Acta Odontologica Scandinavica, 2013; 71: 482–487

ORIGINAL ARTICLE

Influence of surface treatment on the wear of solid zirconia

LEONIDAS KONTOS, CHRISTINE SCHILLE, ERNST SCHWEIZER & JÜRGEN GEIS-GERSTORFER

University of Tuebingen, Department of Prosthodontics, Section Medical Materials & Technology, Germany

Abstract

Objective. Recently there has been talk of the use of full-contour solid zirconia crowns or bridge restorations with no porcelain overlay. This could be a useful solution for patients with bruxism or limited interocclusal space. However, the hardness of zirconia could affect the opposite natural dentition. The aim of this *in-vitro* study was to investigate the role of surface treatments on the wear of a zirconia material and its antagonist. ***Materials and methods.*** Fifty plates (10 × 10 × 1 mm) made of zirconia (LavaMulti™ ZrO_2, 3M ESPE), divided into five equal groups, were sandblasted and ground under standardized conditions with a fine-grit diamond bur (Komet Brasseler, Germany) to simulate clinical conditions. Group (a) was only fired, (b) was fired and sandblasted, (c) only ground, (d) was ground and additionally polished (EVE Ceramic Polishing-Set, Pforzheim) and (e) was ground and glazed. Wear behavior was measured with a pin-on-disk apparatus ABREX against 6 mm steatite balls as antagonists (45°, 5 N load, 5000 cycles, water). The amount of wear was determined topographically using a 3-D profilometer (Concept 3D, Mahr, Germany) by measuring the height loss of the antagonist and the depth of wear Pt of the zirconia. ***Results.*** In groups (a), (b), (c) and (d) the wear value Pt could not be determined (<1 μm). Wear values of the antagonists (steatite balls) revealed a similar outcome in contact with (b), (c) and (e) in the range of 81–85 μm, whereas (e) was more abrasive but not significantly. A noticeable difference in the wear of the antagonist showed group (d) to have the smallest value. ***Conclusion.*** Polished zirconia seems to have the lowest wear on the antagonists, in contrast with the other kinds of surface treatment.

Key Words: *abrasion, glazing, polishing, sandblasting*

Introduction

Under wear in the oral cavity we understand a procedure, during which the teeth lose their natural and physiological shape and form [1]. This procedure is caused from either natural or pathological reasons [2,3]. The exact mechanism that leads to the wear of the tooth structure is, to this very day, not clear. What is known is that there exists an interaction between chemical and mechanical factors [4]. This kind of wear has an influence on the health of the human organism. This occurs because of the impairment of the masticatory system, due to a modification of the tooth-structure, of a secondary bite reduction, of a tooth-sensibility or even of an esthetic modification [5]. This process can be widely observed in patients with increased muscle tone and parafunctional habits [5–9]. However, in the case that the substance loss can be induced or even forced by the use of dental materials, this phenomenon is then more distinct. Therefore, it is important for the clinician to give serious consideration to the kind and form of treatment of the restoration materials that are used. Seghi et al. [10] suggested only the use of restoration material with a similar wear potential in comparison to the enamel. The wear potential of several materials varies obviously and depends on their type, microstructure, surface condition, roughness and of the ambient conditions [11,12].

In this context, gold alloys seem to be an advantage, besides their esthetic drawbacks, not only because of their resistance to abrasion, but also because they cause less substance loss to the opposite dentition [13]. The esthetic disadvantages of the alloys could be eliminated with the use of ceramic restorations, however these feature a higher abrasiveness [14,15]. The abrasiveness of the respective ceramic depends on several factors such as its hardness, homogeneity,

Correspondence: Dr Med Dent Leonidas Kontos, University of Tuebingen, Department of Prosthodontics, Section Medical Materials & Technology, Osianderstraße 2-8, 72076 Tübingen, Germany. Tel: +49 7071 2986191. Fax: +49 7071 295917. E-mail: leonidas.kontos@med.uni-tuebingen.de

(Received 5 December 2011; accepted 27 March 2012)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.3109/00016357.2012.696690

Table I. Material and surface treatment.

Groups	A	B	C	D	E
Surface-treatment	Fired LavaMulti™ ZrO_2 (as produced)	Fired plus sandblasted LavaMulti™ ZrO_2	Only ground with a fine-grit diamond bur LavaMulti™ ZrO_2	Ground and polished LavaMulti™ ZrO_2	Ground and glazed LavaMulti™ ZrO_2

absence of porosities, crystal size, -distribution and -morphology [5]. These crystals are essential for the increase of the hardness of the veneering ceramic. The more crystals that contain the matrix of the veneering porcelain, the more abrasive is its impact [16].

However, the hardness of the ceramic is not determining for its wear potential. According to a review [12] the hardness of the ceramic plays a secondary role for the wear of the opposite enamel. More important seem to be the microstructure, the roughness, the conditions in the oral cavity, the quality of the saliva and the pH-value. Porosities within such ceramics and other surface defects, which are produced by an inadequate firing technique, act as stress concentrators and result in greater wear, a reduction of their breaking resistance and a bad esthetic result [5]. A lot of studies claim that relatively 'soft ceramics' are more abrasive, in comparison to the so-called 'hard-ceramics' [10,17–19].

These days there is the opportunity to manufacture full anatomic restorations from an oxide ceramic, respectively from zirconia. There are only a few studies, both as *in vitro* and clinical, that are concerned with this subject. The monolithic zirconia crown, respectively bridge, has the advantage that, because of the absence of a veneering material, the danger of chipping of the weaker glass ceramic is eliminated [9]. An additional indication is in the use of restoration, that a veneering of the core material should be avoided, as for example in the case of the full ceramic inlay-bridges [20]. Moreover, the high strength of the material allows working with layer thickness. This is of benefit to the tooth structure. From the other side, the extraordinary hardness of zirconia [21,22] could lead to a higher wear of the antagonist [9]. Ideally, the wear amount of the ceramic should be equal to the annual physiological substance loss of the tooth in the molar region. This amounts to ~ 20–40 μm/year [23].

Special regard should be given to the grinding of the zirconia restoration in the mouth and to the surface treatment in the dental laboratory. The type of treatment and the choice of the instruments used can strongly influence the surface texture, which again leads to a greater wear of the opposite tooth. Wear tests *in-vitro* are basely accomplished with a chewing simulator. Besides this there are further apparatuses for wear testing, such as for example Acta (Willitech, Munich, Germany) or Abrex (Innowep, Wuerzburg, Germany).

The aim of this *in-vitro* study was to define the wear behaviour of a Y-TZP ceramic with the Abrex, after several surface treatments.

Materials and methods

Fifty plates of 10 × 10 × 1 mm made of zirconia (LavaMulti™, LOT 386437, 3M ESPE, Seefeld, Germany), were divided into five equal groups (see Table I). The specimens were ground (Group C) standardized and unilaterally with a fine-grit diamond bur (ISO-No. 806 314 111514 014, Komet Brasseler, Lemgo, Germany), with the aid of a special self-made apparatus and subsequently polished (Group D) (EVE ceramic polishing set, Ernst Vetter, Pforzheim, Germany). After grinding, Group E underwent only glazing (Cercon Ceram Kiss Glaze, DeguDent GmbH, Germany).

Figure 1. Left: the Perthometer S6P. All specimens were topographically recorded over a surface area of 3 × 3 mm with 121 profiles; right: the Abrex-Apparature.

Figure 2. Left: Steatite ball in the messing sleeve; Right: Holder of the sleeve with integrated steatite ball, which represents the antagonist.

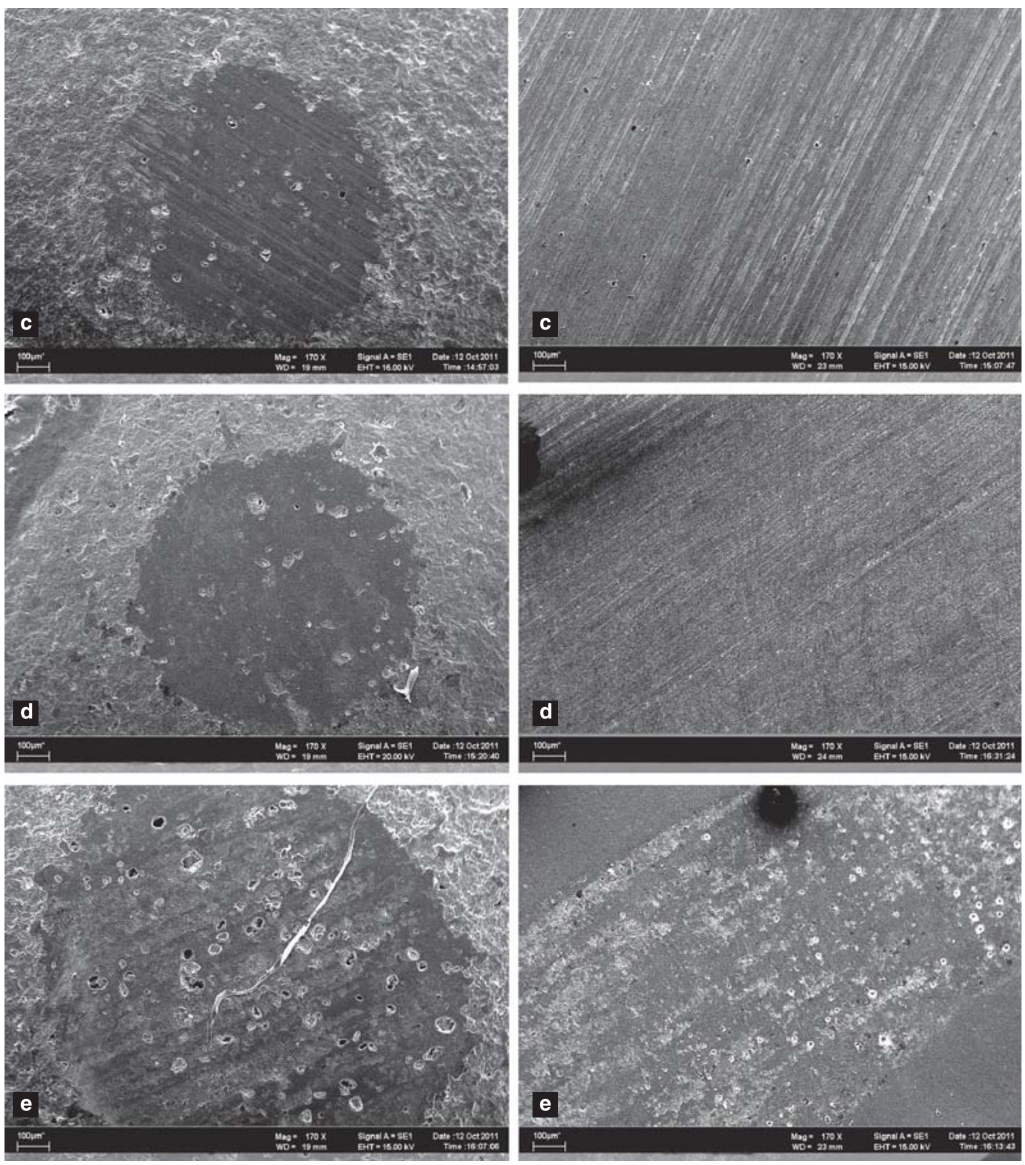

Figure 3. Exemprarily photos of the groups C (only ground), D (polished), E (glazed) from the antagonists (left) and the corresponding ZrO_2-specimens (right).

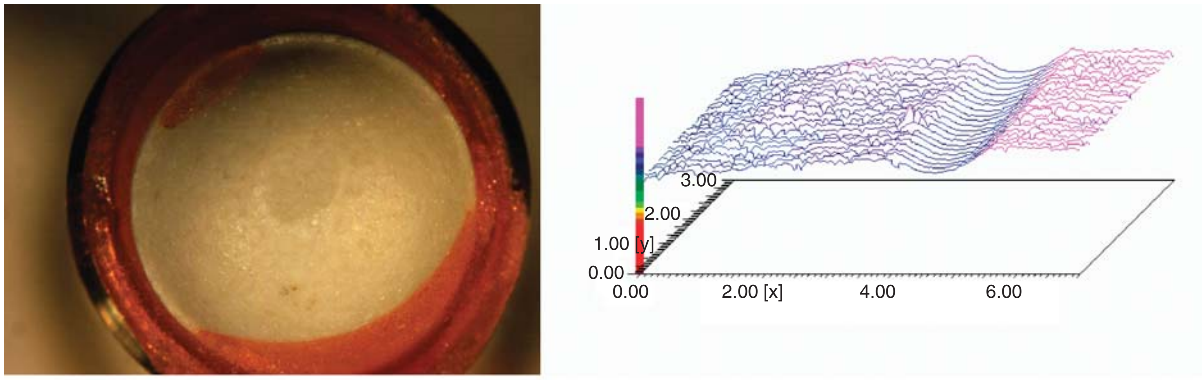

Figure 4. Left topography with visible wear trace of group E after 5000 cycles. Abrex; Right the corresponding substance loss.

Every specimen underwent a topographical detection of the starting situation and of the situation after 5000 cycles of Abrex (5 N, 45°, impact & slide) (Innowep, Wuerzburg, Germany) by using a profilometer (Perthometer R6P and software Concept 3D Ver. 7.1, MAHR GmbH, Goettingen, Germany) over a surface of 7 × 3 mm with 121 profiles (Figure 1) to determine the roughness. The wear depth was calculated from the Pt-value. For simulation of a standardized wear, steatite balls (magnesium silicate, CeramTec, Plochingen, Germany) were used as antagonists [24]. They were embedded in special sleeves with self-curing resin (GC Pattern Resin, LS GC, GERMANY GmbH) (Figure 2). The specimen was inserted into a special position on the Abrex apparatus (Figure 1). The point of the impact of the antagonist holder on the sample was adjusted and the test started. To simulate the oral humidity, the specimens were automatically kept wet with distilled water every 50 cycles for 3 s. This permanent thermal cycling with water removed wear debris from the specimen surface, kept them wet during the whole testing situation and caused additional ageing of the specimens [24].

All steatite balls were subjected to light microscopy (Wild Heerbrugg AG, Heerbrugg, Switzerland) before and after wear test (Figure 3). The surfaces were examined at a 10 × magnification. With the aid of a calibrated Image-Software (Image Pro Plus) the diameter of the abraded area of the steatite balls was measured and the substance loss was calculated. For statistical analysis, the students *t*-test ($p < 0.05$) was done with the aid of special software (Origin 6.9). Fotos with a 170 × magnification were made with the help of SEM (LEO 1430, Zeiss, Germany).

Results

Wear of the ZrO_2-specimens

The highest roughness showed the sandblasted surface (0.44 ± 0.23 μm), followed by the glazed one (0.32 ± 0.12 μm). Wear on the zirconia specimens could only be found in group E (glazed) (Table II and Figure 4) and amounted to 46 ± 22 μm. For the other groups, wear could not be determined because there was too little to be detected (<1 μm).

Wear of the steatite-balls

Wear on the steatite balls was detectable for every surface treatment. The wear amount of the antagonists varied between 66–85 μm. The highest wear was found in group E (glazed) (85 ± 33 μm), but with no significant difference.

The polished surface (Group D) provided the lowest wear (66 ± 23 μm) with a significant difference to the rest of the groups. Concerning the roughness of the specimens, a significant difference was found between the polished and the sandblasted surfaces.

Table II. Mean and standard deviation ($n = 10$) of the wear of the material and antagonist situation.

	Surface treatment	Ra	Pt	SL
A	as fired	0.29 (0.03)	n.d.	69 (21)
B	as fired plus sandblasted	0.44 (0.23)	n.d.	81 (23)
C	only ground	0.30 (0.09)	n.d.	84 (41)
D	ground and polished	0.23 (0.11)	n.d.	66 (23)
E	ground and glazed	0.32 (0.12)	46 ± 22	85 (33)

n.d., not defined; Ra, Surface roughness of Lava™ ZrO_2 [μm]; Pt, Wear depth of Lava™ ZrO_2 [μm]; SL, Substanceloss of steatite balls [μm].

Discussion

Polished solid zirconia demonstrated the lowest wear against the antagonists (66 ± 23 μm). The sandblasted (81 ± 23 μm), ground (84 ± 41 μm) and glazed zirconia (85 ± 33 μm) provided a higher wear. Tambra et al. [25] investigated the wear of polished (0.40 μm), unpolished zirconia (as produced) (0.44 μm) and of a gold alloy (0.24 μm). However, natural enamel was used [25]. In a similar study, polished zirconia showed less wear than glazed zirconia (4.41 mm^2) and veneering ceramic (6.057–8.23 mm^2) [24]. There are studies which favour polishing and finishing of a glass ceramic. This leads to a smoother surface in comparison to a glazed surface or to a reduced plaque adhesion [26–28]. Therefore, a lot of authors suggest a chair-side polishing and the glazing by a technician in the laboratory [18,29,30]. In another study it was found that the influence of polished zirconia (0.31 μm^3) is superior in comparison to glazed (0.78 μm^3), whereas natural teeth were used as antagonists [9].

The glazing option is associated with disadvantages. Besides the higher roughness of the surface, the thinly applied glaze layer (ca. 100 μm) disappears after a period of function [31]. A rough surface of the used ceramic material consequently appears, which can in turn act very aggressively [5,15,18,30–33]. To prevent this situation, ceramic surfaces which have lost their glaze should be polished afterwards [13]. On the other hand, authors believe that a glazed surface is superior to a polished surface [34]. All cited studies support the opinion that polished zirconia has the best influence on the antagonists, independent of the test parameters [9,23,25]. The surface hardness, quality and breaking strength of the material, the roughness and hardness of the antagonist, the amount of the load and the sliding distance are all factors which can influence the wear amount of the tested material [31].

The present study constitutes a 2-Body wear experiment of zirconia specimens against steatite balls [9,35]. There are a lot of variations for the accomplishment of such studies in the literature. A 3-Body wear experiment in combination with zirconia balls or natural enamel instead of steatite balls could have an influence on the result, because of the variation of the surface, the morphology and of the biological features of the natural tooth structure [36,37,38]. However, in contrast to the steatite balls, the zirconia antagonists seem to be more ideal because they keep their shape during the whole testing period, without affecting the end result [38–40].

In conclusion, polished zirconia seems to have the lowest wear on the antagonists, while glazed zirconia loses the thin glaze after a certain time of function, with the result of the appearance of the rough and more abrasive surface of zirconia. In comparison to the chewing simulator, wear tests can be accomplished in the shortest time with Abrex that can lead to the same results. Further clinical studies are required to support the results of the *in vitro* testings [41].

***Declaration of Interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

[1] Brostow W, Krieger RE, Malabar FL, Brostow W. Science of materials. Einstieg in die moderne Werkstoffwissenschaft. München: Hanser; 1985.
[2] Gregory-Head B, Curtis DA. Erosion caused by gastroesophageal reflux: diagnostic considerations. J Prosthodont 1997;6: 278–85.
[3] Smith BG, Bartlett DW, Robb ND. The prevalence, etiology and management of tooth wear in the United Kingdom. J Prosthet Dent 1997;78:367–72.
[4] De Gee AJ, Pallav P, Davidson CL. Effect of abrasion medium on wear of stress-bearing composites and amalgam *in vitro*. J Dent Res 1986;65:654–8.
[5] Esquivel-Upshaw JF, Young H, Jones J, Yang M, Anusavice KJ. *In vivo* - Wear of enamel by a lithia disilicate-based core ceramic used for posterior fixed partial dentures: first-year results. Int J Prosthodont 2006;19:391–6.
[6] Bauer W, van den Hoven F, Diedrich P. Wear in the upper and lower incisors in relation to incisal and condylar guidance. J Orofac Orthop 1997;58:306–19.
[7] Adahci LK, Saiki M, de Campos TN. An *in vitro* investigation of human enamel wear by restorative dental materials. J Radioanal Nucl Chem 2001;249:465–8.
[8] Pigno MA, Hatch JP, Rodriguez-Garcia RC, Sakai S, Rugh JD. Severity, distribution, and correlates of occlusal tooth wear in a sample of Mexican-American and European-American adults. Int J Prosthodont 2001;14:65–70.
[9] Jung SY, Lee JW, Choi YJ, Ahn JS, Shin SW, Huh JB. A study on the *in vitro* wear of the natural tooth structure by opposing zirconia or dental porcelain. J Adv Prosthodont 2010;2:111–15.
[10] Seghi RR, Rosenstiel SF, Bauer P. Abrasion of human enamel by different dental ceramics *in vitro*. J Dent Res 1991;70: 221–5.
[11] Oh W, DeLong R, Anusavice KJ. Factors affecting enamel and ceramic wear: a literature review. J Prosthet Dent 2002; 87:451–9.
[12] Heintze SD, Cavalleri A, Forjanic M, Zellweger G, Rousson V. Wear of ceramic and antagonist–a systematic evaluation of influencing factors *in vitro*. Dent Mater 2008; 24:433–49.
[13] Monasky GE, Taylor DF. Studies on the wear of porcelain, enamel, and gold. J Prosthet Dent 1971;25:299–306.
[14] Hudson JD, Goldstein GR, Georgescu M. Enamel wear caused by three different restorative materials. J Prosthet Dent 1995;74:647–54.
[15] Jagger DC, Harrison A. An i*n vitro* investigation into the wear effects of selected restorative materials on dentine. J Oral Rehabil 1995;22:349–54.
[16] Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent 1996;75:18–32.
[17] Yap AU, Teoh SH, Hastings GW, Lu CS. Comparative wear ranking of dental restorative materials utilizing different wear simulation modes. J Oral Rehabil 1997;24: 574–80.
[18] Magne P, Oh WS, Pintado MR, DeLong R. Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent 1999;82:669–79.

[19] Clelland NL, Agarwala V, Knobloch LA, Seghi RR. Wear of enamel opposing low-fusing and conventional ceramic restorative materials. J Prosthodont 2001;10:8–15.
[20] Kern M. Clinical long-term survival of two-retainer and single-retainer all-ceramic resin-bonded fixed partial dentures. Quintessence Int 2005;36:141–7.
[21] Guazzato M, Albakry M, Ringer SP, Swain MV. Strength, fracture toughness and microstructure of a selection of all-ceramic materials. PartI. Pressable and alumina glass-infiltrated ceramics. Dent Mater 2004;20:441–8.
[22] Cramer von Clausbruch S. Vom Zirkonsand zur High-End Keramik. Das Dental-Labor 2009;51(7):1137–42.
[23] Lambrecht P, Bream M, Vuylsteke-Wauters M, Vanherle G. Quantitative *in vivo* wear of human enamel. J Dent Res 1989; 68:1752–4.
[24] Rosentritt M, Preis V, Behr M, Hahnel S, Handel G, Kolbeck C. Two body wear of dental porcelain and substructure oxide ceramics. Clin Oral Invest 2011;8:1–9.
[25] Tambra TR, Razzoog ME, Lang BR, Wang RF, Lang BE. Wear of enamel opposing YPSZ zirconia core material with two surface finishes, wear of enamel opposing YPSZ Zirconia core material with two surface finishes. J Dent Res 2003; Abstract # 915.
[26] Goldstein GR, Barnhard BR, Penugonda B. Profilometer, SEM, and visual assessment of porcealin polishing methods. J Prosthet Dent 1991;65:627–34.
[27] Grieve AR, Jeffrey IW, Sharma SJ. An evaluation of three methods of polishing porcelain by comparison of surface topography with the original glaze. Restorative Dent 1991;7:34–6.
[28] Patterson CJ, McLundie AC, Stirrups DR, Taylor WG. Efficacy of a porcelain refinishing system in restoring surface finish after grinding with fine and extra-fine diamond burs. J Prosthet Dent 1992;68:402–6.
[29] Douglas HB Jr, Moon PC, Eshleman JR, Lutins ND. The occlusal dimensional change upon glazing porcelain. J Dent Res 1981;60:828–9.
[30] Jagger DC, Harrison A. An *in vitro* investigation into the wear effects of unglazed, glazed, and polished porcelain on human enamel. J Prosthet Dent 1994;72:320–3.
[31] Albashaireh Z, Ghazal M, Kern M. Two-body wear of different ceramic materials opposed to zirconia ceramic. J Prosthet Dent 2010;104:105–11.
[32] Krejci I, Lutz F, Reimer M, Heinzmann JL. Wear of ceramic inlays, their enamel antagonists, and luting cements. J Prosthet Dent 1993;69:425–3.
[33] Baharav H, Laufer BZ, Pilo R, Cardash HS. Effect of glaze thickness on the fracture toughness and hardness of alumina-reinforced porcelain. J Prosthet Dent 1999;81: 515–19.
[34] Klausner LH, Cartwright CB, Charbeneau GT. Polished versus autoglazed porcelain surfaces. J Prosthet Dent 1982; 47:157–62.
[35] Harrison A. Wear of combination of acrylic resin and porcelain, on an abrasion testing machine. J Oral Rehabil 1978;5: 111–15.
[36] Wassell RW, McCabe JF, Walls AW. A two-body frictional wear test. J Dent Res 1994;73:1546–53.
[37] Wassell RW, McCabe JF, Walls AW. Wear characteristics in a two-body wear test. Dent Mater 1994;10:269–74.
[38] Ghazal M, Albashaireh ZS, Kern M. Wear resistance of nanofilled composite resin and feldspathic ceramic artificial teeth. J Prosthet Dent 2008;100:441–8.
[39] Ghazal M, Kern M. The influence of antagonistic surface roughness on the wear of human enamel and nanofilled composite resin artificial teeth. J Prosthet Dent 2009;101: 342–9.
[40] Ghazal M, Kern M. Wear of human enamel and nano-filled composite resin denture teeth under different loading forces. J Oral Rehabil 2009;36:58–64.
[41] Heintze SD, Zappini G, Rousson V. Wear of ten dental restorative materials in five wear simulators–results of a round robin test. Dent Mater 2005;21:304–17.