Three-body wear of 3D printed temporary materials

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ARTICLE INFO

ABSTRACT

Objective. The aim of this study was to investigate the three-body wear of different additively manufactured temporary materials, one temporary PMMA material for CAD/CAM milling and one resin-based composite for direct restorations as a control group by using an ACTA machine.

Methods. Specimens (n = 8) of the 3D printing materials 3Delta temp, NextDent C&B, Freeprint temp were additively manufactured by DLP 3D printer. Postprocessing was carried out according to the manufacturer's specifications. Telio CAD were cut out of blocks, Tetric Evo-Ceram was applied directly and light cured. Three-body wear was simulated with an ACTA machine. Data were statistically analysed (ANOVA, post hoc test: Tukey, p < 0.05). The worn surfaces of the specimens were examined with a FE-SEM.

Results. The average mean wear was $50 \pm 15\,\mu m$ for Tetric EvoCeram < $62 \pm 4\,\mu m$ for 3Delta temp < $236 \pm 31\,\mu m$ for Telio CAD < $255 \pm 13\,\mu m$ for NextDent C&B < $257 \pm 24\,\mu m$ for Freeprint temp. After 200,000 cycles, the wear and wear rates for Tetric EvoCeram and 3Delta temp were significantly lower than those for the other materials. SEM revealed that 3Delta temp has a higher filler proportion than the other 3D printing materials but less than Tetric EvoCeram.

Significance. The filler content influences the wear behaviour of additively manufactured materials as well as dental restorative composite materials. While most 3D printing materials have a low inorganic filler load, which qualifies the materials for temporary use only, one 3D printing material has an optimized composition that would qualify the material for longer clinical service time if wear is considered as the outcome variable.

1. Introduction

The application of computer aided design (CAD) and computer aided manufacturing (CAM) in dentistry has developed significantly over the last two decades. The work sequence consists of a total of three sub steps: data acquisition by 3D scanning, design of the object in the CAD software and its manufacturing by the subtractive or additive CAM system. In dentistry, CAM systems such as milling machines are most frequently used. Today more than 25 years have passed since the introduction of 3D printing technology and most

patents have expired. This has enabled other companies to bring numerous new additive systems into market in recent years, which has encouraged the development of new applications and new materials for dentistry. 3D printing machines are now affordable, get smaller and lighter. Nowadays, additive systems are no longer just a niche product, but are already superior to subtractive manufacturing in certain areas of dentistry [1,2]. Currently the 3D printing technology is mainly used to build models, implant templates, splints and temporary restorations [3–6]. Important advantages of 3D printing are that several objects can be produced per processing operation, a reproduction of complex geometries is possible and material gradients can theoretically be generated. With regard to the material properties it seems like there is still inferiority of printed objects, there is still inferiority to subtractive materials.

3D printing or additive manufacturing is a generic term for various processes. The most widely used method in dentistry is stereolithography (SLA) and the related digital light processing (DLP) technique. The SLA and DLP Technique uses a vat of curable photopolymer resin, where a build plate descends in small increments and the liquid polymer is exposed to light for polymerisation. At the SLA approach the UV laser or laser diode draws a cross section layer by layer to build up the object. The DLP approach uses a digital projector screen to transfer a single image of each layer across the entire build plate at once. Recently, new 3D printing temporary resins for the indication of onlays, crowns and bridges have been released. The materials differ in their filler content and can be used for a medium-term application up to 24 months. They are therefore particularly suitable for fixed tooth-coloured splints. Edelhoff et al. have shown previously the benefit of fixed tooth-coloured splints in the form of individual PMMA restorations for newly defined occlusal dimension [7,8]. The restorations are fabricated with conventional restauration material on the basis of a wax-up or with a CAD/CAM system, closely approximate the definitive restorations in terms of their function and aesthetics. Bonded tooth-coloured splints provide a pleasant aesthetic and functional evaluation of newly occlusal dimension in terms of a 24-h treatment.

However, little is known about the properties of the 3D print materials in such a long period of use. An important factor for midterm use is a high wear resistance of the materials in order to maintain the vertical dimension. In vitro wear tests are useful for the fast assessment of the wear resistance of resin composite materials. The purpose of this study was to investigate the three body wear resistance of 3D printed resin materials in comparison to one milled PMMA and one direct composite materials.

The null hypothesis tested in this study was that there would be no significant differences in amount of wear between the materials regardless of their manufacturing technique.

2. Material and methods

Table 1 summarizes the materials investigated and their main compositions as publicly made available. Five restorative materials were investigated. Three 3D printed materials for temporary use: 3Delta temp (Deltamed, Friedberg, Germany),

C&B (NextDent, Soesterberg, Netherlands), Freeprint temp (Detax, Ettlingen, Germany). As negative control group the milled PMMA material TelioCAD (Ivoclar Vivadent, Schaan, Liechtenstein) and as positive control group the direct resin composite Tetric EvoCerman (Ivoclar Vivadent, Schaan, Liechtenstein) were tested.

For producing the 3D printed samples, a computer-assisted STL file was created in Fusion360 (Autodesk, Mill Valley, USA) and imported into the CAMbridge software (3shape, Copenhagen, Denmark), where the samples were positioned parallel to the building platform. Subsequently, this file was imported into the software Netfabb (Autodesk, Mill Valley, CA, USA) for final preparation of the 3D printing process. All 3D print materials were manufactured by using the bottom up 3D printer D20II (Rapidshape, Heimsheim, Germany) with the corresponding material settings. Postprocessing was carried out according to the manufacturers' specification, e.g. samples of Freeprint temp and Nextdent C&B were cleaned for 5 min in an ultrasonic activated bath of 96% ethanol. Delta temp was cleaned by centrifugal force for 3 min (Allegra X-15R, Beckmann-Coulter Life Science, Indianapolis, IN, USA). Subsequently all samples were post-cured for 2×2000 flashes under nitrogen atmosphere (Otoflash G171, NK Optik, Baierbrunn, Germany). PMMA samples were cut out of TelioCAD blocks. Specimens (n = 8 per material) were fixed adhesively with in an ACTA sample-holder-wheel, Tetric EvoCeram was applied directly and light cured (Elipar Freelight 2, 3M-ESPE, Seefeld, Germany) for 20 s. ACTA wear testing was carried out as previously published [9]. For testing three-body wear in the ACTA machine a sample wheel and an opposing metal wheel were rotated against each other in a bowl containing a third-body medium [10]. In order to simulate the sliding movements and physiological forces appearing during chewing, the antagonist wheel rotated 15% slower than the sample wheel and was pressed against it with a spring force of 15 N. Two sample wheels, with 16 specimens in each have been prepared. The sample wheels were stored in distilled water for 24 h and wet ground with diamond wheels to obtain a perfect cylindrical surface. Subsequently the materials were abraded during 200,000 cycles in a standardized aqueous suspension of ground millet seeds, which was renewed every 50,000 cycles. The wear track was scanned (LaserScan3D, Willytec, Munich, Germany) at 50,000/100,000/150,000/200,000 cycles perpendicular to the running direction of the sample wheel with 1600 line scan measurements per wheel and compared to the two unworn reference planes flanking the abraded area. The average depth of the worn surface relative to the reference planes represented the wear in μm which was evaluated with the computer program MATCH3D (Gloger, Weilheim, Germany). The wear rate was calculated by the upward gradient m plotting a straight line through the measuring points 50,000/100,000/150,000/200,000. Mean values and standard deviations were calculated by the Programm R. Data were statistically analysed using ANOVA and Tukey's test as post hoc test. Differences with $p < 0.05$ were considered to be significant. For the qualitative analysis of the worn surface, one specimen from each material was examined at $5000\times$ and $10,000\times$ magnification with a scanning electron FE-SEM (DSM 982, Zeiss, Oberkochen, Germany)

Table 1 – Brand names, manufacturers, composition (according to manufacturer), and batch numbers of materials tested.

Material	Manufacturer	Lot Number	Matrix	Filler	Filler
3Delta temp	Deltamed, Friedberg, Germany	174909	Methacrylate	Siliziumsdioxid, Dental glass	50wt% 30 vol%
Nextdent C&B	Nextdent, Soesterberg, Netherlands	XK134N01	Methacrylic oligomers, Phosphine oxides		
Freeprint temp	Detax, Ettlingen, Germany	200703	45 - <60 wt% Iso-propylidenediphenol Peg-2 Dimethacrylat, 1 - < 5 wt% 2 Hydrox-yethylmethacrylat, 1 - < 5 wt% Diphenyl(2,4,6 trimethylbenzoyl) phosphinoxid, 1 - <5 wt% Hydrox-ypropylmethacrylat, < 1 wt% Phenyl-bis(2,4,6-trimethylbenzoyl)-phosphinoxid		
Telio CAD	Ivoclar Vivadent, Schaan, Liechtenstein	X37975	Polymethylmethacrylat, Pigments		
Tetric EvoCeram	Vivadent, Schaan, Liechtenstein	X26790	Bis-GMA, Urethane dimethacrylate, Ethoxylated Bis-EMA	Barium glass filler, Ytterbiumtrifluoride, Mixed oxide	82.5 Inorganic filler 75–76 wt%, 53–55 vol%

Table 2 – Mean wear loss (μm) after 50,000, 100,000, 150,000, 200,000 cycles, sd, homogenous subgroups ($\alpha = 0.05$) and wear rate (μm/cycle).

Material	Mean wear loss				Wear rate
	50,000	100,000	150,000	200,000	
3D Delta temp	16(2)a	32(1,4)a	48(3)b	62(4)a	0.30
Nextdent C&B	66(5)b	134(4,6)b	200(7)c	255 (13)b	1.3
Freeprint temp	57(5)c	125(2,8)bc	191(6)c	257(24)b	1.3
Telio CAD	56(5)c	111(210)c	178(10)d	236(31)b	1.2
Tetric EvoCeram	13(5)a	23(2,3)a	35(9)a	50(15)a	0.24

3. Results

The mean wear values, standard deviation, homogenous sub-groups and wear rate of the evaluated materials are shown in Table 2 and graphically depicted in Fig. 1. The wear values after 200,000 cycles ranged from $50 \pm 15\,\mu$m for Tetric EvoCe-ram to $257 \pm 24\,\mu$m for Freeprint temp. Wear rate ranged from $0.24\,\mu$m/cycle for Tetric EvoCeram to $1.3\,\mu$m/cycle for Freeprint temp and Nextdent C&B. Statistical analysis by ANOVA and Tukey's post hoc test revealed a significant difference ($P < 0.05$) between the test materials in terms of wear and wear rate.

After 200,000 cycles, two significantly different groups can be observed. The conventional direct composite Tetric EvoCeram showed the highest wear resistance in the ACTA wear simulation. 3Delta temp revealed the lowest wear in the group of 3D printed materials and was in one subgroup with Tetric EvoCeram. The CAD/CAM material Telio CAD was in the subgroup of Freeprint temp and Nextdent C&B. The wear rate revealed also two significantly different groups after testing the materials for 200,000 wear cycles. The composite Tetric EvoCeram showed the lowest wear rate with $0.24\,\mu$m/cycles. The printed resin 3Delta temp revealed a wear rate of $0.30\,\mu$m/cycles with no significant difference to Tetric EvoCeram.

SEM pictures displayed differences in the worn surface. The hybrid composite Tetric EvoCeram showed different kind of inorganic fillers with a diameter of $<2\,\mu$m and hybrid prepoly-mers of up to $15\,\mu$m. The matrix is partially eroded and plucked out fillers appear as voids. Scratches caused by wear particles can be seen on the surface of the material (Fig. 1a).

Shell-shaped cracks indicate a brittle fracture of the mate-rial. 3Delta showed homogeneously distributed irregular glass fillers with a diameter of $<1\,\mu$m. Defects that appeared to be caused by filler exfoliations were observed (Fig. 1b). The mate-rials Nextdent C&B, Telio Cad and Freeprint print revealed smooth surfaces, fragments of prepolymers, individual areas of plastic deformation with polymer stretching of the matrix and delamination. No larger quantity of inorganic fillers could be detected (Fig. 1c-d).

4. Discussion

The wear resistance is one of the most important factors for the functionality of long-term temporaryrestorations in the oral cavity. In contrast to material properties like for example
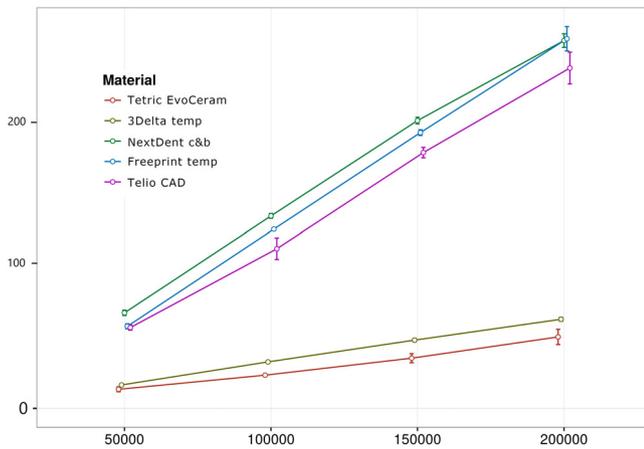
Fig. 1 – Variation of mean wear [μm] with standard deviation as a function of slicing cycles for evaluated materials. Two significant groups were formed after 200,000 cycles.

elastic modulus, hardness or flexural strength, wear is not a material property but system property resulting from the complex interaction of various factors of the tribosystem used of the wear tests.

A distinction is made between masticatory simulators, in which the crushing of food is simulated, and masticatory simulators, which simulate direct tooth-to-tooth contact. The so-called two-body wear simulators, which do not simulate food slurry, have a number of limitations. One of the limitations is the control of the touchdown impulse, which does not exist in the mouth, in two-body wear simulators. Furthermore the simulation of cyclic temperature loads can be a challenge because of the thermal hysteresis of the piping system and the sample chamber [11]. The material, shape and surface treatment of the antagonist also have a considerable influence on the amount of wear of two-body wear simulators: enamel antagonists allow realistic contact simulation. The large variation range of the tooth shape, however, results in a considerable variation of the results. Although the hardness of steatite, is similar to the hardness of enamel, relatively large wear particles are created in the wear simulation, which turns two-body wear into three-body wear [11,12]. The choice of hard antagonists (Empress or Degussit) does not change the shape of the antagonist during the experiments. However, it is only possible to compare materials with similar properties. The reason for this is the non-linear geometry of the spherical antagonist. As long as the tested materials show similar wear behaviour, the contact surface is of the same order of magnitude and even small differences in wear behaviour between the materials can be detected. But as soon as a material shows more wear, filler trapping occurs in the wider contact area and the interpretation of the wear results is no longer straightforward [13]. In the two-body wear simulator one can also observe material transfer to the opposing tooth [14], plastic deformation by creep [13] and the formation of a tribofilm [15]. Under clinical conditions, no material transfer takes place due to the lubrication with saliva and no tribofilm is formed due to the additional food wear. The geom-

etry of the cylindrical antagonist causes a linear increase in the wear rate in the steady state [16]. De Gee and Pallav have very well investigated and documented the wear mechanisms of the ACTA machine [10,17–20]. Gügel et al. identified phytoliths as an abrasive component of the food slurry in the ACTA wear simulation, which prevent the formation of a tribofilm [21]. Thus, the dominant wear mechanism of the ACTA machine is abrasive removal of the matrix between the fillers, which consequently leads to filler-plucking [22]. The linear wear rate and the absence of artifacts such as tribofilm, material transfer and creep qualify the ACTA machine for the comparison of materials with very variable composition and very different mechanical properties as the materials in our study.

3D printing resins have specific viscosity requirements which distinguish them from conventional composites. 3D printer manufacturers face certain challenges: After each exposure cycle, the build platform is raised to ensure that the resin can flow between the gap between the platform and vat. When the viscosity is increased by amount of fillers, gravity and surface tension will no longer be capable to produce a smooth surface, causing the object to be printed incompletely [23–25]. From a procedural point of view, a resin with low viscosity is therefore required, while at the same time fillers must be incorporated in order to improve the mechanical properties and achieve radiopacity. By integrating a volume fraction of large fillers into the 3D printing resin, the total surface area of the fillers can be reduced. The viscosity can thus be kept low and the mechanical properties constant. Compared to conventional composites, the total volume fraction of fillers must be much smaller to keep the materials flowable. 3D printing resins are often stored for longer time in bottles or printing reservoir which contains up to one litre, consequently the mixture of exclusively large fillers would lead to sedimentation and thus irregular distribution of filler. The curing depth is influenced by the amount of photo initiators, the irradiation conditions of the printer (wavelength, power and exposure time), the temperature of the monomer and absorbent ingredients, such as the pigments and fillers. While the first factors can be kept constant, the irregular distribution of fillers can lead to considerable effects on the printing accuracy. The curing depth influenced by the light scatter within the material is described by the law of Beer Lambert [26].

$$z_p = \delta_p \ln \frac{t_p}{T_c}$$

where z_p is the penetration depth in the z direction, t_p is the time it takes to reach the critical dose for polymerization at depth z_p, T_c is the time it takes to reach the critical dose for curing at depth z_0, and δ_p is the characteristic penetration depth, which is also expressed as $\delta_p = 1/\alpha$

$$\alpha = \frac{4\pi k}{\lambda}$$

where λ is the wavelength of the laser and k is the extinction coefficient.

The extinction coefficient k depends on the intrinsic properties of the resin, which includes the loading of fillers, the surface of the fillers and the refractive index of both the fillers and resin. If agglomeration or sedimentation of fillers causes a change in the refractive index between fillers and resin, the

laser light is scattered more strongly, resulting in a reduced polymerization depth. On the one hand, this can lead to the previous layer not being joined to the next, and on the other hand, the light scattering cures more resin around the laser beam, resulting in reduced resolution [23]. Both can result in reduced mechanical properties due to anisotropy. In worst case the lacking connection between the layers can entail in a termination of the printing process. If, on the other hand, the filler load is too low, the light can spread further and the resin volume to be cured increases, leading to polymerisation of layers that are too thick. A homogeneous distribution of the fillers has therefore high priority for the manufacturers. Another possibility to solve this problem is the surface modification of the large fillers. An increased roughness depth is achieved, which prevents the fillers from sinking. Additional smaller fillers can be used to slow down the sinking of the large fillers. However, small fillers have a large total surface, absorbing a lot of resin and resulting finally in increased viscosity of the material. By using round fillers the effect of the viscosity increase can partly compensated. The simplest way to obtain a printable resin, however, is to dispense with larger quantities of fillers at the expense of mechanical properties and to mix only the necessary rheology modifiers and pigments into the resin.

The fact that manufacturers recommend various mixing processes such as shaking, stirring or special roller/tilt mixers up to one hour before using the resins in order to ensure homogeneous distribution of the material shows that homogeneous distribution continues to be a major challenge for manufacturers. In this study, a 3D printing material (3Delta temp) was used which, according to the manufacturer, contains 30% fillers by volume; no comparable information are available for the other two 3D printing materials. The materials Freeprint temp, Nextdent C&B and Telio CAD, which can be found in a homogeneous subgroup, showed the highest absolute wear and wear rate after 200,000 cycles. Therefor the null hypothesis that there is no significant different value of wear between the materials has to be rejected. In contrast to two-body wear testing where compressive and tensile stresses are built up on the filler matrix interface in large dimensions, in three body wear, the inorganic fillers are not loaded directly to a large extend. The abrasive particles mainly wear out the weaker matrix until the fillers are pluck out finally. According to the principle of the matrix protection theory formulated by Jörgensen [27–29] and further explored by Bayne et al. [30], there is a significant influence of the fillers if they are in the scale of the abrasive. Past studies have therefore reported a protective effect of filler incorporation in relation to three body abrasion wear [31–37]. The filler size, shape and the filler volume are shown of particular importance [36]. When the fillers are homogenously dispersed in the matrix and much smaller than the abrasive, they are removed by the abrasive together with the matrix. Wear protection therefore only occurs if the filling material has a size comparable to that of abrasive particles. Previous studies have shown that the presence of small filler particles is beneficial for wear resistance [30,38], especially fillers under 2 μm and particles between 9 and 20 μm play a major role in wear inhibition [39]. The small particles can be packed denser, thus the inter-particle distance is decreased and the filler can work as a microscopic protection

shield against wear of the soft matrix. Bayne reported about an interparticle space of under 0,1 μm working sufficient as wear protection [30]. However, it should be noted, that a direct comparison of the effect of small and large filler is difficult, because the filler volume is not equal. The evaluation of the filler shape with identical particle size showed that irregularly shaped filler particle was more resistant against wear than spherically shaped fillers due to the higher specific surface area for adhesion. Accordingly porous fillers showed a better bonding to the matrix and consequently reduced abrasion of the composite [37,40]. 3Delta temp, which exhibits the lowest total wear and wear rate within the group of 3D printing materials, showed in the SEM images homogeneously distributed irregular glass fillers. The average size of the fillers is less than 1 μm. Detached fillers can be seen through pores, which indicates loss of fillers due to abrasion. The significantly more worn materials Freeprint temp and Nextdent C&B showed a smooth surface with widely distributed fillers and prepolymers. The SEM observations of the materials with regard to wear behaviour are therefore in line with the studies described above.

Concerning the filler volume content, one has to consider that the amount of the different filler fractions is not disclosed by all manufactures. According to the manufacturer 3Delta temp contains 50 wt% and 30 vol% of silanized siliziumdioxid and dental glass filler. The conventional direct composite Tetric EvoCeram is in the same homogeneous group as 3Delta temp. The manufacturer specifies a total content of inorganic filler of 75–76 wt% and 53–55 Vol%. The same amount of abrasion of the two materials cannot therefore be explained by the filler content alone. In addition to the filler volume content their adhesion to the matrix by silan coupling agent, the type of matrix and conversion of the matrix plays also a decisive role in the discussion of wear [41–47].

The main matrix component of 3Delta temp is UDMA while Tetric EvoCeram contains Bis-GMA, UDMA and Bis-EMA. The advantages of UDMA is a lower viscosity due to a highly flexible urethane linkage aliphatic core. UDMA has a smaller size and a therefore higher concentration of double bonds in contrast to Bis-GMA and Bis-EMA [48]. Resulting in higher conversion rate and hardness which can be correlated with higher wear resistance [49,50]. This assumption is supported by Sekiya et al. and Kawai et al. who report increased wear resistance of experimental resin-based UDAM composites compared to Bis-GMA-based composites, although these composites contained the same amount of fillers [51,52]. Considering these factors the type and conversion rate of the matrix could be a significant factor for the wear resistance of 3Delta temp although lower filler volume is applied in comparison to Tetric EvoCeram. However, their singular significance for the total wear of a material cannot be deciphered due to the lack of knowledge about the commercial materials.

The SEM images of the materials showed surface defects that allow conclusions to be drawn about local failure mechanism. Deep erosion of the matrix has exposed the glass fillers at the surface due to abrasive wear in Tetric EvoCeram and 3Delta Temp, to a large extend still integrated into the matrix due to their shape and also their adhesive pretreatment with silane. Compared to the filled materials the wear rate is four to five time higher for the materials Freep-
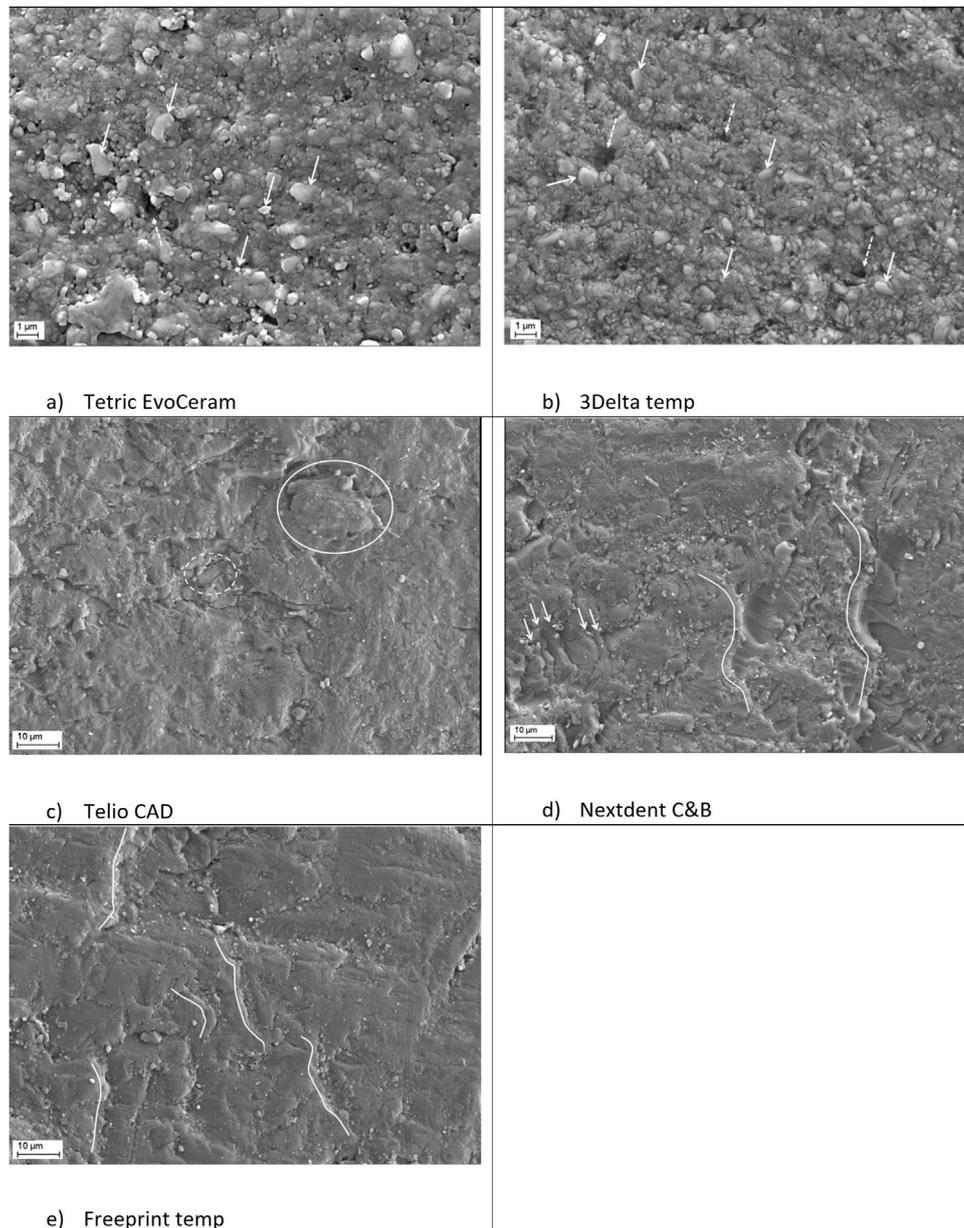
Fig. 2 – SEM micrographs of the wear surfaces inside the wear scars after three-body wear with 200,000 wear cycles show (Magnification1000× or 5000×). Individual filler particles of different size and distribution can detected on the worn surface (a and b) (white arrows), there are defects caused by detached fillers (a and b) (dotted arrow); c), d) and e), the worn surface on the specimens were homogenously, in the direction of abrasion individual areas of plastic deformation (white lines) with polymer stretching of the matrix (white circle), prepolymers (dotted circle) and delamination (white arrows) were observed.

rint temp, Nextdent C&B and Telio CAD. In the SEM images individual areas of polymer stretching of the matrix can be detected (Fig. 2c). Substructures which may be prepolymers can be recognized in Fig. 2c. Subcritical crack growth arrest line may be caused by the production of splinter prepolymers or by fractures. Plastic Deformation which poses as crescent-shaped waves can be seen in the wear area which has been described by Shu in the delamination theory [53]. The pressure in the contact zone of the counter surfaces compresses the millet suspension to a very thin film and causing increasing shear stresses below the material surfaces. Through these forces, acting on the matrix, local plastic deformations struc-

tural changes and finally crack formation are initiated. By printing the materials horizontally to the building platform shear stress can even result in accelerated delamination by 3D printed materials because of weaker inter-layer than intra-layer bonding [54,55]. Factors that could affect anisotropy of the parts include post-curing, printing temperatures [56,57] and axis resolution/layer thickness [57,58]. In the SEM pictures a predominantly fatigue caused material removal of the materials Nextdent C&B, Freeprint temp and Telio CAD can be recognized. An abrasive component caused by sharp-edged phytoliths, would be more clearly represented by scratches in running direction on the surface and cannot be recognized.

This observation may be explained by the relatively low E modulus of the material Freeprint temp, Nextdent C&B and Telio CAD [59]. Leading to shallow penetration depths of the abrasive phytoliths.

Most DLP printers work with LED light sources whose wavelength has an emission maximum at 385 nm. Classical activators such as camphor quinone are no longer useful because their absorption spectrum does not match the emission spectrum of the LED. Individually customized properties such as rapid polymerization and high activity at room temperature are required. A class of photoinitiators that meets the above requirements are phosphine oxide derivatives with an absorption spectrum in the violet and UV ranges. Accordingly, TPO and BAPO with an absorption spectrum of λ_{max} 380 nm and 370 nm respectively were used in the Freeprint Temp.

Even though Telio CAD is manufactured under industrial conditions with high degree of cure it did not differ with regards to the amount of wear after 200,000 and wear rate to the materials Nextdent C&B and Freeprint temp. This finding and the fact that the hybrid-filled materials showed lower wear suggests that the amount of inorganic filler provides the best wear protection and is more important than the choice of manufacturing process, matrix and degree of cure.

5. Conclusion

Within the limits of this study, it can be concluded that 3D printed temporary resin materials has comparative wear resistance to already established materials for temporary use. The knowledge of the properties seems essential for clinical material selection, as the differences between the individual materials were more pronounced than the differences between the manufacturing techniques. There is a significant difference between the 3D printed temporary materials. One 3D printed material preformed comparatively to the well-established conventional composite. The addition of filler to the resins increases the wear resistance significantly and is assigned the highest role. Therefore a material with high filler content is recommended for long term provisional use.

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