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RESEARCH ARTICLE

EFFECT OF PREPARATION DESIGN ON MECHANICAL PROPERTIES OF ENDODONTICALLY TREATED TEETH.

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Abstract

This study is aimed to evaluate the effect of different tapers and restorative cavity designs on the fracture resistance of the endodontic retreated tooth. Sixty lower first premolar human extracted teeth from the teeth bank of faculty of dentistry, Ain Shams University have been used in this study and divided into 3 different groups. Group I: Access cavity class I preparation was made. Group II: Access cavity occluso-mesial cavity (OM) class II preparation was made. Group III: Access cavity mesio-occluso-distal (MOD) class II cavity preparation was made. These main groups were further sub divided into two sub groups, subgroup A: cleaning and shaping was done using Twisted File (TF) #25 taper 0.04, subgroup B: cleaning and shaping was done using Twisted File (TF) #25 taper 0.06. The fracture resistance of all groups had been evaluated & analyzed; results using Two-Way ANOVA showed that the cavity design had a significant effect on the fracture strength. On the other hand, neither the taper nor the interaction of the independent variables (taper and cavity design) had a significant effect on the fracture strength of teeth. It has been concluded that the remaining coronal tooth structure is the corner stone in weakening the tooth structure while the root canal geometry is not a mechanical cause of failure.

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Introduction:-

Loss of dentin is an important predisposing factor for tooth structure during root canal treatment which causes eventually extraction of the tooth [1].

A lot of factors cause the loss of tooth structure such as dental caries, therapeutic procedures as access cavity preparation, restorative cavity preparation and root canal preparations [2,3].

A lot of debate along the past years was raised about whether the amount of coronal tooth structure or apical tooth structure is highy affecting the fracture resistance of the tooth and the prognosis of endodontically treated tooth.

The cavity design which either simple access cavity preparation or loss of one or more walls affects the fracture resistance of the tooth [4]. Fractures are even more frequently recorded with root canal treated teeth. Excessive removal of the coronal and radicular dentin during the root canal treatment procedures (RCT) and the lower residual moisture content may lead to a massive reduction in the strength and increase tooth's susceptibility to fracture [5].

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Loss of axial walls, which is quite common in teeth in need to root canal treatment, also significantly decreases the fracture resistance of the hard dental tissues [6].

A previous study [7] claimed that occlusal cavity preparation during root canal treatment may reduce the mechanical resistance of the remaining dental hard tissues by 20%. A need for removal of the marginal ridges will surely widen the cavity further into the interproximal space. Resistance of dental structures will be reduced by 2.5-fold. This may result in an overall 46% decrease in the fracture resistance.

In case when both marginal ridges are affected, the resistance will be decreased by 63% where mesio-occluso-distal (MOD) cavity preparation design that measures half of the intercuspal distance with rounded internal angles, and either divergent or convergent internal wall angulation will weaken the remaining tooth structure [8].

Also, a lot of rotary systems introduced into the market proposed different root canal geometries.

The twisted files, which is a file manufactured by twisting of NITI alloy in the R phase provides various instruments tapers such as 0.04, 0.06, 0.08. As the instruments taper increases it removes more infected dentine which leads to cleaner canal walls.

Some authors claimed that removal of hard tissues from dentine walls increase the chance of root fracture [3], and others claimed the opposite that increasing the root canal preparation taper allow forces to be better distributed in the apical third of the canal which has the result to allow better distribution forces and increase the tooth resistance to fracture.

So the debate whether, the loss of tooth structure coronally due to caries and different designs of cavity preparation, including one or more walls of tooth structure, or different canal tapers and geometries have more dramatically weakening effect on the tooth and make it more vulnerable to fracture.

Based on this idea, our study focused on comparison between the effect of three different coronal cavity preparation designs combined with different root canal preparation tapers on the fracture resistance of endodontically treated human extracted lower premolar teeth. Such study design wasn't presented in the literature before.

Material and Methods:-

Sixty lower first premolar human extracted teeth from teeth bank of faculty of dentistry, Ain Shams University had been used in this study and randomly divided into 3 equal groups. Group I: where a class I Access cavity preparation was made. Group II: Access cavity occluso-mesial cavity (OM) class II preparation was made. Group III: Access cavity mesio-occluso-distal (MOD) class II cavity preparation was made. Each group was furtherly subdivided into two subgroups. Subgroup A: preparation has been made using Twisted file (Sybron Endo rotary NiTi TF, Mexico) #25 taper 0.04 in a crown down manner until reaching the working length. Subgroup B: preparation has been made using Twisted file (Sybron Endo rotary NiTi TF, Mexico) #25 taper 0.06 in a crown down manner until reaching the working length. In all groups, root canal was flushed with 5mm freshly prepared 2.5% sodium hypochlorite solution during instrumentation.

Canals were then obturated using thermo-plasticized continuous wave technique in each group with the corresponding taper of the master cone (META BIOMED Gutta percha). AH+ resin sealer was used. Teeth were stored in 100% humidity for 2 weeks for the sealer setting.

In all groups, the coronal and the radicular cavity was filled by core material Multicore Flow (Ivoclar Vivadent, Schaan, Liechtenstein) according to manufacturer's instructions where the tested samples were formerly etched using 37% phosphoric acid etchant (Scotchbond™ Universal Etchant, 3M ESPE) and then adhesively bonded using Universal adhesive (Single Bond Universal™, 3M ESPE).

Roots of the tested samples were coated with a single layer of low viscosity rubber impression material (Imprint II, 3M ESPE, St. Paul, MN) to mimic the natural periodontal ligament. [9] The coated roots were then embedded into acrylic resin blocks attempting to conduct the fracture resistance test. The buccal cusps of all restored sample teeth were obliquely stressed (at 45° inclination) till fracture by the aid of a round end rod on a universal testing machine

(LLOYD Universal Testing Machine, LR 5K, Ametek / Lloyd Instruments) running at a crosshead speed of 0.05 mm/min [10].

The maximum load at failure was recorded for each specimen and the collected data were then statistically analyzed using both ANOVA and Tukey's comparisons at a = 0.05 to determine the significance of the differences detected between subgroups. The fracture pattern of each specimen was also assessed to find out the specific areas of weakness (crown, core, post, or the root).

Results:-

Means ± standard deviations (SD) for effect of taper and cavity design on the fracture resistance of tooth structure are presented in table 1. Two-Way ANOVA showed that the cavity design had a significant effect on the fracture strength. On the other hand, neither the taper nor the interaction of the independent variables (taper and cavity design) had a significant effect on the fracture resistance of teeth.

Table 1:-Means ± Standard Deviations (SD) and coefficient of variation (CV%) for the effect of taper and cavity design of fracture strength of teeth

Cavity Design	Taper		
	Subgroup A (4%)	**Subgroup B (6%)**	**P**
	Mean ± SD	Mean ± SD	
Group I (Class I)	405.17± 55.78 a (13.76%)	350.37 ± 157.75 a (45.02%)	0.22
Group II (OM)	287.41 ± 26.12 b (9.09%)	296.71 ± 58.7 b (19.78%)	0.65
Group III (MOD)	250.77 ± 94.1 b (37.52%)	266.32 ± 103 b (38.67%)	0.72

P = Probability for the effect of taper.
Means with the same letter within each column are not significantly different at $p \leq 0.05$.

Discussion:-

The survival of endodontically treated teeth is basically dependent on the fracture resistance from mechanical point of view, the loss of tooth structure is the imminent factor causes tooth fracture [11,12], which leads eventually to tooth extraction [13-16].

To go through the steps of the root canal treatment starting from the elimination of caries and coronal cavity design followed by endodontic access cavity preparation then the root canal preparation, these steps may result in excessive loss of tooth structure hence weakening of the whole skeleton and finally reduction of the fracture resistance [4, 11, 17]. In this study three cavity designs with gradual increase in amount of loss of tooth structure were tested to simulate different situations happened in vivo. Coronal preparations were either made as conventional access cavity (class I), access cavities with occluso-mesial extensions (OM cavities) or access cavities with mesio-occluso-distal-extensions (MOD cavities).

In our study, it was found that the coronal cavity preparation combined with the access cavity preparation design both have an impact on the fracture resistance of the endodontically treated sample teeth due to the progressively decreasing coronal tooth structure with subsequent endangerment of the structural integrity and fracture resistance of endodontically treated teeth **(Dang N. et al) [18].**

The method of root embedment may impact the fracture resistance significantly. Thus, in the our present study, simulation of the natural situation regarding the periodontal ligament around the tooth was done using polyvinyl siloxane, an elastomeric impression material which is able to prevent stress concentration at the cervical region of the tooth owing to imitating the natural accommodation of the tooth in the bony alveolus **[10]**. Also, the LLOYD testing machine (LR 5K, Ametek / Lloyd Instruments) was used to measure the fracture resistance of teeth because of the simplicity and most frequent use of this method to evaluate tooth strength **[19, 20]**. However, such in vitro test provided a static load until failure occurs, whereas what happens in the oral cavity is that loads are dynamic and, thus, it may not mimic the in vivo conditions [21].

It should be noted that according to the condition of our study, the large cavity of MOD relatively to the small crown of lower premolar had a dramatic effect on the fracture resistance of the remaining tooth structure.

Regarding the root canal treatment part, this infection of the canals and removal of microorganism is a target either by mechanical enlargement or chemical disinfection [22].

From biological point of view, mechanical removal of dentine removes the bacteria that penetrate and colonies inside dentinal tubules [23, 24], so improper removal of infected dentine may lead to worsening the prognosis of treatment and subsequent post treatment failure.

From the mechanical point of view, the remaining dentine thickness is the antagonist against tooth fracture and accordingly more dentin removal decreases the fracture resistance [4, 9].

The result of this study shows that the MOD cavity significantly decreased the fracture resistance more than the OM cavity and class I access cavity. While for root canal shaping, the current study showed no significant reduction to fracture resistance by 0.06 taper instrumentation compared to 0.04 taper.

In agreement with our results, a previous study from **Sabeti M. et al** [9], showed the same results and in agreement with **Lang H. et al, 2006,** [3] the study showed that during instrumentation, keeping root canal outlines unaltered, tooth fracture resistance is relatively unaffected.

Also, the large diameter of the lower premolar root relatively to the small canal diameter, was not affected by the increased taper.

From this result, it was obvious that the loss of coronal tooth structure is the most effective factor that affects the tooth fracture while root canal preparation geometry was less effective factor on tooth fracture. So, conservation of the coronal tooth structure is much more important for the restorability and final success of the whole treatment.

It could be noticed that in our study we didn’t apply forces directly to the roots in comparison of tapers as most of literatures did [25]. Instead, we were testing the fracture resistance of both coronal and root part at the same time. Inaddition, the point of loads in vivo is at the cusp not directly on the root.

For this limitation, we suggest a finite element analysis to mimic the clinical condition that may also give a valuable data.

The second limitation is that the lower premolar has small crown which largely affected by MOD cavity, while it has a relatively large round root in relation to the small root canal diameter which may not be affected easily by the increased taper. So, this result may not apply to other teeth with larger crowns and smaller roots as the lower molars for example.

Also, the evidence-based facts may also be achieved from multiple clinical trials with long term follow up.

Conclusions:-

Restorative cavity designs and coronal tooth loss caused more dramatic effects in the fracture resistance than increasing the taper of root canal geometry of lower premolars which wasn’t significant.

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