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IN-VITRO EVALUATION OF THE RETENTION OF DIFFERENT PREFABRICATED POSTS LUTED WITH DIFFERENT CEMENTS

VREDNOTENJE ZDRŽLJIVOSTI IN VITRO RAZLIČNIH MONTAŽNIH STEBRIČKOV, UTRJENIH Z RAZLIČNIMI CEMENTI

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The aim of this study was to assess and compare the mechanical resistance and the retentive force of metal and composite post systems cemented with different types of cements. Three different designs of prefabricated titanium alloy posts were used in the study, i.e., active, passive and combined, as well as AgPd cast posts and two different fibre-reinforced composite post systems. In accordance with the experimental design these posts were cemented with zinc phosphate, self-curing composite resin or self-adhesive, self-etching, luting agent. Comparing the results between the different metal post designs, cemented with zinc phosphate, a statistically significant difference in the retention was found between all the analysed posts. The best results with the pull-out test were obtained with the active posts, then the passive, followed by the combined posts. The metal cast posts cemented conventionally with Zn-phosphate demonstrated the lowest retentive force value, based on all the measurements. The bond strengths between the post and the root dentine were influenced statistically by the post design (active, passive, combined or cast) and material, metal vs. composite. The active Ti posts showed significantly superior retention in combination with all the cements. The Ti alloy posts achieved higher retentive force values than the composite posts, in general. The composite cements compared to the Zn-phosphate ensure a better retentive strength for all the posts, including individually cast posts.

Keywords: retention, prefabricated titanium posts, fibre-reinforced composite posts, cements, pull-out testing

Namen te študije je bil oceniti in primerjati mehansko odpornost in sile zadržanja kovinskih in kompozitnih stebričkov, utrjenih z različnimi vrstami cementov. V študiji so bile uporabljene tri različne konstrukcije stebričkov iz titanove zlitine – aktivna, pasivna in kombinirana, kot tudi uliti stebrički iz AgPd in dva različna sistema stebričkov, utrjenih z vlakni. Skladno z izvedbo preskusov so bili stebrički utrjeni s cink-fosfatom, s samopopravljivo kompozitno smolo ali samovezalnim samojedkalnim zamaznim sredstvom. Primerjava rezultatov med različnimi izvedbami kovinskih stebričkov, utrjenih s cink-fosfatom je pokazala statistično pomembno razliko v zdržljivosti analiziranih stebričkov. Najboljši rezultati pri preizkusu puljenja so bili doseženi pri aktivnih stebričkih, nato pri pasivnih, sledili so jim kombinirani stebrički. Kovinski uliti stebrički, utrjeni z navadnim cink-fosfatom so pokazali najmanjšo silo zdržljivosti, vključujoč vse meritve. Vezalna trdnost med stebričkom in korenom dentina je statistično odvisna od zasnove stebrička (aktivna, pasivna, kombinirana ali ulita) in materiala, kovine proti kompozitu. Aktivni Ti-stebriček je pokazal občutno boljšo zdržljivost v kombinaciji z vsemi cementi. Stebrički iz Ti-zlitine so na splošno dosegali višje sile odpornosti v primerjavi s kompozitnimi stebrički. Kompozitni cementi v primerjavi z Zn-fosfatom zagotavljajo boljšo zdržljivost povezave pri vseh stebričkih, vključno s posamično ulitimi stebrički.

Ključne besede: zdržljivost, montažni titanovi stebrički, z vlakni utrjeni kompozitni stebrički, cementi, preizkušanje s puljenjem

1 INTRODUCTION

The increased popularity of all-ceramic restorations has challenged the ability of dentists to achieve optimal aesthetics when metal posts and cores are used. The intensive development of materials and new technologies provided the introduction of tooth-colour, metal-free posts and core systems that are, progressively, replacing the metal in restorative dentistry. They have certain advantages: better aesthetics, simplified removal, magnetic resonance imaging without distortion, the elimination of galvanic corrosion and grey gingival discoloration are just some of them.[1]

Loss of retention is the most common reason for post failures.[2,3] The retention of posts is influenced by numerous factors related to the their shape and surface configuration, cement characteristics and the interaction between the cement/post and the cement/dentin.[4] Parallel-sided posts have been shown to be more retentive than tapered posts and threaded, so-called "active" posts, have better retention to tooth and core material than the posts with a smooth surface design (Hochman et al., Mezzomo et al. 2003).[5,6] Also, it was proved that the post length affected the retention to tooth structures more strongly than the diameter.[7] Cementing posts with resin luting agents was shown to be an effective procedure in increasing the post's retentive ability.[8] Different cement compositions, mechanical properties, handling characteristics, polymerisation ability (chemical, light or dual)[9], adhesive agent [10], viscosity, cement film thickness and application method, seemed to be important factors for the post's setting and, consequently, the strength of the post's retentive force (D'Arcangelo et al. 2008).[11]

Therefore, the aim of this in-vitro study was to evaluate and compare the mechanical resistance and the retentive force of metal and composite post systems cemented with different types of cements. The goal was to investigate the effect of different post designs (active, passive, combined or cast), materials (metal vs. composite) and cement choice (conventional vs. composite) on post retention, excluding other factors that affect retention, such as the diameter, length, root canal obstruction material and technique, type of adhesive, surface treatment or artificial ageing.

2 EXPERIMENTAL

2.1 Material and specimen preparation

Human teeth, maxillary and mandibular canines recently extracted for parodontal or orthodontic reasons, were used in the investigation. The inclusion criteria were as follows: the absence of severe root curvatures, root decay, defects, cracks, previous endodontic treatment and the root length had to be at least 14 mm, measured from the Cementoenamel Junction (CEJ). They were cleaned of bone and soft tissue, blood and saliva and immersed in 0.9 % NaCl solution, where they were stored at 4 °C for one week, until the mechanical testing was performed. The crown surfaces of each tooth were sectioned 1 mm below the CEJ, perpendicular to their long axis to allow direct access to the root canals. A diamond disc rotary cutting instrument mounted on a high-speed hand-piece with water-spray cooling was used. To eliminate the effect of root-canal obturation material and technic, no endodontic treatment was performed.

For the individually cast AgPd posts the root canals were enlarged mechanically with a set of drills (ISO size 45–80) to a depth of 10 mm. The standard procedure was then used for modelling this type of post, from autopolymerising acrylic resin which, in a conical shape with diameter 1.0–1.20 mm in the coronal third and 0.70–0.90 mm in the apical part, matched with the prepared root canal perfectly. The root-canal preparation for all prefabricated post systems was done according to the manufacturer's instructions with original set instruments to a depth of 10 mm, measured from the sectioned surfaces. Three different types of industrial prefabricated posts made of titanium alloy were used: parallel-sided posts with 17 mm length and 1.0–1.20 mm in diameter, active with threads and passive with grooves and cuts. Posts with combined benefits of cylindrical and conical posts, active and passive surfaces, designed cylindrical with self-tapping threads at the top (1.30 mm diameter) and tapered apex with a smooth surface (0.90 mm diameter). The composite posts were reinforced with glass fibres, had a conical shape, 20 mm length and were 1.20 mm in coronal and 0.90 mm in apical diameter.

The selected teeth, 180 canines, were distributed randomly into three groups (A, B, C), each with four subgroups (1, 2, 3, 4), consisting of 15 teeth. According to the study design in the Group A, Ti alloy posts were cemented with zinc phosphate (Harvard®, Germany): A1 passive posts: HeadMaster tapered head, passive (NTI, Kahla Gmbh, Germany), A2 active posts: HeadMaster tapered head, active (NTI, Kahla Gmbh, Germany), A3 combined posts: Cytco-K (Dentsplay Maillefer, Swiss) and A4 AgPd cast posts. In Group B, these 4 groups of metal posts were cemented with a self-curing luting composite (MULTILINK, Ivoclar Vivadent AG, Liechtenstein). Group C consisted of composite posts: C1 composite posts reinforced with glass fibres (RelyX™ Fiber post, 3M ESPE, USA) were cemented with zinc phosphate cement (Harvard®, Germany); C2 composite posts reinforced with glass fibres (RelyX™ Fiber post, 3M ESPE, USA) were cemented with self-adhesive self-etching universal resin cement (RelyX™ Unicem, 3M ESPE, USA); C3 composite posts reinforced with glass fibres (RelyX™ Fiber post, 3M ESPE, USA) were cemented with self-curing luting composite (MULTILINK, Ivoclar Vivadent AG, Liechtenstein) and C4 glass fibre-reinforced composite posts (FRC Postec Plus,

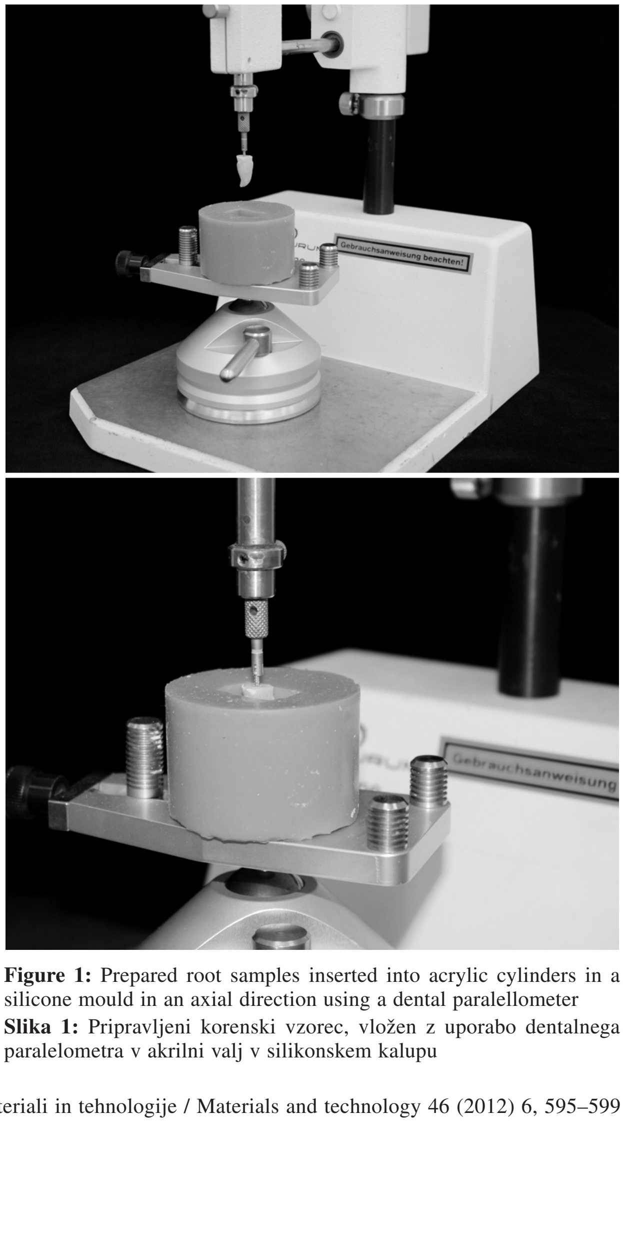

Figure 1: Prepared root samples inserted into acrylic cylinders in a silicone mould in an axial direction using a dental paralellometer
Slika 1: Pripravljeni korenski vzorec, vložen z uporabo dentalnega paralelometra v akrilni valj v silikonskem kalupu

Ivoclar Vivadent AG, Liechtenstein) cemented with MULTILINK, from the same manufacturer.

There was no pre-treatment of posts and they were cemented following the manufacturer's recommendations with no core build-up procedure. Autopolymerising acrylic material, after mixing, was poured into silicone moulds and then the teeth were embedded in these specially made acrylic cylinders. Root specimens with different posts were inserted with a dental parallelometer to secure the axial direction and stable position until the acrylic resin was not definitely polymerised (**Figure 1**).

2.2 Pull-out testing

Each sample was subjected to a pull-out test using an Instron 1122 universal material testing machine at a crosshead speed of 1.0 mm/min until the failure of the specimen was evident. The Instron machine used for testing consisted of two segments. The upper mobile part for pulling the end of the post was gripped directly by the vice of the testing device. The lower part was used for fixing the acrylic block in a holder, so that the longitudinal axis was vertical and the direction of the tensile loading was transmitted parallel to the long axis of the post fixture. With this machine a controlled force in the range 0–1 kN was applied for separating the posts from the teeth structures. The load required for loosening the post as a result of the fracture in the cement seal was measured and recorded in newtons (N). Using this method all the prepared acrylic blocks with AgPd cast posts, titanium and composite posts were exposed to continual tensile loading until the posts were dislodged from the root slide. The maximum failure-load values were registered by means of a force-displacement curve on graph paper.

2.3 Statistical analysis

The recorded data for each specimen were analysed statistically with a 2-way analysis of the ANOVA variance (factor-post-type/cement-type).The tensile bond strength values between the groups were compared using the Bonfferoni-, t- and Mann Whitney U-test.

Descriptive data for all groups and variables were expressed as mean ±SD, min, max and 95 % confidence interval. A normal distribution was tested using the Koglomorov-Smirnov test. If the data were normally distributed, one-way ANOVA (Bonfferoni as a post-hoc analysis) was used for the analysis of differences between three and more groups and the t-test between two groups. Non-parametric data were analyzed using the Mann Whitney U-test.

All the reported p values were two-sided; the differences were considered significant when the p value was <0.05.

3 RESULTS

The results of the measured retentive force for different metal posts cemented with Zn phosphate and composite cements after the ANOVA analysis are presented in **Table 1**. Comparing the results between different metal post designs, cemented with zinc phosphate (A-group), the Bonfferoni test showed that there was a statistically significant difference in retention between all the analysed posts (**Figure 2**). The highest values were achieved by the active posts, then the passive, followed by the combined posts. The AgPd cast posts demonstrated the lowest retention, (**Figure 2**). When the composite cement was used for the B experimental group, statistically significant higher retentive force values were found with active posts and

Table 1: Retentive force values (descriptive statistics) for different metal posts
Tabela 1: Sile zdržljivosti (opisna statistika) za različne kovinske stebričke

post type	cement type	$\bar{X}$ ± (SD)	Min	Max	$CI_{95\ \%}$
passive posts	Zn phosphate	504 ± 48.37	440	600	477.21–530.79
	composite	565 ± 119.28	260	730	499.28–631.39
active posts	Zn phosphate	602 ± 79.84	450	780	557.79–646.21
	composite	670 ± 45.86	590	760	644.60–695.40
combined posts	Zn phosphate	428 ± 68.81	360	580	389.89–466.11
	composite	484 ± 49.33	400	600	457.35–511.99
AgPd cast posts	Zn phosphate	178 ± 29.32	120	220	162.10–194.57
	composite	366 ± 87.35	240	560	317.96–414.71

Table 2: Retentive force values (descriptive statistics) for composite posts
Tabela 2: Sile zdržljivosti (opisna statistika) pri kompozitnih stebričkih

C-group	$\bar{X}$	Med	SD	min	max	$CI_{95\ \%}$
C-1	166	170.00	39.71	100	240	144.34–188.32
C-2	211	200.00	34.30	170	300	192.34–230.33
C-3	202	200.00	29.92	155	260	185.49–218.64
C-4	267	270.00	35.50	190	310	248.01–287.33

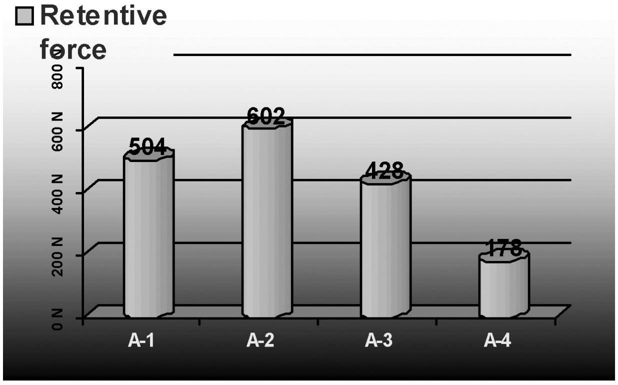

Figure 2: Mean values of retentive force for metal post systems cemented with zinc phosphate (A-group)
Slika 2: Glavne vrednosti sil zdržljivosti za sisteme kovinskih stebričkov, pritrjenih s cink-fosfatom (skupina A)

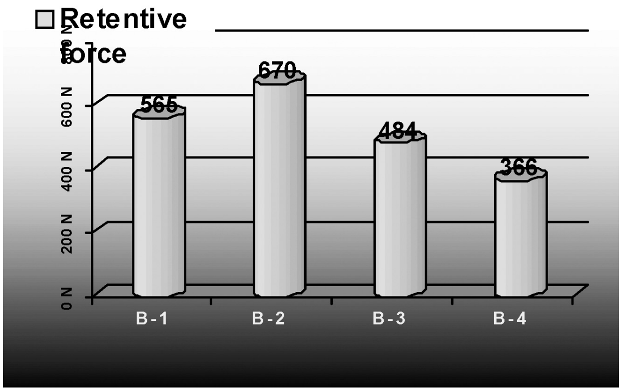

Figure 3: Mean values of retentive force for metal post systems cemented with composite cement (B-group)
Slika 3: Glavne vrednosti sil zdržljivosti za sisteme kovinskih stebričkov, pritrjenih s kompozitnim cementom (skupina B)

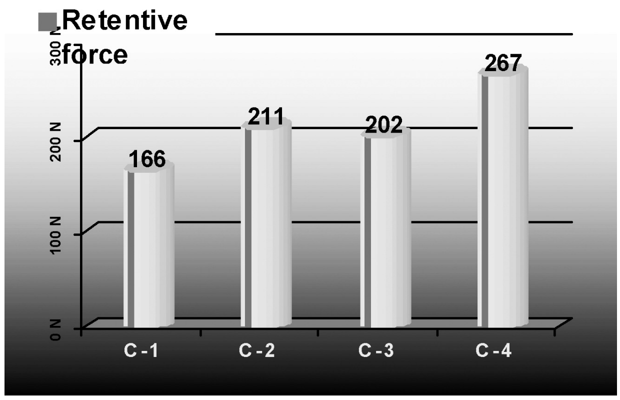

Figure 4: Mean values of retentive force for composite post system cemented with different cements (C-group)
Slika 4: Glavne vrednosti sil zdržljivosti za sisteme kompozitnih stebričkov, pritrjenih z različnimi cementi (skupina C)

the lowest for the cast posts. No statistically significant difference was found between the retention strength of the passive and combined posts luted with composite cements (Bonfferoni test; p = 0.052), **(Figure 3)**. Comparing the results between the same posts cemented with different cements, the t-test presented a statistically significant difference for all the posts, except the passive (t-test; p = 0.076) and the values of the retentive force were always higher for the composite cementing. For the cast metal posts the retentive force was two times lower when the standard cement was applied. According to the results of the intergroup comparison (Mann Whitney U test; p = 0.595) a statistically significant difference was not found only between the C-2 and the C-3 group. As presented in **Table 2** and **Figure 4**, among the composite posts the highest retention was achieved in the C-4, when the FRC posts were cemented with self-curing luting composite, but it was significantly lower statistically than the metal posts.

4 DISCUSSION

Several studies[12–14], including this one, have shown that composite cements ensure significantly better retentive strength for all post types, including individually cast, posts compared to Zn phosphate. Unlike the zinc phosphate cement, adhesive resin cement systems have the ability to adhere to the dentin walls and the post with a reinforcing effect.[15,16] Similar values of retentive force were found in the study by Sen D., Poyrazoglu E. and Tuncelli B. (2004)[17], where prefabricated passive and combined post types were cemented with different adhesive cements and Zn-phosphate. No significant difference was found between the composite posts cemented with a self-adhesive self-etching resin cement and self-curing luting composite. These findings are in accordance with the previous results[18,19] and may be explained by the differences in the correspondence of the surface-energy characteristics of the posts and the cements.[20] The AgPd cast posts cemented with Zn-phosphate cement as a standard procedure, which was used in clinical practice for many years, demonstrated the poor retention. The results from our study, as well as the Menani group study (2008)[21], showed that if metal cast dowel systems are used, the increased retention could be achieved by cementing them with composite cements.[22]

The active Ti alloy posts showed a significantly superior retention in combination with all the cements, but the clinical relevance is questionable, because excessive retention increases the risk of tooth fracture during the cementation process or later under functional loading. Prefabricated composite post systems had retention values significantly lower than all the design types of Ti posts and cast metal posts cemented with composite luting agent, as in the study Gallo et al. (2002)[23] and Balbosh et al. (2005)[24]. Although Ti-posts demonstrated better retention[25], the values of retention force of the composite posts are considered to be sufficient for the successful restoration of endodontically treated teeth[26]. These advantages are superior esthetics, maximum preservation of the teeth substance, inducing a uniform stress distribution and minimal tension during cementation and functional loading, good retention for core materials; the elasticity module for the composite posts is similar to the dentin elasticity.[27,28]

The results seen in clinical use may differ from the results in this in-vitro study because other factors influence the success rate of restoring the endodontically treated teeth, such as root-canal sealers and irrigation agents. Furthermore, the results of this study might be different if the specimens were subjected to thermocycling or dynamic loading during the experiment, prior to the mechanical separation testing.[29,30] However, what could be the optimal preparation for glass-fibre-reinforced composite posts and a dentin treatment procedure before cementing for enhancing retention needs further investigations.

5 CONCLUSIONS

Based on these findings of pull-out mechanical testing, and within the limitations of this study, the following conclusions can be drawn:

- The highest retention force values were obtained with active posts, then passive, followed by combined posts.
- Prefabricated fibre-reinforced composite post systems had retention values significantly lower than all the design types of titanium posts and cast metal posts cemented with a composite luting agent.
- Composite cements compared to Zn-phosphate ensure significantly better retentive strength for all posts, including individually cast posts.
- The choice of cement, post material and design are important factors influencing the retentive strength of the post systems.

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