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A comparative study of shear bond strength of zirconia and nickel-chromium (NI-CR) alloy for cast post and core made by CAD/CAM software

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Abstract

The present study was performed to compare the shear bond strength of zirconia and nickel-chromium (Ni-Cr) alloy for cast post and core made by CAD/CAM software. In this study, 40 post and core samples, including 20 zirconia posts and cores and 20 Ni-Cr cast posts and cores, were prepared in the laboratory. All posts and cores were cemented using SuperCem resin cement. In order to assess the resistance to cutting of the specimens, a Zoic Ruel - z020 universal testing device was employed. Subsequently, the applied force gradually increased until the post and core were separated from the tooth. The utilized device is a digital testing apparatus that quantifies the magnitude of force necessary for separation and presents the results graphically. Once the data was gathered and encoded, statistical analysis was performed using SPSS 7.1 software, employing both descriptive and inferential statistics to calculate and compare the mean forces. In the group utilizing Ni-Cr for cast post and core, the mean shear bond strength was recorded at 211.60 newtons, while the average shear bond strength in the zirconia group for cast post and core was measured at 187.43 newtons. An independent t-test was employed to compare the average cutting force values between two groups, one utilizing zirconia casting and the other using Ni-Cr casting. The calculated t-value was 1.505, and the corresponding significance level was 0.141. In conclusion**,** given that the p-value exceeded 0.05, there was no statistically significant disparity observed in the amount of cutting force between the two studied groups of zirconia and Ni–Cr alloys. Considering the aforementioned findings, it is advisable to utilize zirconia posts and cores in the case of anterior teeth due to their beauty.

Keywords: CAD/CAM technology, Cast Post and Core, Dental Materials, Shear strength, Zirconia Post and Core.

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1. Introduction

In situations where the tooth's crown structure is compromised due to multiple factors, causing it more prone to failure, the preferred treatment approach entails implementing post and core therapy followed by the application of a veneer as a protective covering [1-3]. The teeth that have received endodontic treatment commonly necessitate the utilization of a dowel or post to enhance their strength and the application of a crown to provide safeguarding, contingent upon the extent of crown damage and the specific tooth involved. However, recent retrospective clinical investigations have prompted a reassessment of this notion. Based on a study involving 220 endodontically treated teeth, Ross determined that 61% of teeth that had been in functional use for a period of five years or more did not undergo restorative procedures involving a dowel. Sorensen and Martinoff documented a comparable rate of success for anterior teeth that were restored, regardless of whether a dowel was utilized or not [2]. Post and core systems have been employed in the field of dentistry for over two and a half centuries. The process of selecting an appropriate post and core system is challenging and complicated. Conversely, ensuring the proper transmission of forces along the root decreases the risk of root fracture, and various characteristics of the post, including its diameter, length, and fracture strength, can significantly influence this aspect [4, 5]. Alongside the longstanding utilization of cast posts, the market also offers two categories of prefabricated posts: metallic posts such as titanium and Ni-Cr alloy (stainless steel), and non-metallic posts including fiberglass and zirconia. Non-metallic posts are recognized for their aesthetic appeal and ability to establish a bond with resin cement within the canal and the core buildup. When it comes to bonding non-metallic posts, there exist at least two primary interfaces: the first is between the post and the luting agent (cement), while the second is between the cement and the dentin [6]. Evidently, when different materials with distinct mechanical properties are interconnected under force application, it engenders tension between the two materials. The intensity of this tension increases in proportion to the disparity in mechanical properties between the materials. In bonded non-metallic posts, the region with the greatest stress is observed in the gap between the post and the luting cement, thus increasing the probability of failure within this gap [7].

Metals have been exclusively employed as the construction materials for substations for an extended duration of time. Cast metal posts and cores have gained popularity due to their notable success rates, promising long-term prognosis, straightforward application, and cost-effectiveness [8]. Given that these systems involve the preparation of the post and core in a unified and specialized manner, there is a relatively precise restoration of the canal space morphology. These systems are predominantly utilized in cases where there is limited residual crown structure, single-rooted teeth with reduced crown dimensions, misaligned teeth, and the need to rectify the angulation and align it parallel to the adjacent tooth [1,2,4]. The utilization of cast posts characterized by a high elastic coefficient presents a drawback in the form of direct force transmission from the post to the tooth contact surface, potentially leading to tooth fracture [9, 10]. In most cases, such fractures are irreparable [11]. Alternatively, employing a post with an elastic coefficient comparable to that of ivory is suggested to yield a biomechanical performance that is more uniform and advantageous [12]. Conversely, the primary challenge associated with restoring post-treated anterior teeth lies in the presence of a noticeable shadow beneath all-ceramic restorations, which arises from the dark hue exhibited by all-metal and carbon fiber posts [13]. To address this issue, several solutions have been proposed, including the utilization of carbon fiber posts coated with zirconia, zirconia posts, prefabricated posts reinforced with fibers, and ultimately, resin materials fortified with fibers [14]. Among the tooth-colored post options, fiberglass posts stand out, and their usage has demonstrated a reduced incidence of root fracture, likely attributed to their comparable elastic coefficient with tooth dentin [15]. In a study conducted by Gu et al. [16], it was demonstrated that the combination of fiber and titanium posts, particularly when utilized in conjunction with resin cement, yields improved outcomes. Torres-Sánchez et al. [17] discussed the utilization of glass fiber posts in conjunction with resin-reinforced glass ionomer cement as a means to enhance the fracture strength of root-treated teeth. Studies comparing the fracture strength of fiber posts and cast posts have yielded inconsistent findings, leading to varying viewpoints regarding the utilization of these systems [18].

In recent years, notable progress has been achieved in computer technology within the field of modern dentistry. CAD/CAM technology is a computer-generated and designed system. The advanced system comprises a computer device, a scanner, and a lathe, wherein ceramic blocks are automatically cut following the process of scanning and designing.

For numerous decades, this procedure has been employed across diverse industries and has gained significant popularity within restorative dentistry as a method for fabricating molds, casts, and implants, as well as temporary and permanent restorations. Long-term follow-up studies spanning a duration of 10 years have presented favorable outcomes for a specific system, with the results showing improvement as technology continues to advance. The system has the ability to simultaneously restore multiple teeth within a single session. This procedure involves the utilization of diverse blocks, available in a range of sizes and colors, to achieve the desired outcome [19, 20]. The utilization of CAD/CAM technology in dentistry streamlines the restoration process by minimizing the involvement of intermediaries and mitigating the influence of numerous factors that could impact the quality of the final work. As a result, achieving predictable restoration outcomes becomes more straightforward [21]. The findings of a study examining the fracture strength of zirconia post and core systems, Ni-Cr and NPG metal castings, and glass fiber with composite cores revealed that custom-made zirconia posts and cores prepared using the MAD-MAN method exhibited lower fracture strength compared to the other groups. NPG casting posts and cores, along with glass fiber posts combined with composite cores, exhibited the highest fracture strength among the tested groups. Anyway, there were no statistically significant differences observed between these values and those obtained from nickel-chrome casting cores [22]. According to a study conducted by Jalalian et al. [23], caution should be exercised when utilizing FRC posts with zirconia coating as they have been associated with undesirable tooth fractures. Therefore, the use of glass fiber posts is deemed preferable [23].

Given the introduction of CAD/CAM technology to the Iranian market and the absence of similar investigations in this domain, the examination of existing studies on the tensile strength of posts and zirconia cores produced using the CAD/CAM system revealed that limited research has been conducted in this area due to the novelty of this technology within dental laboratory systems. The utilization of computer-based systems (CAD/CAM) for dental prosthetic treatments incurs various costs for the patient, dentist, and laboratories. In the event of treatment failure, these costs can escalate unexpectedly, necessitating the need for treatment repetition. Given the significance of the research topic, this study was designed and executed using the CAD/CAM system to investigate the shear bond strength of zirconia posts and cores as well as cast Ni-Cr posts and cores.

2. Materials and Methods

The present study is laboratory-based research that was conducted at the Department of Dental Materials and Biomaterials Research Center, Shiraz Dental School, Shiraz between July 2019 and October 2020. The statistical population for this study comprised zirconia posts and cores produced using the CAD/CAM device from the pritidenta® brand, as well as manually fabricated Ni-Cr casting posts and cores. The zirconia samples utilized in this study were sourced from pritidenta®, a German brand, while the cast Ni-Cr cores were obtained from Wiron® 99, a German brand manufactured by BEGO. The sample size consisted of 20 zirconia posts and cores, along with 20 Ni-Cr casting posts and cores. The inclusion criteria for the posts and cores selected for this study required them to possess optimal tooth compatibility and be accurately positioned on the tooth during the testing process. Samples were excluded from the test due to discrepancies observed between the posts and cores in relation to the teeth. Stratified sampling was employed as the sampling method. Data collection was conducted through a field-based approach, where the posts and cores were subjected to testing, and the associated data was recorded.

2.1. Methods

Initially, a total of 40 extracted canine teeth were chosen, and each sample underwent standard root canal treatment. Following the determination of the working length (0.5 mm shorter than the radiographic apex), the canal was thoroughly cleaned and shaped using the conventional Step back method. A 5.25% solution of sodium hypochlorite was utilized for washing purposes, while the canals were filled with gutta-percha (Meta Biomed, South Korea) and sealed with ZOE sealer (Golchai brand) through the lateral condensation technique. Subsequently, the crowns of all samples were cut using a high-speed turbine (NSK, Nakanishi, Japan) in the presence of abundant water. This procedure ensured that a minimum of 2 mm of intact crown tissue remained, allowing for the formation of a ferrule upon completion of the cutting line. Subsequently, a deep chamfer cut was made on all tooth surfaces, positioned 0.5 mm above the cementoenamel junction (CEJ), with a width measuring 1 mm. After that, the tooth canal was molded using an acrylic resin template (GC Corporation, Tokyo, Japan) through the direct method for Ni-Cr casting posts and cores. In addition, an additional set of 20 models was generated using the CAD/CAM method for zirconia-integrated posts and cores. A three-dimensional (3D) image was generated using the CORiTEC 250i scanner CAD/CAM system, followed by the fabrication of posts and cores. Specifically, the CAD/CAM system was employed to produce zirconia posts and cores. The length of the cores in all samples was standardized to be 8 mm. Subsequently, the teeth were immobilized within green acrylic resin, having a height of 2 cm and a diameter of 1.8 cm, and then positioned within a metal ring (Figures 1 and 2). The tooth was positioned within the acrylic resin along its longitudinal axis, ensuring that the finishing line of the tooth was maintained at a minimum distance of 2±1 mm from the surrounding acrylic material. The samples were assigned random numerical identifiers and assessed for their optimal compatibility with the tooth. The alignment of the top section of the post and core with the tooth was established to ensure a seamless fit, with no visible gaps between the post, core, and tooth. Additionally, the post demonstrated adequate stability and resistance when lifted from the tooth, and there was no rotational movement observed when force was applied to the post and core using a finger. Prior to testing, the samples were affixed to the teeth using a Dual Cure resin cement. Following the placement of cement inside the canal and repositioning of the post and core onto the tooth, the tooth was subjected to light exposure from a light-curing device for a duration of 40 seconds, targeting both the buccal and lingual aspects of the tooth. This process occurred after a 20-second interval. Subsequently, the samples were subjected to cutting force using a universal testing device (Zwick-Roel) equipped with a stainless-steel clamp. The separation of the post and core from the tooth was achieved by applying the force at a controlled speed of 0.5 mm/min. The testing machine initiated the application of cutting force at a velocity of 0.5 mm per minute while providing real-time feedback on the screen, displaying the manner and magnitude of the force exerted on the posts and cores. The point at which the post and core became detached from the tooth was identified as the initial location of separation between the two. Furthermore, the universal testing machine stopped its operation when a decrease in pressure was detected during the force application, capturing the final applied force on the screen.

2.2. Data analysis

To compare the mean values between the two types of posts and cores, Kolmogorov–Smirnov test was employed. The results were subject to descriptive analysis, which involved the utilization of linear graphs, mean values, and standard deviation. The data analysis for this research was conducted using the SPSS Statistics 17.0 software.

3. Results and discussion

To assess the current research's data distribution status, the Kolmogorov–Smirnov test was employed. Based on the test outcomes, it was observed that the data distribution was normal. This study involved the examination of 40 samples divided into two groups of 20, in order to compare the shear bond strength of zirconia and casting posts and cores. The first group consisted of zirconia posts and cores, while the second group comprised cast posts and cores. Then, the shear bond strength of each group was assessed, followed by conducting a comparative analysis between the groups. The results obtained from the analysis revealed that the mean shear bond strength of the post and cores of the zirconia group was determined to be 187.43 (Table 1). In contrast, the findings indicated that the mean shear bond strength of the post and cores of the cast group was 211.60. Subsequently, an independent t-test was employed to compare the shear bond strength between the cast and zirconia posts and cores. The achieved data are presented in Table 2. The findings indicated that there is no statistically significant difference between the average shear bond strength of the post and core in the zirconia group and the shear bond strength of the post and core in the cast group ($t = 1.505$; $p = 0.141$).

This study was conducted to compare the shear bond strength between the post and core of zirconia, Ni-Cr casting, specifically focusing on anterior teeth. According to the findings of this investigation, the shear bond strength of the posts and cores of zirconia exhibited no statistically significant difference when compared to the shear bond strength of the posts and cores of Ni-Cr cast. Considering these findings, it is advisable to utilize zirconia posts and cores for anterior teeth due to their aesthetic appeal. The significance placed on esthetics in the anterior region has experienced a substantial rise, resulting in an increased demand for the application of zirconia posts and cores. Anyway, the utilization of zirconia posts and cores has been restricted due to their comparatively lower fracture resistance in comparison to the posts and cores of Ni-Cr cast [22]. In explaining the reduced fracture strength of custom-milled zirconia posts, it is crucial to consider the mechanical properties of zirconia. Zirconia posts have been reported to exhibit a higher yield strength compared to fiber and titanium posts, with values of 58±4 newtons in contrast to 27±1 newtons and 54±3 newtons, respectively [24, 25]. Additionally, the bending strength of zirconia posts has been found to be similar to that of gold and titanium, with reported values of approximately 1200 MPa and 900 MPa, respectively [26]. Conversely, the notable elastic modulus of these posts, measured at 200 MPa, contributes to their exceptional strength and rigidity, preventing any plastic deformation [27]. Based on the research findings, it appears that the load failure value of zirconia posts and cores exceeds the force exerted by human biting, thereby ensuring the clinical reliability of such frameworks [28]. Research findings have indicated that the Hard machining method offers enhanced marginal fit, attributed to the absence of shrinkage during the sintering process [29]. Nonetheless, their high hardness presents challenges in terms of milling, resulting in increased difficulty and time required for the milling process. Restorations fabricated using the hard machining method from fully sintered blocks exhibit a notable presence of monoclinic zirconia [30], which commonly leads to surface microcracks [31], thereby diminishing the mechanical characteristics of zirconia [32]. In contrast, the soft machining method involves the utilization of semi-sintered blocks that are subsequently subjected to high-temperature sintering, resulting in a shrinkage of approximately 20-25%. To achieve an appropriate marginal fit, compensatory measures are required, such as designing the framework to be slightly larger in size [33]. Furthermore, as the sintering process occurs subsequent to milling, the end product exhibits improved organization, strength, and elevated mechanical properties [34]. Moreover, this procedure serves to inhibit the conversion of the T phase to M, thereby preventing the presence of the monoclinic phase on the surface of the restoration, unless the surface undergoes shaving or sandblasting. Consequently, it is advised by the majority of manufacturers that TZP-3Y blocks intended for dental applications should not undergo shaving or sandblasting [30]. In a study conducted by Sevil Sahmali et al (2004), the tensile strength of metal posts and tooth-colored posts were compared using various types of cement. The researchers concluded that the tensile strength of Ni-Cr cast posts and cores when coupled with Panavia F, ProTec Cem, and Vitremer cements, exceeded that of zirconia posts [35]. The type of cement used is a contributing factor to the tensile strength of zirconia posts and cast Ni-Cr posts. In a study conducted by Sevil Sahmali et al. in 2004, it was found that Panavia F cement exhibited the highest level of post bond on tooth [35]. In a study conducted by Kurthukoti et al. [27], the fracture strength of central maxillary teeth was investigated using three different post systems: zirconia, fiber, and biological dentin. The researchers found that biological dentin posts exhibited the highest fracture strength, while fiber posts demonstrated the highest occurrence of repairable fractures. Zirconia posts exhibited the least fracture strength and were frequently associated with irreparable failures. In a study conducted by Gu et al. [16], it was observed that fiber posts exhibited superior fracture strength in anterior teeth, particularly when utilized in conjunction with resin cement, surpassing the fracture strength of cast Ni-Cr posts. Beck et al. [24] reported no discernible difference in fracture strength between fiber posts and custom-milled zirconia in their study. However, their study employed simulated root canals constructed from transparent plastic instead of natural teeth, and the samples were exposed to cyclic loading with a force of 50 Newtons.

Sara Habibzadeh et al. [22] reported in their study that fractures occurring in the posts and cores of zirconia group were non-repairable, manifesting as apical root fractures. On the other hand, fractures observed in fiber posts were frequently repairable in the cementoenamel junction (CEJ) region, resulting in the separation of the veneer from the tooth. The majority of failures occurred in the casting of posts and cores, specifically in the porcelain veneer, and were predominantly observed in the cervical region of the root as vertical cracks. This article emphasizes the significance of acknowledging that the distribution of stresses within the tooth root is greatly influenced by the properties of the base material. The fiber post exhibits an elastic coefficient ranging from 30-40 GPa, which is in closer proximity to the elastic coefficient of ivory (15-40 GPa), compared to cast and zirconia posts. The utilization of such a post in the restoration of root-treated teeth enables the facilitation of natural bending movements of the tooth. This significant factor has resulted in a reduction of stress accumulation at the interfaces, leading to a biomechanical behavior of the restoration set that closely resembles that of a healthy tooth. However, these posts offer the advantage of being removable and repairable without the associated risk of root perforation [36]. During the cutting test conducted in our study, it was observed that 40% of zirconia cores separated from their post in the cervical region of the tooth. In a study conducted by Gu et al. [16], it was found that tooth fractures repaired using fiber posts exhibited a higher probability of being repairable in comparison to repairs involving titanium posts and Ni-Cr casting. Freedman [37] noted that teeth that underwent restoration with post and core of Ni-Cr cast are susceptible to an increased risk of vertical root fractures, primarily attributed to heightened stress concentration in the apical region. In a study conducted by Zeynep Ozkurt et al (2010), the tensile strength of zirconia post and core bonds was measured within the range of 123 to 436 newtons [38]. In our study, the mean shear bond strength for zirconia posts was 187.43. In a 2012 study conducted by Thermal Yousif Marghalani et al., an assessment was made to compare the stress distribution in endodontically treated canine teeth that were restored using posts and cores of zirconia or gold alloy. The Von Mises stress rate was found to be 8.966 MPa for zirconia posts and cores, and 8.752 MPa for gold alloy. Additionally, the maximum tensile strength was measured as 9.623 MPa for zirconia post and core and 8.166 MPa for gold alloy. Overall, there were no statistically significant distinctions observed in the maximum stress levels in most areas [39]. In another study, it has been observed that dental restorations experience forces ranging from 60 to 250 newtons during normal functioning and even reach 500 to 800 newtons within brief time intervals. Nevertheless, the magnitude of these forces varies depending on the location, with ranges of 400 to 890 N in molars, 222 to 445 N in premolars, and 133 to 334 N in canines [40].

Figure 1. Post and core sample of zirconia

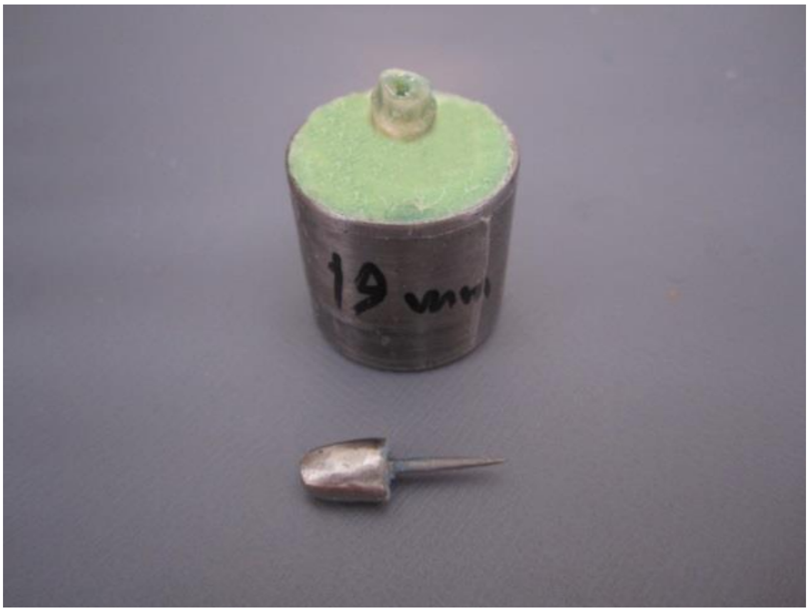

Figure 2. Cast metal post/cores obtained from Ni-Cr alloy

Table 1. The mean and standard deviation of the shear bond strength of post and core in zirconia and casting groups

Groups	Number of participants	Average	Standard deviation	Minimum	Maximum
Shear bond strength of post and cores in zirconia group	20	187.43	33.92	143.6	260.0
Shear bond strength of the post and cores in cast group	20	211.60	63.33	121.0	324.4

Table 2. Comparison of shear bond strength of post and core in zirconia and casting groups

Groups	Average	Standard deviation	The degrees of freedom (DF)	T-value	P-value
Shear bond strength of post and cores in zirconia group	187.43	33.92	38	1.505	0.141
Shear bond strength of the post and cores in cast group	211.60	63.33			

The zirconia group demonstrates a capacity to withstand the load, suggesting that the selection of an appropriate post and core type for a patient can be determined based on factors such as the patient's condition and the presence or absence of oral para-functional habits. The posts and cores investigated in the present study may not exhibit a significant difference in their bond strength at the beginning of their function; however, it cannot be concluded that their resistance to tension will remain unchanged after several years of oral function.

4. Conclusions

There is no significant difference in shear bond strength between zirconia posts and cores fabricated by the CAD/CAM machine and manually cast Ni-Cr posts and cores. However, considering aesthetic considerations, the utilization of zirconia posts and cores is recommended in the anterior regions. It is advisable to avoid using zirconia posts and cores in cases involving oral para-functional habits.

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