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EXPERIMENTAL AND NUMERICAL EXAMINATION OF PREMOLAR TEETH REINFORCED WITH GLASS FIBER ROOT CANAL POSTS

BADANIA DOŚWIADCZALNE I NUMERYCZNE ZĘBÓW PRZEDTRZONOWYCH WZMACNIANYCH SZKLANO-POLIMEROWYMI WKŁADAMI KORZENIOWYMI

S t r e s z c z e n i e

Praca przedstawia ocenę wpływu wzmocnienia włóknami szklanymi na odporność na pękanie zębów przedtrzonowych odbudowywanych przy pomocy implantów korzeniowych. Badania laboratoryjne wykonano dla 21 usuniętych ludzkich przedtrzonowców stochastycznie podzielonych na trzy grupy. Grupę I stanowiły zęby odbudowywane techniką wkładów korzeniowych i materiałem kompozytowym; w grupie II zęby rekonstruowano kompozytową koroną bez wzmocnienia szklanym wkładem; natomiast grupę III stanowiły tzw. zęby zdrowe. Otrzymane wyniki wskazują, że dla obu metod rekonstrukcji koron zębów po leczeniu endodontycznym prawidłowo stosowanych w praktyce klinicznej otrzymuje się zadowalające wartości wytrzymałościowe odporności na kruche pękanie. Badaniom laboratoryjnym towarzyszyły symulacje numeryczne MES oraz analiza wytężenia struktur korony przedtrzonowca wzmacnianych szklano-polimerowym wkładem korzeniowym.

Słowa kluczowe: przedtrzonowiec, własności wytrzymałościowe, wkłady z włókien szklanych, kompozyt mikrohybrydowy, MES

A b s t r a c t

This study evaluated the influence of glass fiber reinforcement on the fracture resistance of root canal treated premolar teeth. Laboratory tests were done for 21 freshly extracted single rooted human premolars randomly distributed into three groups. The teeth in group I were root canal treated and reconstructed with fiber post and composite crowns; in group II teeth

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were root canal treated and reconstructed with composite crowns but without post reinforcement; and in group III teeth were left untreated. The obtained results suggest that both tested methods of root treated teeth reconstruction, if correctly applied in clinical practice, can achieve satisfactory fracture resistance. Laboratory tests were done with respect to numerical FEM simulations and effort analyses of premolar crown structure reinforced with glass fiber root post.

Keywords: premolar, strength properties, glass fiber posts, micro hybrid composite, FEM

1. Introduction

Root canal treated teeth are considered to be structurally different from unrestored vital teeth [1]. They dry over time and the dentin undergoes changes in collagen cross-linking [1]. It has therefore been suggested that endodontically treated teeth are more brittle and may fracture more easily than vital teeth [2]. For many years, the cast gold post and core has been regarded as a "gold standard" in post-and-core restorations due to its superior success rate [3]. The utilization of metallic posts yields a root fracture index of approximately 2 to 4 % [4], which has been assigned to stress concentration. For this reason, fiber posts were developed that presented an elasticity modulus (E) closer to that of dentin (post ═ 20 GPa, dentin ═ 18 GPa) when compared to cast posts and prefabricated metallic (E ═ 200 GPa) and ceramic posts (E ═ 150 GPa), therefore allowing absorption and uniform distribution of stresses to the remaining root structure instead of concentrating them [5]. Today prefabricated fiber-reinforced composite (FRC) posts are being used increasingly in dental clinical practice [5]. Recently however in several paper the use of a direct restoration without placing any posts for restoring endodontically treated teeth was proposed [6, 7].

The aim of this paper was to investigate the strength properties of direct resin composite complete crowns made on severely damaged premolars with and without fiber post reinforcement by means of both laboratory study and numerical FEM simulations. Premolar teeth were chosen, as they are considered the weakest human teeth.

2. Materials and methods

Twenty one freshly extracted human premolars were selected for the study. Only sound teeth with an average length of 23,0 ± 1mm a bucco-lingual coronal width of 9,0 ± 1mm, and a mesio-distal coronal dimension of 7,0 mm ± 1mm were included in the study. The clinical crowns were removed up to approximately 1,5 mm above cement-enamel junction and root canal treated according the procedure described by Sorrentino [8]. The specimens were randomly distributed into three groups. In group I, after root canal treatment, fiber posts (Enapost, Micerium, size #2, taper 2%) with a composition of 72% uni-directional glass fibers, 21% resin (Bis-GMA, UDMA, BDDMA) and 7% barium borosilicate filler were utilized. After 10 mm deep preparation, posts were adhesively cemented using high filler contained (75%) resin composite cement (Ena Cem HF, Micerium) according to the manufacturer's instruction. The core build up was performed in 2 mm layers of micro hybrid composite with 75% of filler content and compressive strength of 450-490 MPa. Each layer was light cured for 20 s, followed by polymerization for 40 s. In group II, no post-preparations were made but standardized cavities in the canal orifice were prepared using a cylindrical diamond stone (40000 cycles min with water cooling, 2 mm, depth and 2 mm diameter). The adhesive procedures were attempted in a similar manner to group I. In group II, the composite build up was performed without any post reinforcement. In both groups, following the crown preparation with 0,8mm chamfer at the cement-enamel junction, the direct composite crown (Enamel Plus) was created according to the methodology described by Fokkinga [7]. In group III, teeth were left untreated. Each tooth of the three groups was embedded in a block of self-curing acrylic resin surrounded by steel cylinders with the long axis perpendicular to the base of the block. The teeth were embedded approximately into the cement-enamel junction, and stored an incubator at 37 C, 90% humidity for 24 h, in order to simulate an oral environment.

Fig. 1. Subsequent stages of premolar tooth sample preparation with glass fiber post reinforcement.
Rys. 1. Kolejne etapy preparacji korony przedtrzonowca wzmacnianej szklano-polimerowym wkładem korzeniwym

A universal strength machine (INSTRON 4465) was used for static fracture resistance testing. Each specimen was inserted into the holding device with an inclination of 90 degrees in relation to the horizontal plane. A controlled load was applied by means of a diameter of 2,5 mm stainless steel ball in a direction parallel to the longitudinal axis of the tooth. Pressure from the ball was applied at the level of the palatal cusp, 2 mm from the tip of the cusp towards the central fossa, in order to simulate an occlusal load. The load was applied at a cross head speed of 1mm/min. All samples were loaded until fracture and maximum breaking loads were recorded. The data from the fracture resistance evaluation was submitted to Krukal Wallis test.

Numerical modelling and strength analyses were done with CAD CATIA and FEM ANSYS programs.

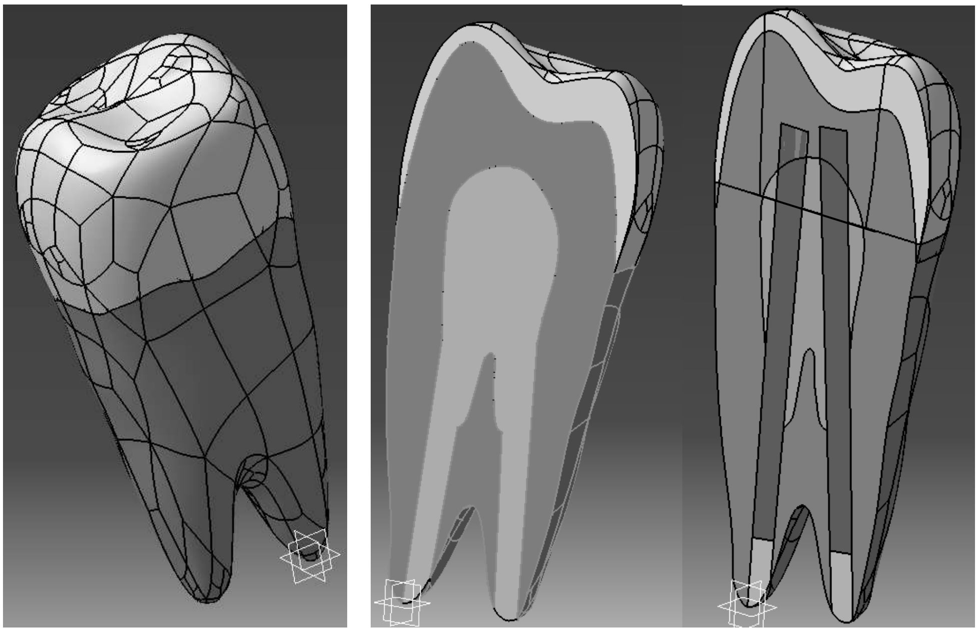

Fig. 2. Numerical models of healthy premolar and reinforced with glass fiber root post

Rys. 2. Modele numeryczne przedtrzonowca wzmacnianego szklano-polimerowym wkładem korzeniowym

3. Results and discussion

Specimens fractured at failure loads of 659 N to 1608 N. Although the Krukal Wallis test did not show significant difference (P≤0,05) between the mean failure loads of groups I and II, the trend was observed for a higher mean failure load in group I. The Kruskal Wallis test showed significant difference between groups I and III (p=0.010) and groups II and III (p=0.037). The highest mean fracture resistance was recorded for group I at 1210 ± 359 N, followed by group II at 1075 ± 265 N and group III at 551 ± 267 N .

The results of numerical strength analyses of strain and stress distributions in dentine, enamel, composite material and glass fiber implant for all considered configurations of reconstruction will be shown during the presentation at the conference.

This study simulated "the worst-case scenario" of extracted premolars representing severely damaged and root filled teeth. The conventional restoration would be a metal post-and-core and crown coverage with sufficient ferrule [5]. A change of paradigm has occurred based on the advantages of adhesive restorations, which seems to make post insertion unnecessary. A recent study by Krejci et al [6] discussed the need for a re-evaluation of post use especially where adhesive techniques are used to construct the core. In this context the purpose of the present study was to obtain data on the behavior of the direct resin composite complete crown with or without posts. In this study the group reinforced with fiber posts achieved slightly better results, however there was no significant difference between two groups. As a consequence, the null hypothesis was confirmed. However the endodontically treated teeth with composite crown reconstruction from group I and group II showed significantly better fracture resistance than sound teeth with no treatment.

Table 1

Mean fracture loads, standard deviation, minimal, median and maximal values for various tested groups. P = 0.006

Group	n	mean fracture load [kN]	SD	min	mean	max
I	7	1.210	0.3591	0.659	1.326	1.608
II	7	1.075	0.2651	0.866	0.993	1.591
III	7	0.551	0.2674	0.158	0.584	0.948

Table 2

The energy of damage, standard deviation, minimal, median and maximal values for various tested groups. P = 0.323

Group	n	energy of damage [J]	SD	min	me	max
I	7	1.500	0.7398	0.676	1.314	2.761
II	7	0.998	0.8485	0.224	0.430	2.070
III	7	0.828	0.7002	0.064	0.780	2.094

3. Conclusions

Despite the limitations of this study, it was demonstrated that severely damaged root canal treated premolars restored with direct resin composite crowns with and without fiber post had similar fracture resistance under static load. Both of the groups restored with composite resin crowns had significantly higher fracture resistance than sound, untreated teeth. The results suggest that both tested methods of root treated teeth reconstruction, if correctly applied in clinical practice, can achieve satisfactory fracture resistance.

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