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REVIEW

Customized Post and Cores Fabricated with CAD/CAM Technology: A Literature Review

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Abstract: Post and core restorations are a widely accepted method to restore endodontically treated teeth with compromised tooth structure. The use of computerized technology to fabricate customized post and cores is a simple and quick alternative to conventional methods. A literature search was conducted, and a summary of articles describing fabrication techniques and materials used to fabricate post and cores with computer-aided design and computer-aided manufacturing (CAD/CAM) has been provided. Several techniques have been reported to restore endodontically treated teeth with CAD/CAM post and cores, including direct and indirect methods. Zirconia, composite resin, and hybrid ceramic were the most commonly reported materials. Published reports on CAD/CAM post and core are limited; however, further studies are needed to investigate the long-term outcome of this treatment.

Keywords: post and core, CAD/CAM, endodontically treated teeth

Introduction

Customized cast post and core is commonly indicated to restore extensively damaged teeth due to caries or bruxism.[1] Since the custom-made design provides a good fit for the prepared post space, it is indicated for elliptical or flared canals where the prefabricated posts fail to adequately adapt to the canal.[2] The better adaptability of custom-cast post and core aids in resistance against torsional stress.[3] These customized post and cores serve as corono-radicular stabilizers for single-rooted and premolar teeth, which become weak due to the cumulative effect of loss of tooth structure during tooth and access preparation.[3] Likewise, in multi-rooted teeth with extensive loss of tooth structure, these customized posts resist rotational forces.[4]

Ideally, a post and core should aid in crown retention.[5] It should be biocompatible, harmless, and have high tensile strength and high fatigue resistance to an occlusal and shear load.[1] A post should evenly distribute forces to the surrounding root surface and should extend apically to be at least crown height or two-thirds the length of the root.[6,7] This helps distribute the stress equally and offers resistance to occlusal load.[7] Additionally, the color of the post and core should be close to the color of natural dentin, especially during the restoration of anterior teeth.[8] This review presents a brief background on customized post and cores, and the available evidence on the more current CAD/CAM fabricated post and cores.

Materials and Methods

A comprehensive electronic search was conducted in the PubMed database. All peer-reviewed and full-length studies in the English language were included. The search was performed using the following keywords: “CAD-CAM” or “CAD/CAM,” and “post and core,” “post-and-core,” or “post-core.” Articles included were indexed in Google Scholar, PubMed Central, Scopus and/or Web of Science database.

A total of twenty-two manuscripts were selected for analysis, of which fourteen were in-vitro studies, four were technical articles, and four were clinical reports.

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Conventional Customized Post and Core

There is clinical evidence of the placement of posts in the roots of damaged teeth for more than 250 years. These restorations were first introduced in early 1728 by Pierre Fauchard, also known as the father of modern dentistry.[9] In 1745, Claude Mounton, a French dentist, published the design of the gold crown with a gold post that was fixed into the root.[9] In the 1800s, metal posts were replaced with wooden posts. However, wooden posts absorbed fluids, leading to the expansion of the wood and subsequent root fracture.[10] Later, an American dentist, C.M. Richmond, introduced a porcelain-facing, single-piece, post-retained crown that served as a bridge retainer and was known as the "Richmond crown".[11] In the 1930s, custom-cast posts and cores were developed that involved the casting of the post and core as separate components.[4] This technique resulted in a better marginal adaptation of the final restoration.[11]

Customized post and cores can be fabricated using one of the two techniques: a direct technique with a resin pattern, or an indirect technique with the help of elastomeric impressions of the prepared canal.[12] The advantage of using customized post and cores is that they fit the root canal space of most teeth, including those with oval canals, and are easy to remove during retreatment.[13] Furthermore, both post and core serve as a single unit and reduce the risk of core separation.[14] Even when treating proclined teeth, the angulation of the core in cast post and cores can be modified to match the shape of the crown of the proclined teeth.[13,15] A study by Balkenhol et al reported a good long-term prognosis of teeth restored with custom-cast post and cores along with a survival rate of 7.3 years.[16] Similar studies by Dietschi et al and Maccari et al reported high fracture resistance of teeth restored with custom cast post and cores.[17,18] However, a disadvantage with cast metal posts is that they require more chairside and laboratory time, making the procedure relatively more expensive.[19]

Materials for Fabricating Conventional Post and Cores

Materials used for manufacturing posts and cores are categorized as metallic or non-metallic.[20] Custom cast post and cores are made from gold alloys, such as type III and type IV, silver-palladium, or base metal alloys.[21–23] Given the high success rate, favorable mechanical properties, and ease of fabrication, the cast gold post and cores are considered superior to other materials, while base metal alloys are considered to be a lower-cost option.[23] Base metals are stiffer than dentin; however, and thus create high levels of stress within the tooth.[24] In addition, the degradation of base metal alloys releases substances that could be harmful to patients.[25] A retrospective study reported that a success rate of 89% to 98.5% was achieved with cast post and cores for single crown restorations after at least seven years of placement.[16,26] These cast posts and cores can be considered for the preparation of multiple abutments and in individuals with severe tooth wear.[15] However, due to the high modulus of elasticity compared to dentin, these custom-made posts and cores increase the risk of root fracture.[27] They may also cause discoloration in the thin gingival and bone tissue, resulting in inferior aesthetics.[28] In addition, the color of the core may impact the results of the translucent ceramic crown if the crown thickness is less than 1.6 mm.[29]

Although cast posts and cores were considered the gold standard for many years, an increase in patient demand for superior aesthetics led to the development of ceramic posts and cores. This led to an increase in the use of castable glass ceramics and glass infiltrated ceramics.[19,30] Zirconia posts were first introduced in 1995[31] as an alternative to cast metal post and cores, making them ideal to use on teeth with extensive loss of coronal structures.[30] Given the high translucency and the ability to match tooth color, these posts were aesthetically superior and resulted in restoration resembling natural teeth.[32] Fracture resistance of endodontically treated teeth with customized zirconia posts was higher than cast metal posts and cores and glass fiber posts with composite resin cores.[33] However, the high modulus of elasticity of zirconia transfers high stresses to root dentin, increasing the risk of root fractures.[34] In addition, establishing a strong bond to the acid-resistant zirconia can be challenging,[35] and in case of treatment failure, it may be extremely difficult to retrieve zirconia posts from root canals.[13]

CAD/CAM Fabricated Post and Core

Computerized technology has been used to aid in fabricating single crowns, fixed partial dentures, removable partial, and complete dentures.[36–40] This technology offers several advantages, including increased accuracy, a standardized manufacturing procedure, an easier and faster way of fabricating restorations in a larger capacity, and efficient means of quality control.[41]

CAD/CAM technology utilizes either "additive" or "subtractive" manufacturing methods. Additive manufacturing builds products by gradually printing structures, layer by layer. Many printing technologies have been reported, such as Stereolithography (SLA), Selective Laser Melting (SLM) and many others.[38,42] The subtractive method, on the other hand, involves removing material to fabricate the desired product, through machining and milling or laser ablation technologies. The subtractive method of fabrication has been reported to produce mechanically superior restorations, compared to those made with the additive manufacturing method.[43,44] However, about 90% of the prefabricated block material gets wasted while creating the desired restoration.[45] The additive method approach has gained in popularity, as it produces complex structures with high precision without any waste of material.[46]

Given the advantages, the CAD/CAM technology has been considered for the fabrication of custom-cast post and core. The use of CAD/CAM technology in the post and core fabrication was first elaborated in 2007 by Awad and Marghalani[14] and later by Strecker and Geissberger.[47] This was followed by multiple in vitro studies and case reports utilizing various techniques and materials, which are further elaborated in the following sections. Table 1 provides a summary of previous reports on CAD/CAM post and cores.

CAD/CAM vs Conventionally Fabricated Post and Cores

The use of a CAD/CAM technology to fabricate custom post and cores has been reported to successfully fulfill the clinical requirement in an efficient and practical way.[48] Several studies have compared customized, CAD/CAM-fabricated post and cores to conventionally made and prefabricated ones. A recent study reported that CAD/CAM composite resin post and cores provided sufficient adaptation to the post space and were less time consuming to fabricate, although cast post and cores had a slightly better adaptation.[49] Similarly, an in vitro study[50] reported conventionally cast Co-Cr alloy to be more accurate in terms of apical gap when compared to those milled from the same alloy. The reported gap, however, was within the clinically acceptable range. This finding agrees with another study, where conventionally cast post and cores had better apical adaptation than 3D-printed Co-Cr post and cores.[51]

A finite element analysis was conducted to compare the effect of CAD/CAM-customized zirconia with cast-gold post and cores on the stress distribution in the regions of the crown, core, root, and underlying bone. It is concluded that CAD/CAM-customized zirconia posts can serve as alternatives to cast gold posts, especially in the aesthetically demanding zones.[52]

The mechanical properties of CAD/CAM post and cores have also been evaluated. An in vitro study reported that CAD/CAM-customized glass-fiber post and cores possess a fracture resistance that is comparable to conventional cast post and cores, although greater than prefabricated fiber posts.[53] Furthermore, fracture modes are favorable with CAD/CAM fabricated post and cores, while cast post and core and prefabricated posts have catastrophic fractures.[53] Another report compared the fracture resistance of CAD/CAM polymer-infiltrate post and core to prefabricated fiber posts (with or without relining) and concluded that CAD/CAM post and cores have greater fracture resistance compared to relined fiber posts.[54]

A similar study by Eid et al compared push-out bond strengths and failure patterns between posts and cores made with CAD/CAM technology and prefabricated posts with composite cores.[55] The study concluded that the CAD/CAM-customized post and cores possess better retention of root canal dentin than the prefabricated ones.[55] Another study evaluated the effect of various surface treatments on the tensile bond of CAD/CAM-fabricated zirconia post and cores and concluded that sandblasting with alumina particles, tribochemical silica coating, or tribochemical silica coating followed by silanization, enhances the tensile bond strength of zirconia post and cores, with no significant differences among the surface treatments that were evaluated.[56]

The customized post and cores made with CAD/CAM technology exhibited comparable mechanical behavior to conventionally made ones. Although the accuracy of digital fabrication methods is within the clinically acceptable range, the conventional casting methods offer superior adaptation to root canals.

Techniques for Fabricating CAD/CAM Post and Core

As with conventionally made cast post and cores, the fabrication of CAD/CAM post and cores can be either indirect or direct.

Table 1 List of Available Evidence on the Fabrication of CAD/CAM Post and Cores

No.	Name	Year	Article Type	Fabrication Method	CAD/CAM Technology	Material(s) Used
1	Awad and Marghalani[14]	2007	Technical article	Scan of directly made resin pattern	Milling	Zirconia
2	Streacker and Geissberger[47]	2007	Technical article	Scan of directly made resin pattern	Milling	Zirconia
3	Liu et al[58]	2010	Clinical report	Impression, wax pattern made then scanned	Milling	Glass fiber reinforced (GFR) composite
4	Sipahi et al[56]	2011	In vitro study	Resin pattern was made and scanned	Milling	Zirconia
5	Marghalani et al[52]	2012	In vitro study	Scan of directly made resin pattern	Milling	Zirconia and gold
6	Chen et al[48]	2014	Clinical report	Impression was made and scanned	Milling	GFR composite
7	Lee et al[61]	2014	Technical article	CAD/CAM core cemented to prefab post	Milling	Zirconia
8	Chen et al[70]	2015	In vitro study	Not specified	Milling	GFR composite
9	Passos et al[71]	2017	In vitro study	Impression was scanned	Milling	Hybrid ceramic
10	Spina et al[68]	2017	In vitro study	Pattern resin made and scanned	Milling	• Hybrid ceramic • Nano-ceramic composite resin • GFR composite
11	Lee[72]	2018	Technical article	Impression was made and scanned	Milling	Zirconia
12	Falcão Spina et al[59]	2018	Clinical report	Impression was made and scanned	Milling	Nano-ceramic composite resin
13	Tsintsadze et al[66]	2018	In vitro study	Direct scan vs impression scan vs cast scan	Milling	GFR composite
14	Eid et al[55]	2019	In vitro study	Pattern resin made and scanned	Milling	• GFR composite • Hybrid ceramic
15	Eid et al[73]	2019	In vitro study	Pattern resin made and scanned	Milling	GFR composite
16	Eid et al[65]	2019	In vitro study	Pattern resin made and scanned	Milling	• GFR composite • Hybrid ceramic
17	Hendi et al[50]	2019	In vitro study	Direct resin pattern vs impression scan vs direct scan	Milling	Co-Cr alloy
18	Moustapha et al[63]	2019	In vitro study	Direct resin pattern vs impression scan vs direct scan	Milling	GFR composite
19	Pang et al[53]	2019	In vitro study	Direct scan	Milling	GFR composite
20	Libonati et al[62]	2020	Clinical report	Direct scan	Milling	GFR composite
21	Eid et al[74]	2021	In vitro study	Pattern resin made and scanned	Milling	• Hybrid ceramic • Nano-ceramic composite resin • GFR composite • Base metal
22	Kanduti et al[51]	2021	In vitro study	Direct scan	3D Printing	Co-Cr alloy

Indirect (Semi-Digital) Technique

The semi-digital technique involves a digital scan of a wax or resin pattern, or a scan of a post-space impression. Following the scan, a virtual design is created, and the cast post and core restoration is milled (or printed).[57] This technique was adopted in the earliest report on CAD/CAM fabricated post and cores,[14] where a custom-made zirconia post and core were milled from a zirconia block. Initially, a direct acrylic-resin pattern was fabricated to record the anatomy of the post space. Later, the resin pattern was scanned, milled, and sintered to create a custom-made ceramic post and core. A similar report exhibited the fabrication of post and core patterns with an auto-polymerizing resin.[47] Following this, the pattern was sent to a laboratory where it was scanned and milled.

Another clinical report demonstrated a different indirect technique. An impression of the cast was taken, and then a wax pattern was created and digitized with a scanner.[58] More recently, a report discussed a method of fabricating a CAD/CAM-customized post and core design based on a scan of a polyvinyl siloxane impression instead of an acrylic resin or wax pattern.[59] The reported technique involved scanning the impression followed by milling the nanoparticle-filled resin block to obtain a customized post and core. This method requires less chairside time and therefore results in better work efficiency, compared to the use of direct acrylic-resin patterns. Alternatively, the fabrication of CAD/CAM post and core can be performed indirectly by making an impression of the post space, followed by pouring with scannable stone. The stone cast can then be scanned, followed by designing and milling.[60]

Perucelli et al[48] compared the adaptation of CAD/CAM post and cores made with different indirect fabrication workflows (ie, a scan of a resin pattern made on the tooth or on the cast, or a scan of an impression). All techniques had comparable adaptations that were within the clinically acceptable range.[48]

Direct (Fully Digital) Technique

The fully digital or direct technique involves the direct optical impression of the post space. It uses a digital scan of compatible scan posts in conjunction with drills that prepare the root canal space,[61] or a direct scan of the root canal space intraorally.[62] Afterward, a restoration design is created using software, followed by milling. The fully digital or direct technique is beneficial as it reduces chairside time and simplifies the laboratory procedure for post and core fabrication.[57] Directly scanning the post space eliminates the risk of inaccuracies incurred by the use of impression materials, gypsum models, and pattern materials, such as resin and wax.[57]

Direct vs Indirect Technique

Moustapha et al[63] conducted a study to evaluate which of the direct or indirect digitalization techniques produced milled post and cores with a better adaptation. According to reports, direct or fully digital workflow with an intraoral scanner results in better adaptation compared to indirect digitalization of pattern or impression. Although the direct digitalization technique has an edge over the indirect technique, it can sometimes be difficult to record the narrow root canal space during post and core scanning. The intraoral camera of the CEREC system is reported to scan post-space length up to 10 mm.[64] Thus, studies have typically performed a 9 mm post-space preparation length before scanning.[65] In cases where post space is longer than 10 mm, the use of indirect technique to fabricate CAD/CAM post and cores is preferable.

Post retention, cement layer thickness and nanoleakage were assessed for CAD/CAM post and core made by direct scanning of the post space, scanning of a polyether impression, or scanning of a plaster model.[66] Post retention was highest for post and cores fabricated by the direct scanning technique, while cement thickness and nanoleakage were generally similar.

Most reported studies have used indirect fabrication of CAD/CAM post and cores. Although directly scanning the root canal space offers a quick and easy approach, the use of indirect methods may be indicated when restoring teeth with long or narrow root canal space.

Materials Used to Fabricate CAD/CAM Post and Core

Several materials have been used to fabricate CAD/CAM post and cores. Most earlier reports fabricated CAD/CAM post and cores by milling zirconia blocks,[14,47,56] while the majority of later reports used a glass-fiber reinforced composite.[48,55,65] The fabrication of a CAD/CAM customized resin-based post and core is a lucrative option as it combines the benefits of both traditional custom-made posts and prefabricated fiber posts.[48] Resin-based post and cores have a modulus of elasticity that is closer to dentin, and thus when they fail, the resultant fractures are typically more repairable, compared with those that occur with zirconia.[67] In addition, composite resin-based materials do not require sintering, which allows precise manufacturing of the post and cores and reduces manufacturing time and cost.[60] All reported ceramic- and resin-based materials yielded excellent aesthetic outcomes when teeth were restored with an all-ceramic crown.

Manufacturers have also developed new CAD/CAM materials by combining ceramics with composite resin, to create a material that has the high mechanical property and the color stability of ceramics along with the low modulus of elasticity and higher resilience of resin composites.[68] Examples of such hybrid materials include Enamic (VITA Zahnfabrik, Bad Säckingen, Germany), which is composed of 75% of feldspathic porcelain and 25% of composite resin; and Lava Ultimate (3M, St. Paul, MN, USA), which includes composite resin with 80% of nano-ceramic particles.[68] Newer materials have also been reported to fabricate CAD/CAM post and cores, such as Polyetheretherketone (PEEK),[58] which reduces stress concentration and decreases the frequency of root fractures due to the relatively low modulus of elasticity.[69]

An in vitro study[68] evaluated the push-out bond strength and the fracture resistance of different materials used to fabricate CAD/CAM post and cores, including hybrid ceramic (Enamic), nano-ceramic composite resin (Lava Ultimate), and an experimental glass-fiber reinforced epoxy resin. Bond strength was similar among all tested materials. Fracture resistance, however, was highest with nano-ceramic composite resin, while the hybrid ceramic and glass-fiber reinforced resin had comparable values. These values have been attributed to the modulus of elasticity of nano-ceramic material, which is closest to that of dentin. In addition, when cemented with resin cement, a similar composition may have resulted in a better biomechanical force distribution and thus higher fracture resistance.[68] It is worth mentioning that all materials had fracture-resistance values that were much higher than the average adult occlusal force applied during the function, which is reported to range from 70N to 150N.[68]

More recently, the use of milled,[50] and 3D-printed[51] Co-Cr alloy has been reported in in vitro studies, which were compared to cast post and cores. Although many of the other materials used were described in case reports, there is no report on clinical use of CAD/CAM fabricated Co-Cr alloy, possibly due to the inherent aesthetic disadvantage of metal alloys, especially given the numerous alternatives that offer superior aesthetic properties.

It is difficult to indicate the advantage of a certain material over another, as most published data are clinical reports, with milled zirconia and glass-fiber reinforced composites being reported most frequently. Therefore, a comparison of the various materials and their mechanical properties warrants further investigation.

Conclusion

The use of CAD/CAM technology in the field of dentistry is no longer limited to crowns, inlays, onlays, and dentures. With increasing evidence of success with CAD/CAM customized post and cores, this approach can be considered as an alternative to conventional techniques. Although these post and core restorations offer good fracture resistance, bond strength, adaptation, and superior aesthetics, there are limited in vivo studies published to date. Therefore, several long-term studies are required to substantiate the results of clinical reports.

Abbreviations

3D, three-dimensional; Co-Cr, cobalt-chromium.

Disclosure

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