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Article

Post and Core for Telescopic Crown Retained Dentures – An In Vitro Comparison of Different Materials Using Chewing Simulation

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Abstract

Due to extra axial forces, post and core (PC) treatment shows the worst survival probability if the tooth is used as an abutment for telescopic crown retained dentures (TCD). The reason for this is a mismatch of the mechanical properties between PC material and dentin or a bad accuracy of fit of PC resulting in tooth fracture or decementation. However, the inclusion of severe damaged endodontically treated teeth needing PC is often mandatory in order to receive a statically stable situation for TCD. Thus, an advancement of PC treatment for TCD is of high clinical interest. Recently it is possible to fabricate customized PC with favourable mechanical properties by using CAD/CAM technology. Therefore, the aim of this study was to compare the performance of these PC (CAD/CAM PC) to customized cast PC (CPC) and prefabricated fibre-reinforced PC (PFPC) in a TCD set-up using a chewing simulator. The investigation group with CAD/CAM PC showed neither tooth fracture nor decementation in contrast to CPC and PFPC in which both types of failure were recorded. Thus, CAD/CAM PC showed significantly better performance than CPC and PFPC. Within the limitations of this study CAD/CAM PC are therefore recommendable for PC treatment with TCD.

Keywords: post and core; telescopic denture; CAD/CAM; chewing simulation

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1. Introduction

Telescopic crown retained dentures (TCD) are a frequently used treatment option for patients with few remaining teeth.[1,2] Though, in many cases it is mandatory to include also severe damaged endodontically treated teeth needing PC in order to receive a statically stable support for the denture.[3] However, in scientific dental literature many authors described a significant difference between survival of abutment teeth with and without PC that should be considered when it comes to treatment planning for TCD.[4,5] Furthermore, the majority of studies investigating the survival probability of PC considering different covering prosthetic restorations found the worst results for abutment teeth of TCD.[4,6,7] This applies both to the survival probability of PC itself [7,8] and to the risk for extraction of the abutment tooth.[9] The main reasons for this are the extra axial forces that occur when the TCD is inserted and removed incorrectly by the patient [6] or when the denture saddle is incongruent to the edentulous jaw areas.[5] Due to the rigid connection between the abutment tooth and the denture,[3,5] the occurrence of these forces is also responsible for the increased risk of root fracture especially in the first five years after fitting of PC [9] and is even further exacerbated if the mechanical properties of the PC material does not match to those of dentin.[10–12] In particular, this is the case with customized cast PC (CPC) that have been the gold standard for PC treatment during the past decades.[10] That is why many authors recently prefer the use of prefabricated fibre-reinforced PC (PFPC) as these have an elastic modulus similar to that of dentin and beyond that can be fitted in a single session.[12–14] However, it has to be kept in mind that PFPC

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have a poorer fit in the prepared root canal compared to customized PC.[15] This is particularly relevant in the context of the extra axial forces linked to TCD as it can lead to an increased risk of decementation. [7,16] Moreover, bad accuracy of fit of PC is associated to an increased risk for secondary caries, thus an increased risk for tooth loss.[7,16] Furthermore, due to polymerization shrinkage a thick resin layer between the post and the root canal wall can lead to an uneven force transmission into the root dentin with an associated increased risk for root fracture.[15,17,18].

In the context of the occurrence of extra axial forces with TCD, also fracture of abutment teeth without PC or even without endodontical treatment is frequently described as one of the most common causes of failure with TCD.[3,5,19] However, this type of failure is not mandatorily connected to the extraction of the tooth,[20] because fracture often occurs within the area of the preparation for telescopic crown leaving out the root but resulting in an insufficient coronal height to refit the telescopic crown without additional effort.[21] In these cases PC can be used to refit the telescopic crown on the abutment tooth in order to recover the function of TCD.[22] However, the long term survival of this treatment using CPC and PFPC is not satisfying.[23] Therefore, a further development of PC treatment especially for abutment teeth of TCD is of high clinical interest [23] and the focus of recently published studies [24].

Latest technical advances in intraoral scanners and digital manufacturing made it possible to scan the post space preparation and to mill customized PC in a fully digital CAD/CAM workflow.[15] Firstly, this workflow increases the accuracy of fit not only compared to PFPC but also compared to analogue manufactured CPC.[25] Secondly, the mechanical properties of the manufactured PC can be improved because there are dentin-like materials that are limited to CAD/CAM fabrication and showed favorable results in anterior teeth with extra axial forces resulting in decreased risk for root fracture and decementation.[10] Summarising these results, the advantages of CPC and PFPC can be combined in CAD/CAM PC by using modern digital technologies thus PC treatment of TCD could be improved by this workflow as well. Therefore, the aim of this study was to compare the performance of CPC, PFPC and CAD/CAM PC in a TCD set up using artificial altering in a chewing simulator. The following null hypotheses were put forward in order to answer the research issue:

– There is no significant difference between CPC, PFPC and CAD/CAM PC concerning root fracture during chewing simulation.
– There is no significant difference between CPC, PFPC and CAD/CAM PC concerning decementation of PC during chewing simulation.

2. Materials and Methods

In order to calculate the statistically significant sample size for the present study a power analysis with a pursued power of 95% was conducted using the data of a comparable study.[10] Thus, the sample size was determined on 30 teeth per investigation group (CPC, PFPC and CAD/CAM PC). Table 1 illustrates the materials with the elastic modulus used in this study for CPC, PFRP and CAD/CAM PC fabrication in relation to the elastic modulus of dentin.

Table 1. Materials for CPC, PFRP and CAD/CAM PC with elastic modulus in relation to dentin.

	Materials	Product Name	Brand	Elastic Modulus
CPC	Non-precious alloy	Wirobond C	BEGO	180 Gpa
PFRP	glassfibres / epoxy resin	ER post	Komet	30 GPa
CAD/CAM PC	glasfibre mats / composite	Trina	Bicon	18.8 Gpa

Elastic modulus of dentin: 18.6 GPa **[26].**

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For this study, 90 human lower canine with comparable root sizes of 15 mm length and 6 mm width (± 1.0 mm) were selected.[27,28] The teeth had been extracted for therapeutic reasons and their use for research purposes was approved by the ethics committee of the Medical Faculty of *[removed for anonymity reasons]*. The crowns were removed up to 2 mm above the cementoenamel junction using a disc grinder with water cooling. Then, a chemo-mechanical endodontic treatment was processed by using 3.0% sodium hypochlorite and a system of rotary files (F-360 ISO 15-45, Komet, Germany). This was followed by filling with gutta-percha (ISO 45, Taper 0.04, Coltène/ Whaledent AG, Switzerland) and sealer (AH Plus, Dentsply DeTrey, Germany), using the one-point technique. After the cure time of the sealer (24 h), the post space preparation was conducted using the ER System (ISO 90, Komet, Germany) at a length of 10 mm. Additionally, a rotation lock by means of a 3 mm box at the root canal entrance and a chamfer line was prepared with diamond burs under constant water cooling. Subsequently, the roots were examined, and teeth with infractions, cracks and root caries were excluded. The analysis was carried out under a digital light microscope (Smartzoom 5, Zeiss, Germany) and based on X-ray findings.

Furthermore, 90 identical lower jaw models of the tegument for TCD with an abutment tooth 43 were 3D-printed (SHERAPrint 30, Shera, Germany) out of a resin for dental models (SHERAmodel stone, Shera, Germany) (Figure 1).

Figure 1. 3D-printed model of the tegument for TCD with abutment tooth 43.

Subsequently, the abutment tooth was removed on the model and a hole was drilled to fit the root of the human lower canine using impression material (Impregum, 3M, Germany) as a simulated periodontal ligament. Three measurements using *Periotest* (Periotest Classic type 3218, Medizintechnik Gulden e.K., Germany) were processed, to verify that the simulation of the periodontal ligament was equivalent to that of a clinical tooth mobility grade 0. If the mean value was outside the range of -08 to +09, the tooth was excluded from further investigation.

On 60 samples, a digitale impression was conducted including all parts of the modell as well as the post space preparation inside the canine by an IOS (Primescan, Dentsply, Germany). With superimposing the dataset for modell printing, the digital construction for CPC and CAD/CAM PC was conducted using the biogernic copy tool considering the space necessary for telescopic crown (TC) (Figure 2).

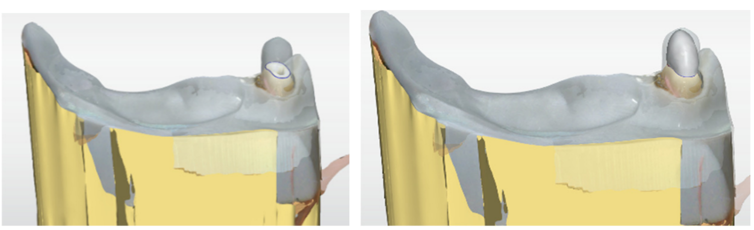

Figure 2. Left: Digital Impression of the modell with canine and superimposition of the dataset for modell printing. Right: Digital construction for CPC and CAD/CAM PC using biogeneric copy tool.

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CPC were fabricated by milling (MCXL, Dentsply, Germany) the dataset of the digital construction of PC in a residualfree burnable resin (Telio CAD, Ivoclar, Liechtenstein) and casting into non-precious alloy (Wirobond C, BEGO, Germany).

CAD/CAM PC were fabricated by milling the dataset of the digital construction of PC in a glasfibre reinforced composite (Trinia, Bicon, USA). Figure 4 shows the PC for CPC and CAD/CAM PC.

CPC and CAD/CAM PC were fitted in the rootcanal using a resin composite (Panavia V5, Kuraray, Japan) according to manufacturers recommendations.

PFPC (ER-Post, Komet, Germany) were fitted in 30 samples by using the same protocol as with the other investigation groups. Additionally, the core was reconstructed with composite filling material (Rebilda LC, Voco, Germany). In order to keep consistency to CPC and CAD/CAM PC in the core dimension, the dataset of TCD was used for 3D-printing a transparant replica of the TCD which was used as a template for core build-up (Figure 3).

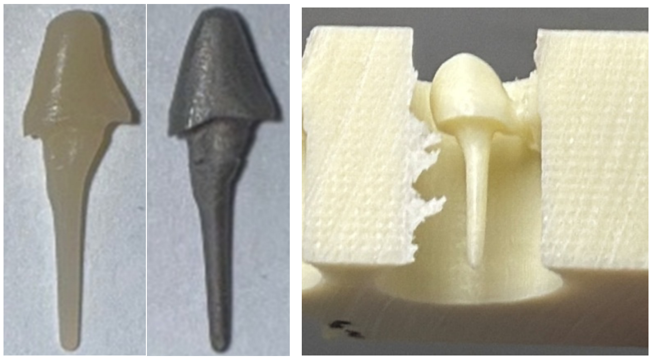

Figure 3. CPC: Residualfree burnable resin PC and cast PC (left). CAD/CAM PC: Milled PC out of glasfibre reinforced composite. (right).

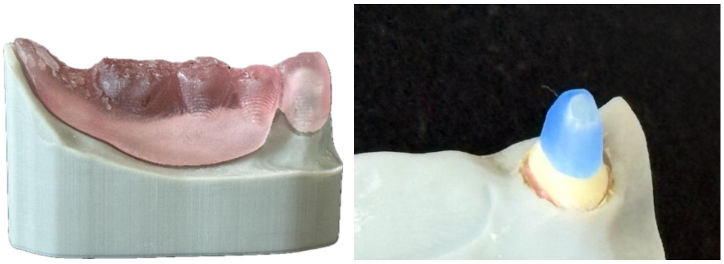

Figure 4. Transparant replica of TCD (left) as a template for core build-up in PFRP (right).

Subsequently, all 90 canine with the fitted PC were prepared for TC using diamond burs with water cooling. The preparation margin was set 2.0 mm below the post-tooth junction in order to achieve a ferule design of TC. Digital impressions of the samples were conducted and TC was designed virtualy in the IOS software.

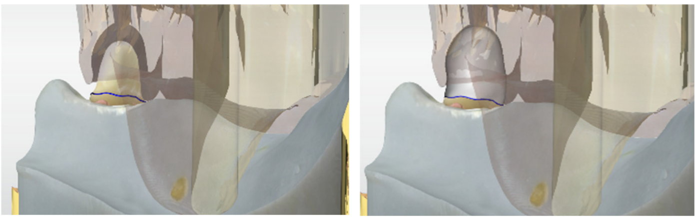

Figure 5. Digitial impression (left) and vitural design of TC (right).

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According to the fabrication of CPC, all 90 TC were milled in residualfree burnable resin, cast in non precious alloy and were fitted on the corresponsing canine with resin composite follwing the same protocal as with the PC.

In order to construct a set-up of an incongruent TCD for chewing simulation, the dataset of TCD was milled in non-precious alloy with an offset of 0.5 mm in the area of the denture sattle. Figure 6 shows the prepared sample for chewing simulation in which a force on 46 resulted in a non-axial force on the abutment tooth and the fitted PC.

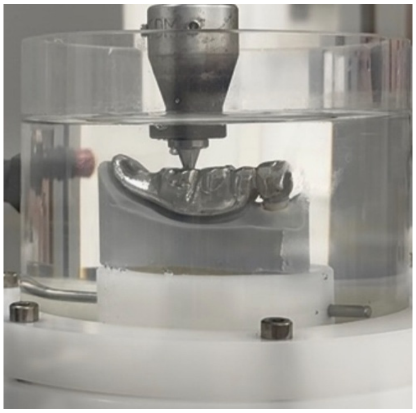

Figure 6. Inkongruent TCD sample for chewing simulation: Force on 46 results in non-axial force on the abutment tooth and the fitted PC.

The chewing simulation was processed for 1.2 million cycles of load under thermocycling in a water bath (SD Mechatronik Chewing Simulator CS-4.8; SD Mechatronik GmbH, Germany) (Figure 6), which equals an intraoral load period of 5 years.[29] After every 240,000 cycles of load, simulating 1 year of intraoral loading period (T1-T5), the chewing simulation was stopped and the canine was analysed for decementation and fracture using a digital light microscope. Therefore, the canine was pulled out of the impression material and was clearly repositionable after the inspection. In case of a decemenation or fracture, the simulated survival time (T1-T5) was documented in IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY, USA) and the sample was excluded from further investigation. Decementations and root fractures during chewing simulation, were assessed using Kaplan-Meier analysis. Cases in which neither decementations nor root fractures occurred were rated as “censored cases”. The pairwise comparison between the three investigation groups was assessed using the Chi-square test in form of Fisher’s exact test. Due to alpha error accumulation, p-values were corrected using the Bonferroni method and the level of significance was set at $p < 0.05$.

3. Results

Two out of 30 CPC lost retention during chewing simulation (one after T3 and one after T4). Moreover, two canine in group CPC showed a root fracture during chewing simulation (one after T3 and one after T5). Therefore, the simulated 5-year survival rate in group CPC was 86.7%. Regarding PFRP, four post decementations were recorded (one after T1, two after T4 and one after T5) and two canine developed a root fracture during chewing simulation (one after T3 and one after T4). Thus, the simulated 5-year survival rate was 80.0%. In group CAD/CAM PC, neither decementations nor root fractures were detected during the 5-year chewing simulation of 1.2 million cycles. Therefore, the simulated 5-year survival rate in this group was 100%.

The pairwise comparisons showed a significant difference between PFRP and CAD/CAM PC ($p=0.02$) and a barely insignificant difference between CPC and CAM/CAM PC ($p=0.056$). Between CPC and PFRP no significant difference was found ($p=0.186$). The Kaplan-Meier survival curves for CPC, PFRP and CAD/CAM PC are illustrated in Figure 7.

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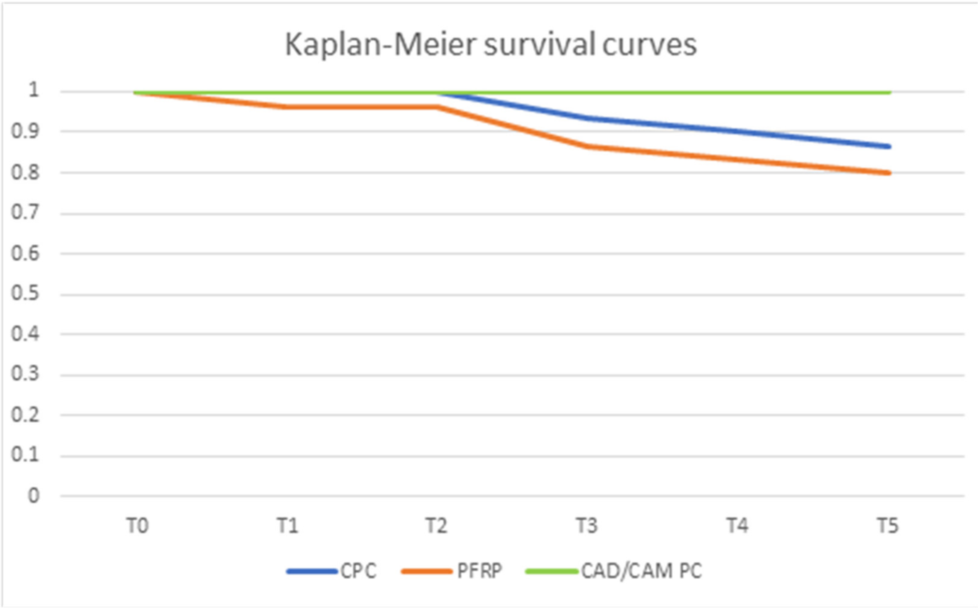

Figure 7. xxx.

Summarising the results, both null hypotheses have to be refuted because CAD/CAM PC showed significantly better performance regarding root fracture and decementation.

4. Discussion

Even though the elastic modulus of alloy used for fabrication of CPC is significantly higher than that of dentin,[30,31] customised CPC is still regarded as the "gold standard" for treating teeth with severe coronal destruction because of its excellent accuracy of fit.[15,32] PFRP have a mechanical behaviour similar to that of dentin but are less stable due to the interface between the PC parts and the poor accuracy of fit in the prepared root canal.[15,17,31,33,34] Furthermore, the use of PFRP is increasing in dental practices.[35,36] In order to combine the advantages of both types of PC, CAD/CAM PC milled out of a material with mechanical properties similar to dentin have been introduced recently.[10,15,25,26] Therefore, a comparison of these three types of PC is of high clinical interest.

Furthermore, TCD are a frequently used treatment option for patients with few remaining teeth,[1,2] but survival probability of PC under TCD is the worst compared to all other types of covering prosthetic restorations.[4,6,7] Therefore, we chose a set-up imitating the common clinical situation of an incongruent TCD in order to test the three different PC types and to evaluate if CAD/CAM PC have an advantage with TCD as well.[10] The artificial oral environment and changing temperatures within the oral cavity affect the retention of PC as well as the PC material itself.[37,38] Therefore, preclinical survival simulation in a set up that is comparable to the clinical situation is essential in terms of material fatigue and further development of new treatment options.[39] Thus, many authors in dental literature reported the use of chewing simulators to analyse the mechanical behaviour of new materials or workflows, similar to the procedure performed in the present study.[39,40] *Rosentritt* et al. described that a simulation of the periodontal ligament is necessary during chewing simulation, since the omission of this resulted in a three times lower susceptibility to fracture, which decreases the comparability to the clinical situation.[41] Therefore, in many studies, a thin layer of impression material was used,[29,41,42] like described in the Materials and Methods for the present study as well.

Concerning the analysis of decementation and root fracture during chewing simulation with thermocycling in the present study, both CPC and PFRP showed root fracture and decementation. For CAD/CAM PC, neither decementation nor root fracture was detected. This result is in line with

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the findings of a previous study investigating the performance of CAD/CAM PC for severely destroyed anterior teeth that are faced with non-axial forces, too.[10] *Hayashi* et al. investigated the in-vitro fracture resistance of pulp-less teeth restored using PFRP and metallic posts in a set-up with non-axial forces. The authors found a significantly higher fatigue limit for teeth restored using fibre-reinforced posts and presumed a similarity of elastic modulus between post and dentin for this result.[43] This is partially in line with the findings of the present study but PFRP performed worse than CAD/CAM PC. One reason for the difference in the findings could be caused of the differing set-up because in the present study, lever forces were loaded on the canine. Thus, not only the elastic modulus might be of relevance for the performance of PC but also the accuracy of fit. Bad accuracy of fit is associated to an uneven transmission of force leading to fracture and decementation when non-axial forces occur.[15,17,18] *Ferrari* et al. compared the clinical survival of CPC and PFRP retrospectively over an observation period of four years. CPC showed root fractures in 9% of cases, whereas no fracture occurred in the group of teeth restored using PFRP. [44] Contrary to this, *Altitinchi* et al. found a 100% failure rate because of fractures after chewing simulation with thermocycling for CAD/CAM PC made of *Trinia*. However, this study did not consider the orientation of the fibre mats to the axis of load, like in the present study.[39] *Suzaki* et al. described the significant influence of fibre orientation for fracture toughness especially when the material was used for PC.[45] This could be the reason for the different results for CAD/CAM PC made of *Trinia* in the present study compared to the findings of *Altinchi* et al. Most studies dealing with the survival probability of PC found the loss of retention as the most common cause of failure,[6,33,46] which is in line with the results of the present study. Even though the loss of retention is described as a relative cause of failure because PC can often be recemented without additional effort,[6] it can still increase the risk for tooth loss.[7] Therefore, we recorded decementation as failure but distinguished between root fracture and decementation in the results.

5. Conclusions

The results of the present study show that CAD/CAM PC can have an advantage over CPC and PFRP in the clinically common set-up of an incongruent TCD. Therefore, within the limitations of this in-vitro study CAD/CAM PC made of fibre reinforced composite can be recommended for PC in abutment teeth of TCD.

Author Contributions: In the following paragraph the individual contribution of all authors to this article is specified: Jonas Adrian Helmut Vogler: Writing—original draft preparation; writing—review and editing; visualization; project administration. Milan Rachold: Investigation; formal analysis. Bernd Wöstmann: Software; supervision; resources. Peter Rehmann: Data curation; validation
Kay-Arne Walther: Conceptualization; methodology. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of *[removed for anonymity reasons]*.

Informed Consent Statement: Informed consent is not necessary for this type of study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy and ethical restrictions.

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Conflicts of Interest: The authors declare no conflicts of interest.

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