

# **Intraoral wear of PICN CAD-CAM composite restorations used in severe tooth wear treatment: 5-year results of a prospective clinical study using 3D profilometry**

## **Abstract**

**Objectives:** To evaluate, in a prospective clinical study over 5 years with *ex vivo* 3D profilometry analyses, the intraoral wear of Polymer-Infiltrated Ceramic Network (PICN) CAD-CAM composite restorations used in severe tooth wear treatment with the One-Step No-Prep technique.

**Methods:** 192 PICN (Vita Enamic) restorations on molars and premolars were included in a prospective clinical study involving patients treated according to the One-step No-prep protocol (n=7). All patients showed clinical signs of bruxism. Replicas of restorations on molars and premolars were realized at each evaluation time (baseline and then every year up to 5 years) and scanned to perform 3D profilometry. Baseline and recall scans were superimposed with Geomagic Control software. The mean material wear was calculated for the full occlusal area (FOA) and for the occlusal contact area (OCA), respectively. Clinical evaluation of restorations was performed at recall.

**Results:** At 5 years, the estimated mean material wear for FOA was inferior to the accuracy threshold of the profilometry measurement chain. For OCA, the estimated mean wear of the material was  $-27.97 \mu\text{m}$ . This material wear was shown to be significantly influenced by time ( $p < 0.0001$ ) and patient ( $p = 0.026$ ), while the type of tooth (molar or premolar) had no influence. At 5 years, the survival and the success rates of restorations were 99.48% and 90.62%, respectively.

**Significance:** The PICN material exhibits a low wear process in the treatment of severe tooth wear despite the presence of clinical signs of bruxism, and it constitutes a suitable material for the One-step No-prep technique.

**Keywords:** Dental materials, biomaterials, Prosthetic dentistry, material wear, CAD-CAM composite, Polymer-infiltrated-ceramic-network, quantitative analysis, profilometry.

## **1. Introduction**

Computer-aided design–computer-aided manufacturing (CAD-CAM) composite materials appeared on the market more than ten years ago and they constitute the most recent class of CAD-CAM blocks for dental prostheses. Composites are well-adapted to milling processes,

particularly chairside, and are gaining popularity thanks to fast manufacturing, related but lifetime, lack of a firing procedure, ability to be milled in very low thickness, and ease of in-mouth adjustments and repair compared to glass-ceramics [1] [2]. Moreover, the industrial manufacturing process of composite blocks produces a significant increase in material homogeneity and a decrease in the presence of flaws [3]. Most importantly, it allows for the use of more performant polymerization modes and innovative material microstructure, resulting in new families of composite materials, with significantly better properties than direct light-cured composites [4] [5]. Currently, CAD-CAM composite blocks can be divided into two subclasses depending on their microstructure: dispersed filler materials (DF), where fillers are classically incorporated by mixing into the monomer matrix and polymerized at high temperature, and Polymer-Infiltrated-Ceramic-Network (PICN) materials, which are the result of the infiltration of a pre-sintered glass-ceramic scaffold with a monomer, which is secondarily polymerized at high temperature but also high pressure (HT-HP) [6] [4]. PICN materials are also called “hybrid ceramics” or double network materials, into which the glass-ceramic particles are interconnected constituting a 3D scaffold, and since the polymerization process is patented, the only PICN material on the market is the Vita Enamic (VITA Zahnfabrik, Bad Säckingen, Germany) [7].

The mechanical properties of CAD-CAM composites blocks have often been investigated *in vitro*. In general, they exhibit mechanical values higher than those of artisanal light-cure composites, particularly in terms of flexural strength, while they are lower than those of reinforced-glass ceramic materials, such as lithium-di(silicate) based glass-ceramics, except for some experimental PICNs. Due to their original microstructure, PICNs show a higher elastic modulus and hardness than DF, these properties being closer to natural tooth tissues than other composite materials [4] [8]. They also exhibit comparable fracture toughness and better damage tolerance than glass ceramics [7], and their damping behaviour related to the presence of polymer makes them particularly interesting in the case of bruxism and related high occlusal stress [9]. In general, CAD-CAM composites, especially PICNs, are recommended in severe tooth wear treatment, where high-performance composites exhibit many other advantages compared to glass-ceramics, such as their ability to be milled in low thickness, their easy-to-adjust character, and their repairability. In particular, the One-step No-prep approach, introduced in 2018, constitutes a minimally-invasive treatment protocol characterized by the absence of a provisional phase (“One-step”) and tooth tissue preparation (“No-prep”), due to the realization of very low thickness restorations [10] [11].

However, data about PICN wear resistance are lacking; however, this information is crucial, especially in patients with bruxism [12]. To author's knowledge, the intraoral wear behaviour of CAD-CAM composites is still poorly studied; only two short-term *in vivo* studies related to DF and PICN materials are available in the literature [13] [14] [15]. In a systematic review of the *in vitro* wear resistance of CAD-CAM composite materials, Laborie et al. reported that PICN (Vita Enamic) show less wear than DF composites and more wear than the lithium-based glass-ceramics, which are more abrasive [16]. However, if *in vitro* studies are useful, easy to perform, cheaper than clinical studies, and allow accurate analysis of the material surface, they face numerous difficulties in reproducing the oral environment and its variations, which can significantly influence their clinical relevance [17] [18] [19]. Therefore, the development of clinical studies, which allow material clinical wear measurement, is recommended [12].

Consequently, the objective of this work was to evaluate, in a prospective clinical study over 5 years with *ex vivo* 3D profilometry analyses, the intraoral wear of PICN CAD-CAM composite restorations used in severe tooth wear treatment with the One-Step No-Prep technique. The 2-year general clinical outcomes of this prospective study were published previously [11].

## **2. Materials and Methods**

### **1. Study design**

The protocol of this clinical study was approved by the Ethics Committee of the University Hospital Center (CHU) of Liege and was registered in the ClinicalTrials.gov database (B707201526682). Written patient consent was obtained before inclusion. The patients were treated by four experienced practitioners from the Department of Fixed Prosthodontics, Institute of Dentistry, CHU of Liege, Belgium.

### **2. Patient selection**

Patients presenting generalized severe tooth wear with an esthetic or functional demand were included in this prospective study. The patients were required to have a minimum of 28 teeth, with a minimum of 3 teeth per posterior sextant to restore with an indirect restoration, and palatal veneers from canine-to-canine superior teeth. The following patients were excluded

from the study: smokers and patients with poor oral hygiene, those with periodontal disease or severe osteoarthritis, and patients with crowns, bridges, or implants. Patients with Parkinson's disease or spontaneous temporomandibular joint pain associated with a mandibular deflection and an opening limitation (< 25 mm) were also excluded.

### 3. Tooth wear diagnostic

#### 3.1 Chemical tooth wear diagnostic

In addition to a thorough clinical examination to detect the presence of dental erosion surfaces (concave, cuneiform, or flat lesions), an accurate medical history was recorded including questions about nutrition habits, general diseases, medications, and environmental factors.

#### 3.2 Mechanical tooth wear diagnostic: non-instrumental approach of bruxism assessment

A clinical examination was performed to register the presence of clinical signs of bruxism, such as dental attrition, cracks/fractures, masseteric hypertrophy, linea alba, exostoses or crenated tongue [20, 21]. The presence of bruxism was recorded if the patient fulfilled at least two criteria: A) reporting of tooth grinding during the night or day; or B) the presence of at least one clinical sign among the following: abnormal attrition wear facets on the teeth; transitory pain or fatigue on awakening felt in the jaw muscles; temporal headaches on waking; and jaw locking on awakening related to teeth grinding during sleep [20] [22]. The use of an occlusal nightguard was noted. A complementary clinical examination was performed by an occlusodontist (i.e., a specialist in occlusion and TMDs) to detect the presence of temporomandibular joint (TMJ) disorder. Occlusal relationships (class III or class II.2 malocclusion, anterior or posterior crossbite, edge-to-edge or open bite) were recorded before treatment.

### 4. Clinical protocol

The patients were treated according to the previously described One-step No-prep protocol [10] [11] (Figure 1). Restorations corresponding to the estimated tissue loss (palatal veneer, posterior occlusal tabletops and veneerlays) were milled from PICN blocks (Vita Enamic HT, Vita Zahnfabrik, Germany; Ceramill Motion 2, Amann Girrbach). The lowest thickness of each

restoration was measured, and the mean restoration thickness registered was  $0.7 \pm 0.3\text{mm}$  for premolars ( $n=56$ ) and  $0.5 \pm 0.2\text{mm}$  for molars ( $n=58$ ). The lowest thickness measured was  $0.11\text{mm}$  on a molar [11]. The restorations were tried and then bonded within two consecutive days at two half-day appointments, one for each maxilla (the upper jaw on the first day afternoon, the lower on the second day morning). They were pretreated following the manufacturer's recommendations, i.e., etching the surface with hydrofluoric acid (HF) for 60 seconds, cleaning it in an ultrasonic bath in ethanol, and then applying a layer of silane (Silane Primer, Kerr, Orange, California, United States). A rubber dam was placed for the posterior teeth but not the anterior teeth. The tooth tissues were cleaned with pumice. A diamond bur at low speed was used to open the tubules of sclerotic dentin and enamel was etched with phosphoric acid. Direct composites were sandblasted with the Cojet system (3M, Saint-Paul, USA) and a silane (Silane Primer, Kerr, Orange, California, United States) was applied. Then a two-step etch-and-rinse adhesive (Optibond XTR, Kerr, Orange, California, United States) was applied following manufacturer recommendations and the adhesive layer was polymerized before restoration bonding. The restorations were bonded with a composite resin cement with the Nexus XTR system (NX3, Kerr, Orange, California, United States), polymerization was performed after excess removal, and final photopolymerization was performed under a glycerin film to avoid the persistence of a polymerization inhibition layer. Major occlusal adjustments were made immediately after bonding of the lower restorations with an Arkansas stone bur, followed by polishing with silicon gums and fine adjustments performed within the following month. A bleaching procedure (home bleaching with a night guard using the Illumine 10% tooth gel kit, Dentsply Sirona, New York, USA) was also performed (which was not possible when the dentin was still exposed). To mask the junction between the palatal veneer and the buccal face of the upper anterior teeth, direct composite (Inspiro, Edelweiss, Zug, Switzerland) was added on a slight chamfer performed across the junction and, where needed, to optimize tooth shape. Finally, an acrylic nightguard (for the upper maxilla) (Orthocryl, Dentaaurum, Ispringen, Germany) was provided to all of the patients.

## 5. Recall

Baseline evaluation was performed after final occlusal adjustments (T0). Occlusal contact points in maximum intercuspation occlusion were photographed and recorded at T0 and at each recall appointment, which were scheduled after 1 year (T1) and each year (T2, T3, T4) up to 5 years (T5).

## 6. Material wear measurement (Figure 3)

The sample included all PICN restorations on premolars and molars.

### 6.1 Replica manufacturing

Restorations were cleaned first with a prophylaxis paste (Detartrine, Septodont, Saint-Maur-des-Fossés, France) and then with alcohol, to reduce the presence of biofilm and contaminants on tooth surface. Double mix impressions with polyvinyl siloxane (PVS) material (Imprint 4 heavy and XLV, 3M ESPE, Seefeld, Germany) were performed on each posterior sextant with a perforated plastic impression tray. The buccal and lingual/palatal parts of the trays were removed in order to involve only the occlusal surfaces and also to reduce PVS deformation during disinsertion (Figure 2). All impressions were carried out by the same practitioner (JO) and poured within 24 h using epoxy resin (2:1 wt% base and catalyst, respectively, PVD, Liege, Belgium). An initial layer of epoxy resin was applied using a plastic brush to ensure that the surfaces were properly wet and devoid of air bubbles. Replicas were cleaned ultrasonically in ethanol for 3 min and gold coated.

### 6.2 Profilometry

Gold-coated replicas were scanned with a custom-made device including an XY motorized board stage and a 100 nm resolution laser sensor (Keyence LK G30 with LK GD500 controller, Keyence Corporation, Osaka, Japan) with a step of 25  $\mu\text{m}$ . Models were placed in a specific custom-made holder to ensure reproducibility of positioning at each evaluation time. In fact, the replica was placed on plasticine resting on a rigid metal plate. Using a piston parallel to the plate, pressure was applied to the occlusal surface of the first molar, which determines the 'horizontality'. Raw data acquisition and processing were performed using a custom-developed software with C# language (Microsoft Visual Studio 2013, Microsoft Corporation, Redmond, WA, USA) coupled to a digital data-acquisition PCI board (NI PCI-6534, National Instruments Corporation, Austin, TX, USA). The resulting matrix of Z values was then transferred to the surface-matching software Geomagic Control 2015 (Geomagic Inc, Morrisville, NC, USA). Baseline scans were transformed into a computer-aided design format (STL) and recall scans were superimposed using a best-fit alignment algorithm. First, the software randomly

selected and aligned 300 data points. After this rough alignment, a fine alignment was performed using 1000 additional data points by iterative rotations and translations, minimizing the root-mean-squared (RMS) difference between the two images. The deviation eliminator function was used to choose data points with a minimum deviation in the z-axis. Only scans that successfully passed this matching process step were used for the wear analysis [23]. To prevent bias in the wear measurement related to artefacts or surface pollution, a threshold value of 300  $\mu\text{m}$  was defined, leading to the exclusion of points with a measured difference greater than 300  $\mu\text{m}$  from the wear evaluation. Each year, a value of 100  $\mu\text{m}$  was added in relation to the reported wear of direct composites [24]. An additional control for adequate matching was the distribution of the z-values in areas that were not subjected to wear (for example, occlusal grooves). In those areas, data points with a difference in z-values greater than 15  $\mu\text{m}$  were excluded. A 3D comparison analysis (with spectrum) was performed to visualize differences of wear between the scans, where the oldest scan was selected as the 'reference' and the newest scan as the 'test'.

A mean wear value was registered both for the entire occlusal surface (Full Occlusal Area (FOA)) and for each occlusal contact area in maximum intercuspation occlusion (OCA). OCA were identified from the clinical pictures. These areas were digitally delimited on each baseline scan using a mask based, which was superimposed to recall scans for wear measurement.

### 6.2.1 Accuracy and precision calibration of the measurement

The accuracy and precision of the measurement chain were assessed in a previous study in a series of three experiments using the reference-free superimposition algorithm of Geomagic software according to the protocol proposed by Rosin et al. [25]: (1) precision of the automatic 3D superimposition algorithm, (2) precision of 3D data acquisition, and (3) precision of the reference-free 3D superimposition [17]. Intrinsic errors of the software superimposition program (experiment 1) resulted in an accuracy of  $0.01 \pm 0.01 \mu\text{m}$  (the accuracy is reported as the mean of the multiple measures and the precision corresponds to the standard deviation. Assessment of the three-dimensional data acquisition produced height differences of  $0.09 \pm 0.09 \mu\text{m}$  (experiment 2). The superimposition when the position of the restoration within the laser scanner was altered after each scanning procedure (experiment 3) resulted in an accuracy of  $0.47 \pm 0.17 \mu\text{m}$ . The vertical resolution of the laser scanner was 15  $\mu\text{m}$ . Therefore, the accuracy threshold of the measurement chain was 15  $\mu\text{m}$  [23].

### 6.3 Laser confocal microscope

3D images of the replica of a restoration at each evaluation time were obtained using laser confocal microscope (Keyence VK 3050, x and y resolution 5  $\mu\text{m}$ , z resolution 1 nm), at 2.5 fold magnification and four images were stitched together (2x2).

## 7. Statistical analysis

Qualitative variables are described using frequency tables (numbers and percentages) while continuous quantitative variables are described using mean and standard deviation. Simple mixed models are used to investigate different effects on mean distances, considering repeated measurements per tooth within each patient. The results are considered significant at the 5% uncertainty level ( $p < 0.05$ ). Calculations were performed using SAS statistical software version 9.4 and graphs using R statistical software version 4.2.2.

## 3. Results

### 1. Clinical data on patients and restorations

Seven patients were recruited (6 males and 1 female), with a mean age of  $37.7 \pm 12.8$  years old, and including a total of 192 PICN restorations. Six patients were in class I and one patient was in class II.2 occlusion. Among the treated patients, 57.2% (n=2) showed a group function, 14.3% (n=1) had a canine function and 28.5% (n=2) had both types of function. Regarding the etiology of wear, all patients showed signs of chemical (erosion) and mechanical (bruxism) wear. All patients reported grinding or clenching habits during the night or during the day. At 5 years, the survival and success rates of restorations (n=192) were 99.48% and 90.62%, respectively including 16 minor chipping, 1 debonding and 1 loss of restoration (tooth fracture). Restorations presenting minor chipping were polished (n=13) or repaired (n=3).

### 2. Profilometry

#### 2.1 Scan data

A total of 113 premolars and molars restorations were included and evaluated at each recall, except at 3 years (n=96 at 3 years due to the absence of one patient with 17 restorations), corresponding to a total of 548 scans over 5 years. Thirty-four restorations were excluded from the results because they were not in occlusion with the antagonistic teeth (n=5), or they were submitted to occlusal adjustments after the baseline assessment (n=13), or they encountered minor chipping or repair on the occlusal surface (n=16). Additionally, 73 scans (13.32%) were excluded from the analyses because they were unable to be matched. Consequently, the total number of scans included in the results was 393. All surfaces studied had PICN restorations as an antagonist.

## 2.2 Material wear measurement

Table 1 shows the evolution of the mean wear of the material considering the FOA and the OCA, respectively.

At 5 years, the estimated mean material wear for FOA was + 5.71  $\mu\text{m}$ , which is lower than the accuracy threshold of the profilometry measurement chain and - 27.97  $\mu\text{m}$  for OCA. There was no significant difference between premolars and molars, while a time and a patient effect were detected. The effect of time was more significant for OCA than for FOA surfaces: this effect is represented graphically in Figure 5.

### 3. Laser confocal microscope

Figure 4 shows the 3D images of the replica of the same restoration as in Figure 3 at each evaluation time. The images show an overall reduction in relief, which is more pronounced in the occlusal contact areas. The measured wear on the FOA at 5 years on this restoration was below the accuracy threshold of the measuring chain (15  $\mu\text{m}$ ), while the measured wear on the OCA was -45.82  $\mu\text{m}$ .

## 4. Discussion

Studying the wear of prosthetic materials involves asking the question: What should be the ideal material's behaviour in terms of wear? In fact, the ideal material is not a material that does not wear, such as zirconia [23] [26]: it should behave as closely as possible to the tissue it replaces, i.e. be biomimetic, being able to follow the evolution of patient occlusion with tooth

wear, and also being also able to adapt to occlusal contact point adjustment errors. Following Lambrechts et al., the wear of opposing enamel is 15  $\mu\text{m}$  and 29  $\mu\text{m}$  per year under normal circumstances for premolars and molars, respectively [27]. However, Esquivel-Upshaw et al. [28] reported enamel wear of 40–80  $\mu\text{m}$  per year.

In the present study, the mean wear of PICN opposing PICN in patients with severe tooth wear and bruxism is lower than those values (– 27.97  $\mu\text{m}$  for 5 years in OCA surfaces, while not detectable for FOA, i.e. inferior to 15  $\mu\text{m}$ ), meaning that the patients treated lost less tooth height than a healthy patient. Figure 4 confirms that the wear process is more pronounced in areas of occlusal contact. Those data confirm results of an *in vitro* study, which showed less wear for Vita Enamic than for enamel [29]. Therefore, within the limitations of this study, PICNs could be considered suitable materials for the treatment of generalized wear, as they resist wear phenomena at least as well as enamel, and do not induce excessive wear of antagonistic restorations when they are made of the same material. In fact, the material may even wear a little more to better mimic enamel. However, it should be noted that the results were patient dependent, and an explanation of this effect may be the wearing of a nightguard. In fact, 3 out of the 7 patients reported not to wear it, and those patients showed higher values of material wear after 5 years (patients 1, 6 and 7). However, there is no proof that the other patients wore their nightguards every night and patient 7 also showed a higher value of material wear despite reporting wearing the nightguard. Other patient-related factors could affect the wear behaviour, such as lifestyle, and most of all severity of bruxism (awake and sleep), which were previously shown to influence the risk level of material wear [30]. In addition to their wear behaviour, PICNs offer numerous advantages in the context of the one-step no-prep protocol, such as their ability to be milled in very low thickness and their damping effect.

Comparison of the present results with the data in the literature is difficult, since intraoral wear of CAD-CAM composites has been poorly studied (to date and to the authors' knowledge, only two *in vivo* studies are available) and measurement methods vary [13] [14] [15]. In fact, different methods have been reported to assess material wear clinically, and Wulfman et al. have reported an important lack of standardization of wear measurement procedures in clinical studies and an important variation in terms of the performance of the different measurement workflows described [17]. Digital profilometry combined with a matching software is reputed as the best technique for wear measurement in clinical studies [31] [32] and is the most often used tool. In the present study, a rate of excluded scans of 13.32% was reported, which is a low and acceptable rate compared to the literature [17] and can be attributed to the precaution implemented within the protocol, aimed at acquiring scans of elevated quality and precision.

Replica use should be avoided as much as possible, but this option is only valid for restorations that can be removed and scanned directly [17]. In fact, replicas generate inaccuracies mainly due to the deformation of the impression material, the casting or the presence of positive bubbles on the surface (see Figure 5). The present protocol aimed to reduce some of these inaccuracies, in particular through the cleaning of the restoration, the injection technique, the use of a hydrophilic silicone and the use of a customized impression tray, which reduces the amount of impression material and allows better control of the silicone layer. In most cases, positive bubbles were unique and smaller than 0.2 mm in diameter (see Figure 5). They were also located at the bottom of the groove, which does not interfere with the analysis of the OCA. On the other hand, the use of intraoral scanners is promising for analyzing the wear of restorative materials and dental tissue [33], but currently they lack accuracy and precision [34]. In the first study related to intraoral wear of CAD-CAM composites [13], 24 single crowns were performed in different materials (two lithium-based glass-ceramic (IPS e-max CAD and Vita Suprinity), one DF CAD-CAM composite (Cerasmart (GC) and PICN (Vita Enamic)). The measurement and recording of the crown surfaces using an intraoral scanner were carried out in the short term. At 6 months, no significant differences were detected between li-based glass-ceramic materials and CAD-CAM composites (DF and PICN) in terms of material and wear-induced antagonist [13]. However, there was a significant difference between DF and PICN, in which DF were shown to be subjected to higher material wear, in addition to being less abrasive for the antagonist. In the second study [14] [15], 12 patients underwent complete rehabilitation with full occlusal coverage restorations (experimental DF CAD-CAM composite or lithium-based glass-ceramic). Impressions were made and the models were scanned with a laboratory scanner (D810, 3Shape, Copenhagen, Denmark), which is less accurate than the scanner used in the present study [17]. At 1 year, the mean material wear for pressed lithium disilicate ceramic restorations was  $90.0 \pm 40.8 \mu\text{m}$  (mean  $\pm$  SD) for the premolar and  $93.6 \pm 24.0 \mu\text{m}$  for the molar, while the mean material wear of the experimental DF CAD-CAM composite was  $186 \pm 107 \mu\text{m}$  (mean  $\pm$  SD) for the premolar and  $342 \pm 242 \mu\text{m}$  for the molar, respectively [15]. These values are much higher than the present results and can be explained by the method used. Results can also be compared with data related to direct composites. Recently, Ning et al. reported results after 5 years of patients with severe tooth wear treated with direct composite restorations made of two different composite materials. Quantitative wear analysis was performed using intra-oral 3D scans (LAVA COS/True Def, 3M) superimposed with Geomagic software (3D Systems, Morrisville, North Carolina, USA). The results showed a mean wear on bearing cusps of molars of  $-464 \pm 185 \mu\text{m}$  (mean  $\pm$  SD) and  $-318 \pm 281 \mu\text{m}$  (mean  $\pm$  SD) for

the two different composite materials, respectively. These values are much higher than those of natural tooth tissue, which highlights one of the disadvantages of direct composites. In the same way, Söderholm et al. reported, using replica and 3D-profilometry, a mean vertical height loss of direct composite of 102  $\mu\text{m}$  after 1 year [24] while two other studies reported, with the same method, values between 20 and 40  $\mu\text{m}$  [35, 36]. Glass-ceramic 1-year mean material wear in the frame of full-mouth treatment was mentioned to vary between 12  $\mu\text{m}$  (feldspathic ceramic) [37] and 90  $\mu\text{m}$  (lithium-based glass-ceramic) (replicas and 3D-laser profilometry) [15]. Surprisingly, these values are also superior to the results of the present study.

Future prospects include the study of material wear resistance at longer term and the evolution of intra-oral scanner resolution, which should make it possible to avoid the use of replicas and improve final accuracy and precision.

## **5. Conclusion**

In the context of the treatment of severe tooth wear, PICN (Vita Enamic), with the same material as antagonist, shows lower material wear values than reported for natural enamel. It does not induce a significant abrasive effect, thus promoting the stability of the recreated vertical dimension of the occlusion while allowing the adaptation of occlusal contacts to function over time. On the basis of the concept that the ideal restorative material for a single-unit restoration should behave like natural tooth tissue in a biomimetic approach, PICNs are appropriate and in-between materials, since zirconia are reported to be wear-resistant, and direct composites wear too much. PICN material wear was limited to occlusal contacts and, at 5 years, the restorations showed excellent clinical results with a survival and a success rates of 99.48% and 90.62%, respectively. In conclusion, PICNs appear to be adapted to severe tooth wear treatment in high-risk patients with bruxism, considering that they combine the advantages, without the disadvantages, of direct composites and reinforced glass-ceramics in terms of material wear, and the ability to be milled in very low thickness (promoting no-prep treatment), as well as the ability to deform thanks to the presence of polymer (promoting occlusal stress adaptation).

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## Bibliography

- [1] A.K. Mainjot, N.M. Dupont, J.C. Oudkerk, T.Y. Dewael, M.J. Sadoun, From Artisanal to CAD-CAM Blocks: State of the Art of Indirect Composites, *J Dent Res* (2016).
- [2] H. Zaghoul, D.W. Elkassas, M.F. Haridy, Effect of incorporation of silane in the bonding agent on the repair potential of machinable esthetic blocks, *Eur J Dent* 8(1) (2014) 44-52.
- [3] R. Giordano, Materials for chairside CAD/CAM-produced restorations, *J Am Dent Assoc* 137 Suppl (2006) 14S-21S.
- [4] J.F. Nguyen, V. Migonney, N.D. Ruse, M. Sadoun, Resin composite blocks via high-pressure high-temperature polymerization, *Dental materials : official publication of the Academy of Dental Materials* 28(5) (2012) 529-34.
- [5] J.L. Ferracane, T.J. Hilton, Polymerization stress - Is it clinically meaningful?, *Dent Mater* (2015).
- [6] M. Sadoun, Composite ceramic block, US, 2011.
- [7] M.V. Swain, A. Coldea, A. Bilkhair, P.C. Guess, Interpenetrating network ceramic-resin composite dental restorative materials, *Dent Mater* (2015).
- [8] L.H. He, M. Swain, A novel polymer infiltrated ceramic dental material, *Dent Mater* 27(6) (2011) 527-34.
- [9] M. Eldafrawy, J.F. Nguyen, A.K. Mainjot, M.J. Sadoun, A Functionally Graded PICN Material for Biomimetic CAD-CAM Blocks, *J Dent Res* 97(12) (2018) 1324-1330.
- [10] A.K.J. Mainjot, The One step-No prep technique: A straightforward and minimally invasive approach for full-mouth rehabilitation of worn dentition using polymer-infiltrated ceramic network (PICN) CAD-CAM prostheses, *J Esthet Restor Dent* (2018).
- [11] J. Oudkerk, M. Eldafrawy, S. Bekaert, C. Grenade, A. Vanheusden, A. Mainjot, The one-step no-prep approach for full-mouth rehabilitation of worn dentition using PICN CAD-CAM restorations: 2-yr results of a prospective clinical study, *J Dent* 92 (2020) 103245.
- [12] W. Banh, J. Hughes, A. Sia, D.C.H. Chien, S.K. Tadakamadla, C.M. Figueredo, K.E. Ahmed, Longevity of Polymer-Infiltrated Ceramic Network and Zirconia-Reinforced Lithium Silicate Restorations: A Systematic Review and Meta-Analysis, *Materials (Basel)* 14(17) (2021).
- [13] A. Aladağ, D. Oğuz, M.E. Çömlekoğlu, E. Akan, In vivo wear determination of novel CAD/CAM ceramic crowns by using 3D alignment, *J Adv Prosthodont* 11(2) (2019) 120-127.
- [14] J.F. Güth, K. Erdelt, C. Keul, G. Burian, J. Schweiger, D. Edelhoff, In vivo wear of CAD-CAM composite versus lithium disilicate full coverage first-molar restorations: a pilot study over 2 years, *Clinical oral investigations* 24(12) (2020) 4301-4311.
- [15] G. Burian, K. Erdelt, J. Schweiger, C. Keul, D. Edelhoff, J.F. Güth, In-vivo-wear in composite and ceramic full mouth rehabilitations over 3 years, *Sci Rep* 11(1) (2021) 14056.
- [16] M. Laborie, A. Naveau, A. Menard, CAD-CAM resin-ceramic material wear: A systematic review, *J Prosthet Dent* (2022).
- [17] C. Wulfman, V. Koenig, A.K. Mainjot, Wear measurement of dental tissues and materials in clinical studies: A systematic review, *Dent Mater* 34(6) (2018) 825-850.
- [18] A.D. Backer, E.A. Munchow, G.J. Eckert, A.T. Hara, J.A. Platt, M.C. Bottino, Effects of Simulated Gastric Juice on CAD/CAM Resin Composites-Morphological and Mechanical Evaluations, *J Prosthodont* 26(5) (2017) 424-431.
- [19] J.L. Ferracane, Hygroscopic and hydrolytic effects in dental polymer networks, *Dent Mater* 22(3) (2006) 211-22.
- [20] e.a. D'Incau, Validité du diagnostic du bruxisme du sommeil, *Rev Odont Stomat* 46 (2017).

- [21] F. Lobbezoo, C.M. Visscher, M. Koutris, P. Wetselaar, G. Aarab, Bruxism in dentists' families, *J Oral Rehabil* 45(8) (2018) 657-658.
- [22] A.A.O.S. Medicine, International Classification of Sleep Disorders, 3rd edn, American Academy of Sleep Medicine Darien (ed), IL ; 2014. Cat 1 (2014).
- [23] V. Koenig, C. Wulfman, S. Bekaert, N. Dupont, S. Le Goff, M. Eldafrawy, A. Vanheusden, A. Mainjot, Clinical behavior of second-generation zirconia monolithic posterior restorations: Two-year results of a prospective study with Ex vivo analyses including patients with clinical signs of bruxism, *J Dent* 91 (2019) 103229.
- [24] K.J. Söderholm, P. Lambrechts, D. Sarrett, Y. Abe, M.C. Yang, R. Labella, E. Yildiz, G. Willems, Clinical wear performance of eight experimental dental composites over three years determined by two measuring methods, *Eur J Oral Sci* 109(4) (2001) 273-81.
- [25] M. Rosin, C. Splieth, M. Hessler, C. Gärtner, B. Kordass, T. Kocher, Quantification of gingival edema using a new 3-D laser scanning method, *J Clin Periodontol* 29(3) (2002) 240-6.
- [26] U. Lohbauer, S. Reich, Antagonist wear of monolithic zirconia crowns after 2 years, *Clinical oral investigations* 21(4) (2017) 1165-1172.
- [27] P. Lambrechts, M. Braem, M. Vuylsteke-Wauters, G. Vanherle, Quantitative in vivo wear of human enamel, *Journal of dental research* 68(12) (1989) 1752-4.
- [28] J.F. Esquivel-Upshaw, W.F. Rose, Jr., A.A. Barrett, E.R. Oliveira, M.C. Yang, A.E. Clark, K.J. Anusavice, Three years in vivo wear: core-ceramic, veneers, and enamel antagonists, *Dent Mater* 28(6) (2012) 615-21.
- [29] Z. Xu, P. Yu, D.D. Arola, J. Min, S. Gao, A comparative study on the wear behavior of a polymer infiltrated ceramic network (PICN) material and tooth enamel, *Dent Mater* 33(12) (2017) 1351-1361.
- [30] K. Ning, E. Bronkhorst, A. Bremers, H. Bronkhorst, W. van der Meer, F. Yang, S. Leeuwenburgh, B. Loomans, Wear behavior of a microhybrid composite vs. a nanocomposite in the treatment of severe tooth wear patients: A 5-year clinical study, *Dent Mater* 37(12) (2021) 1819-1827.
- [31] R. DeLong, Intra-oral restorative materials wear: rethinking the current approaches: how to measure wear, *Dent Mater* 22(8) (2006) 702-11.
- [32] A. Azzopardi, D.W. Bartlett, T.F. Watson, B.G. Smith, A literature review of the techniques to measure tooth wear and erosion, *Eur J Prosthodont Restor Dent* 8(3) (2000) 93-7.
- [33] T. Stober, N. Heuschmid, G. Zellweger, V. Rousson, S. Rues, S.D. Heintze, Comparability of clinical wear measurements by optical 3D laser scanning in two different centers, *Dent Mater* 30(5) (2014) 499-506.
- [34] S. Vandeweghe, V. Vervack, M. Dierens, H. De Bruyn, Accuracy of digital impressions of multiple dental implants: an in vitro study, *Clin Oral Implants Res* 28(6) (2017) 648-653.
- [35] S. Palaniappan, D. Bharadwaj, D.L. Mattar, M. Peumans, B. Van Meerbeek, P. Lambrechts, Three-year randomized clinical trial to evaluate the clinical performance and wear of a nanocomposite versus a hybrid composite, *Dent Mater* 25(11) (2009) 1302-14.
- [36] R. Perry, G. Kugel, K.H. Kunzelmann, H.P. Flessa, D. Estafan, Composite restoration wear analysis: conventional methods vs. three-dimensional laser digitizer, *J Am Dent Assoc* 131(10) (2000) 1472-7.
- [37] H.W. Anselm Wiskott, J. Perriard, S.S. Scherrer, S. Dieth, U.C. Belser, In vivo wear of three types of veneering materials using implant-supported restorations: a method evaluation, *Eur J Oral Sci* 110(1) (2002) 61-7.