6] as explained in literature. One way analysis of variance (ANOVA) showed that there was statistically significant difference among the 4 groups ($p<0.05$). This difference was due to the higher fracture resistance values of Groups C and D. To compare each group with every other group (inter group) pairwise comparisons were done by Tukey's multiple post hoc procedures (**Table - 4**).

When compared the fracture resistance values of Groups A and B by Tukey's multiple post hoc procedures **Table - 5**, it showed no statistically significant differences between these two groups ($p>0.05$). Though the mean values showed that there was a decrease in the fracture resistance of teeth after endodontic treatment, the difference between the fracture resistance of two groups (Group A and B) was small and not statistically significant. These results showed that fracture resistance of endodontically treated mandibular incisors was similar to that of intact teeth. These results were similar to earlier studies [9, 16].

Ho, et al. 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 tooth [9].

Stokes also reported that the fracture resistance of intact and endodontically treated maxillary central incisors [16] was similar.

Trabert KC also confirmed that there was no difference in fracture resistance values of endodontically treated teeth and intact teeth in his study on maxillary incisors [2].

Comparison between the two groups with metal ceramic crowns (Group C and Group D) also showed no statistically significant differences ($p>0.05$) i.e. the fracture resistance values of teeth with metal ceramic crowns were not influenced by the endodontic treatment. The same interpretation could be drawn with this result that endodontic treatment would not jeopardize the fracture resistance of teeth with metal ceramic crowns.

There was a statistically significant difference between the fracture resistance values of

specimens of Group A and Group C ($p<0.05$). This showed that the fracture resistance of a mandibular incisor was not compromised by restoring it with a metal ceramic crown but was increased.

The same results were obtained when compared the Groups A and D; Groups B and C; and Groups B and D. In all these instances, $p<0.05$. This showed that restoring a tooth with a metal ceramic crown increased its fracture resistance irrespective of endodontic treatment.

When the mean fracture resistance of each group was observed, it is highest (1151.43N) for Group C, i.e. the teeth with metal ceramic crown and without endodontic treatment. The second highest was observed for Group D (endodontically treated teeth with metal ceramic crowns) with a mean fracture resistance of 1021.36N. The mean values of these two groups were almost twice as high as the other two groups. This was because of the addition of strength of the metal6. This demonstrates that the fracture strength of mandibular incisors can be significantly increased by restoring them with metal ceramic crowns [6]. The mean fracture strengths obtained in this study were similar to those obtained in other studies. Konstantinos in his study on fracture strengths of metal ceramic crowns stated that the mean fracture strength of anterior teeth with metal ceramic crowns was 995N [19].

One more important finding in this study was that the fracture strengths of samples of any group were more than the maximum incisal bite force in the anterior region. In the literature, the maximum incisal forces of anterior teeth varied, but the amount was almost always below 200N [8, 11] which is much lower than the failure loads of mandibular incisors found in this study.

Conclusion

This study was done to assess the effect of endodontic treatment and metal ceramic restoration on fracture strength of mandibular incisors. The results disproved the popular belief that the extensive preparations involved in endodontic treatment and tooth preparation for metal ceramic crown placement would decrease the fracture strength of mandibular incisors. In fact, the results showed that a metal ceramic restoration would increase the fracture strength of a mandibular incisor.

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