DENTAL MATERIALS 35 (2019) 937–944

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Press-on force during polishing of resin composite restorations

Siegward D. Heintze, Marie Reinhardt, Frank Müller, Arnd Peschke*

R&D, Ivoclar Vivadent, Schaan, Liechtenstein

ARTICLE INFO

Article history:
Received 13 December 2018
Received in revised form
15 February 2019
Accepted 22 March 2019

Keywords:
Polishing
Press-on force
Composite resin
3D force sensor

ABSTRACT

Objective. To measure the press-on force during the polishing of composite restorations carried out by 10 dentists in a clinically simulated procedure.

Methods. Composite restorations (Tetric EvoCeram Bulk Fill) were placed in standardized Class II two-surface cavities in first upper acrylic molars. The surfaces were roughened by sandblasting (50 μm, 1 bar). The tooth was mounted on a tailor-made device with a 3D force sensor (Kistler, Z21134-300, 10H z). Ten dentists (7 male, 3 female) polished one Class II restoration each using the one-step polishing system OptraPol together with a dental handpiece and water spray. The dentists were allowed to use all shapes of the polishing system (small flame, large flame, cup, lens). During polishing, the press-on forces measured for up to 2 minutes. Simultaneously, the polishing procedure was recorded with a digital camera to correlate the forces with the polishing shapes and movements.

Results. In total, 17,999 force measurements were available for analysis. The mean forces of all operators varied between 0.77(±0.63) N and 2.23(±1.48) N; the difference was statistically significant (ANOVA, post-hoc Tukey B, $p < 0.05$). All dentists exerted maximum forces higher than 3 N (between 3.3 N and 18.3 N). Force values exceeded 2 N during 25% of the polishing time. Female dentists polished with a statistically significant lower force than male dentists (ANOVA, $p < 0.001$). Polishing with the large flame and the cup generated significantly higher forces than polishing with the small flame and the lens (ANOVA, post hoc Tukey B, $p < 0.01$).

Conclusions. The press-on forces applied during polishing varied significantly between dentists and within the same dentist. In about 25% of the polishing time, forces were above the 2 N limit, which is recommended by some manufacturers as the maximum polishing force. Test institutes and manufacturers should evaluate the polishing performance of polishing instruments with various press-on forces.

1. Introduction

Polishing of directly placed restorations is a nuisance for many dentists. Although data from representative clinical surveys are not available, we may speculate that most dentists do not spend a great deal of time and effort on the polishing procedure or they even delegate this step to their dental assistants.

And many a dentist may ask: is intraoral polishing of direct restorations really necessary or can the dentist leave it to the

* *Corresponding author at*: Ivoclar Vivadent AG, Bendererstrasse 2, FL-9494 Schaan, Liechtenstein.
E-mail address: siegward.heintze@ivoclarvivadent.com (S.D. Heintze).

https://doi.org/10.1016/j.dental.2019.03.009

patient as tooth brushing with abrasive toothpastes also polishes the restoration to a certain degree? The clear answer is yes — polishing is necessary. A smooth surface reduces plaque accumulation, improves aesthetics, reduces the risk of material staining and wear and is good for the patient's comfort [1–5]. Surface gloss will be more maintained if the dentists spend more time in initial polishing of composite resins to achieve a high initial gloss as a laboratory study has shown that challenged the polished surfaces with a toothbrushing machine [6–12]

To polish a restoration does not only mean to smoothen the restoration surface but also to finish and contour the restoration, to remove any overhangs and excess material, and/or to reshape the restoration due to an inadequate anatomical form. According to a survey carried out by the Clinicians Report among 655 general practitioners in the USA, 78% of dentists contour prior to light-cure [13]. If not, contouring and reshaping must be performed with diamond or tungsten carbide burs. One laboratory study revealed that contouring/finishing with tungsten carbide burs results in a more regular surface than with diamond burs [14]. However, there are also dentists who use polishing systems for this step. In the above-mentioned survey, 57% of dentists said that they use polishing systems for contouring [13]. Roughly, the dental market distinguishes between three different polishing systems: (i) three-step systems with finisher (for contouring), polisher and high gloss polisher; (ii) two-step systems with finisher and polisher and (iii) one-step systems that should perform both finishing and polishing in one step. There seems to be differences between different countries with regard to the use of one-step and two- or three-step polishing systems. While a survey by the North American test institute Dental Advisor revealed that 69% of the US clinical consultants surveyed used single-step polishers [15], only 11% of German dentist used one-step polishing systems according to a GFK survey amongst German dentists [16].

The manufacturers offer different shapes to account for the anatomy of the restored tooth. These shapes comprise flame-shaped polishers or and points in various sizes for finishing/polishing occlusal surfaces, cups for finishing/polishing proximal surfaces and the buccal and lingual surfaces of extended restorations and discs for processing anterior restorations as well as the proximal surfaces of posterior restorations. Furthermore, the polishers can be made of various materials, such as silicone, polyurethane and rubber. By adding small synthetic diamond particles, the polishing effect on both composite and ceramic materials is enhanced. In addition, the range includes flexible discs with aluminium oxide particles of different roughness and polishing brushes featuring special polishing bristles that are especially designed for the polishing of occlusal surfaces [13,15,17]. As far as the polishing performance is concerned, numerous laboratory studies claim to have identified differences between different polishing systems on different composite specimens [18–32]. However, a clinical trial that evaluated the polishing efficacy of four different polishing systems (Diafix-oral diamond polisher, Two-striper MPS gel diamond polisher, Dentsply experimental silicon carbide polisher and Occlubrush) on 10 premolar and 10 molar Class II restorations revealed no significant difference in surface roughness after measuring replicas of the occlusal surfaces [36]. The US test institute CR evaluated 7 different polishing systems with respect to their polishing efficacy on specimens made of Filtek Supreme Ultra and concluded that all 7 were regarded as 'excellent' or 'good to excellent' [13]. The US test institute Dental Advisor rated 9 polishing systems, recording scores between 91% and 98% for all of them [15]. It seems that the difference in polishability between different composite materials is more significant than the difference between different polishing systems and their polishing performance. But only when the difference is very great also in laboratory investigations, as it was the case with the composite material Grandio compared to other materials: both laboratory and clinical trials confirmed the poor polishability of the material Grandio [18,37].

Some manufacturers of dental polishing systems recommend dentists to use a specific press-on force, mostly 2 N or below 2 N (e.g. Kenda and Shofu). However, it is difficult for dentists to assess the press-on force. Dentists may have an idea of force when putting a dental handpiece with a polishing instrument on a normal scale. Yet, this procedure seems to be quite inaccurate. Studies in vitro have shown, that the press-on force has an influence on both surface gloss and surface roughness — depending on the material being polished [38]. Higher gloss is achieved with fine particle hybrid composite resins when polished with 2 N instead of 4 N while microfilled composites seemed to be not affected by the press-on force. Amalgam specimens, in contrast, can be polished to a higher gloss when polished with higher press-on forces.

The goal of the present study was to measure the press-on force during the polishing of composite restorations carried out by 10 dentists in a clinically simulated procedure. Furthermore, the dentist's preferences in terms of the shapes used for polishing were documented.

Four hypotheses were defined:

(1) The press-on force varies significantly amongst the 10 dentists.
(2) The type of polishing shape used influences the press-on force.
(3) The press-on force is above 2 N during a considerable period of polishing time.
(4) The preferences of shapes vary largely between the dentists.

2. Materials and methods

2.1. *Specimen preparation*

Composite restorations (Tetric EvoCeram Bulk Fill) were placed in standardized Class II two-surface cavities on acrylic/plastic models of first upper molars (Ivoclar Vivadent, Article No. 609476). The surfaces were roughened by sandblasting (Renfert, 50 μm Al_2O_3, 1 bar pressure) (Fig. 1).

Ten dentists (7 male, 3 female) who are working clinically at the Ivoclar Vivadent company were selected for this investigation. The mean age of the dentists was 42 ± 6.6 years (range 33–57 years) and the mean clinical experience was 14 ± 4.3 years (range 7–21 years). The ten dentists polished one Class II

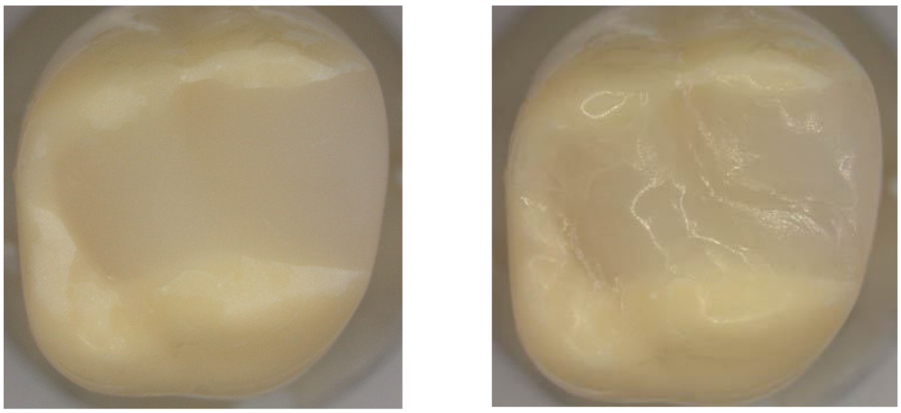

Fig. 1 – Filling after sandblasting (A) and polishing (B).

Fig. 2 – OptraPol polishing system (from left to right): small flame, big flame, cup, lens.

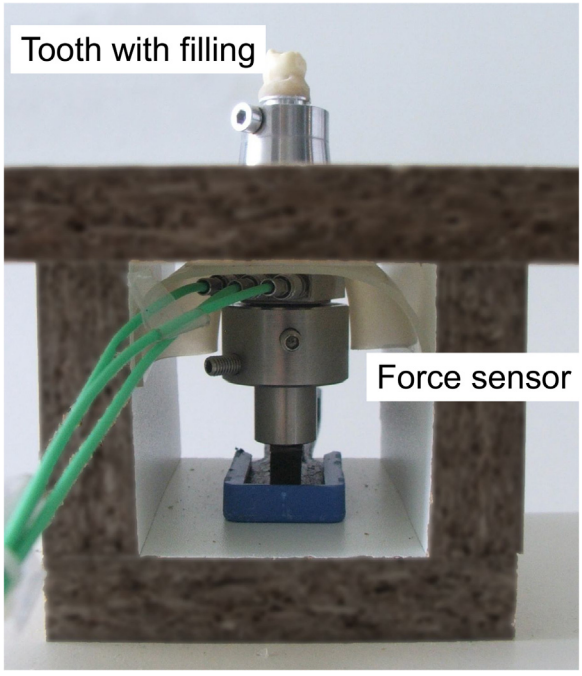

Fig. 3 – Experimental set-up for force measurements during polishing of a Class II composite restoration.

restoration with the one-step polishing system OptraPol using a dental handpiece (KaVo Intramatic 20 LH) and water spray. The dentists were allowed to use all shapes of the polishing system (small flame, large flame, cup, lens) (Fig. 2).

The tooth was mounted on a device with a piezoelectric 3D force sensor (Kistler, Z21134-300, 10 Hz) (Fig. 3). The force sensor was operated together with a Kistler Type 5073 measuring amplifier. The force was recorded using the "Force Measurement Polisher, Version 1.1" software (SD Mechatronik GmbH, Germany). The software of the force sensor can detect and read forces over a running time of maximal 120 s. The sensor was placed under a small wooden table. The table had a centre hole for the measuring head. On the sensor, an antagonist holder was screwed in place. The respective tooth with the filling was mounted in the holder (see Fig. 1). In the hole on the table, the fuselage part of a packaging tin was used; the associated closure lid was also pierced. Thus, a latex rubber dam could be clamped in place in order to protect the sensor from splash water (Fig. 4). At the same time, direct decoupling effects on the sensor were given by means of the latex-film and the packaging tin during the polishing test. A hand rest for the dentist was integrated into the small table as well as a suction mat for the cooling water. In addition to this test setup, a webcam was set up to document the polishing procedure with a video simultaneous with the force readings (see Fig. 4). With the help of a video editing software program (Premiere Elements), the non-polishing phases before the start, after polishing and during e.g. pauses or position changes were recorded and marked accordingly in the data table of the force readings. In order to determine the average value of the readings, only to the values measured during the effective polishing process were used, without including the "zero values" in the series of readings. The principle of 3-way measurements – measurement via x, y and z-axis with a common zero point – caused the values measured to be either positive or negative, depending on the linkage to the

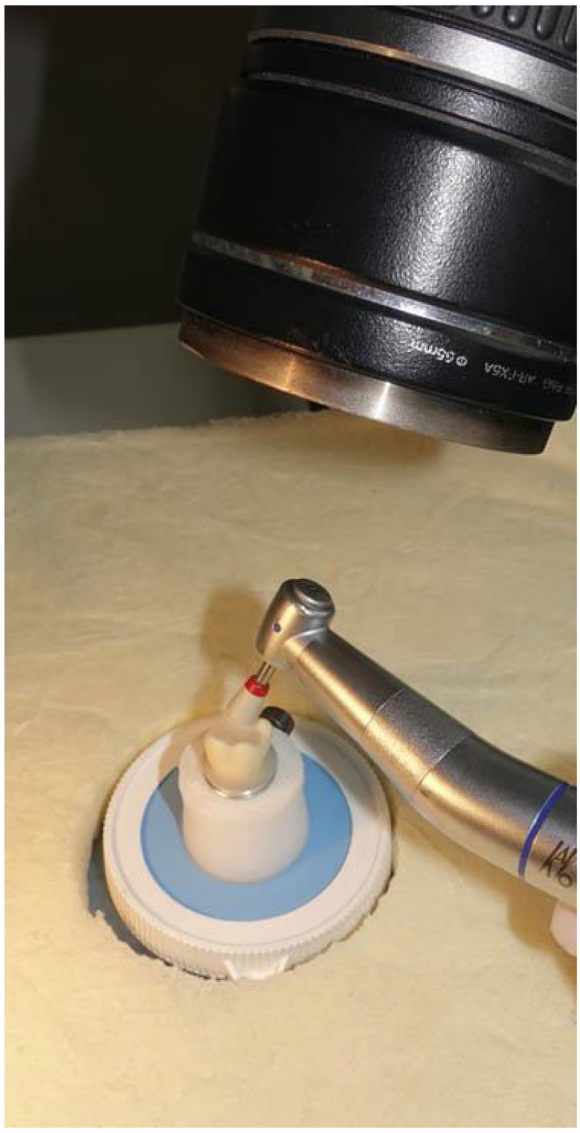

Fig. 4 – Experimental set-up for force measurements during polishing of a Class II composite restoration; above video camera.

sensor. However, the absolute value of the respective value measured was always relevant for the evaluation. Piezoelectric sensors are known to have a drift motion. For longer reading times, the zero point of the output signal can move to the negative or positive side. Also, temperature changes can lead to sensor-internal temperature stresses and thus to temperature errors, which must be corrected accordingly {Kistler Operating Instructions 3-Component Force Sensor, 9251A_002-049d-05.06, © 2006, Kistler Instrumente AG, CH-8408 Winterthur}. Even in the case of the existing series of measurements, some drift effects were found. Therefore, in order to counteract a falsification of the values measured, all measurement series in all three axes were examined for drift and then corrected accordingly. For this purpose, the recorded force values during the non-polishing phases were analyzed. In each case, a trend line of the linear drift was obtained and deducted over the entire series of measurements.

2.2. *Statistical analysis*

For the statistical analysis, only polishing sequences with forces greater than zero were taken into consideration. The explorative data analysis showed a non-normal distribution of the force data in relation to both the dentist and the polishing shape. Several data transformations were applied but none of them really improved the data distribution. Therefore, the raw data were not transformed. For the evaluation of the differences between the different dentists as well as the different polishing shapes, an analysis of variance (ANOVA) with post hoc Tukey B test was applied ($p < 0.05$).

For the evaluation of influencing factors on the press-on forces, a univariate analysis with a generalized linear model was performed.

3. Results

In total, 17,999 force measurements were available for analysis. The mean forces of all operators varied between 0.77 (±0.63) N and 2.23 (±1.48) N (Fig. 5); the difference was statistically significant (ANOVA, post-hoc Tukey B, $p < 0.05$). All dentists exerted maximum forces higher than 3 N (between 3.3 N and 18.3 N). Only 3 of the 10 dentists used all 4 polishing shapes, 3 used three shapes (cup/lens/small flame or cup/small flame/large flame), and 4 dentists used only two shapes (cup/small flame or lens/small flame or lens/large flame) (Fig. 6). The videos showed that the small and large flames were exclusively used for the occlusal part of the filling and the lens and cups for the proximal part of the filling. Polishing with the large flame and the cup generated significantly higher forces than polishing with the small flame and the lens (Fig. 7) (ANOVA, post hoc Tukey B, $p < 0.01$). Female dentists polished with a statistically significant lower force than male dentists (1.38 N (±0.94) versus 1.56 (±1.38) N; ANOVA, $p < 0.001$). However, a multifactorial analysis of variance revealed that the most important factor which was responsible for the variability in the press-on force was the dentist him- or herself (about 14% of variability) and not the shape of the polisher or the dentist's gender (less than 2% of variability each).

Force values were above 2 N during 25% of the polishing time (on average) and above 3 N during 10% of the time on average (Fig. 8) however, these values varied greatly between the dentists. For instance, one of the dentists exerted forces above 2 N for more than 50% of the polishing time.

4. Discussion

This is the first study that investigated the press-on force during polishing using a clinically simulated procedure and involving ten dentists. Not surprisingly, the press-on force varied widely between the ten dentists, which was also the most important factor for the explanation of the variability of the force readings. The selection of the 10 dentists is not representative for dentists who work in a defined region or country but they represent a valuable mixture of dentists at different ages and clinical experience.

Only one composite resin material was chosen to be polished by the dentists as it can be assumed that the polishing

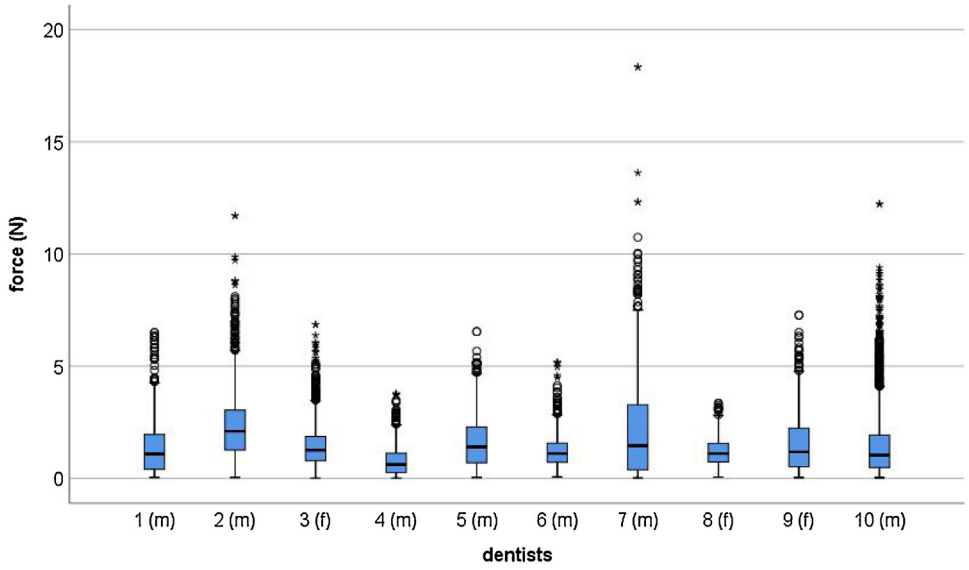

Fig. 5 – Boxplot graphs of press-on force during polishing of a Class II composite resin restoration in relation to the dentist (1–10). m = male dentist, f = female dentist.

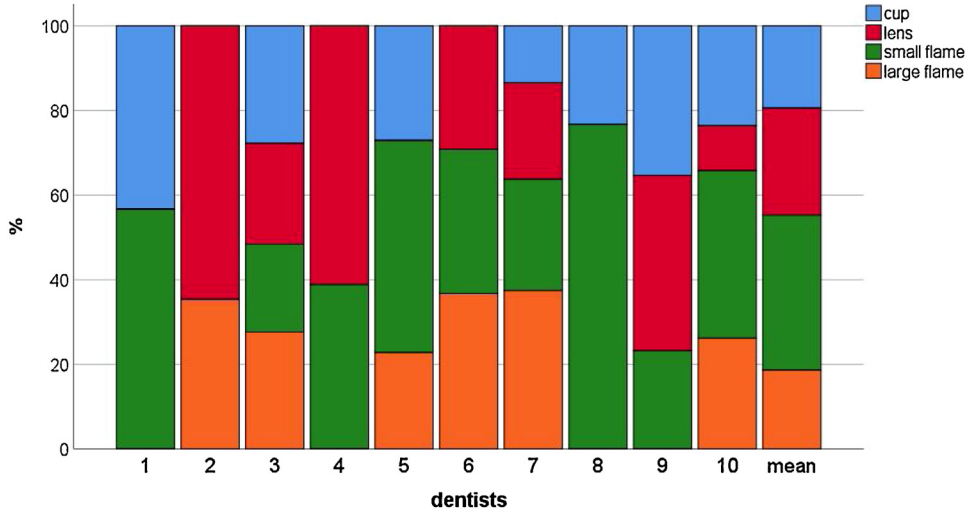

Fig. 6 – Bar diagram of the percentage of total polishing time in relation to the polishing shape and the dentist (1–10) and mean percentage across all dentists (mean).

force may not depend on the composite material to be tested, especially since the occlusal and proximal surface of the fillings were roughened by sandblasting. The good polishing performance of the one-step system OptraPol has been confirmed by laboratory trials [33–35].

The polishing process is a very dynamic task. The polisher is constantly moving on the tooth surface. The forces acting on them are also subject to constant fluctuations. The contact force was rather low, averaging at 2 N, but the force peaks were significantly higher. The force peaks, both qualitatively and quantitatively, were mostly found in the polishing of the occlusal surfaces.

The polishability of dental materials in relation to polishing systems is normally tested in vitro on flat specimens using dental handpieces, a defined rotation speed and a predefined polishing time. In most laboratory studies, the press-on force during the application of the polishing systems is not controlled and this issue is not even mentioned in the material and method or the discussion section of the studies. So far, only three studies mentioned any method applied to control the press-on force. A study carried out to evaluate abrasive bristles used a press-on force of 2.5 N but it did not describe how the force was controlled [39]. Two other studies that evaluated prophylaxis pastes and polishing pastes used a kitchen scale with contactless magnetic switches to keep the press-on force between 1.75 N and 2.25 N [40,41]. Another two studies mentioned light or low pressure that was applied without defining what “light” meant [42,43]. In one study, a calibration

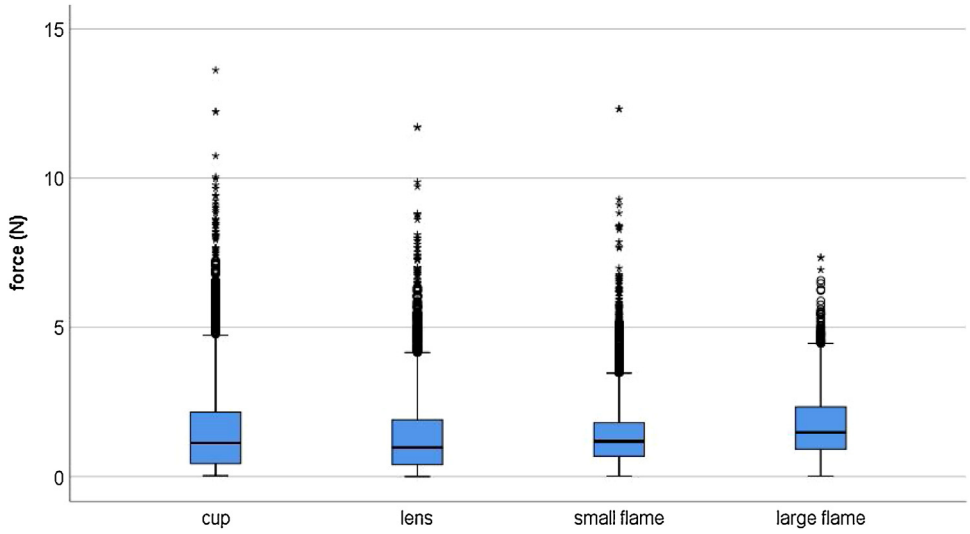

Fig. 7 – Boxplot graphs of press-on force during polishing of a Class II composite resin restoration in relation to the polishing shape.

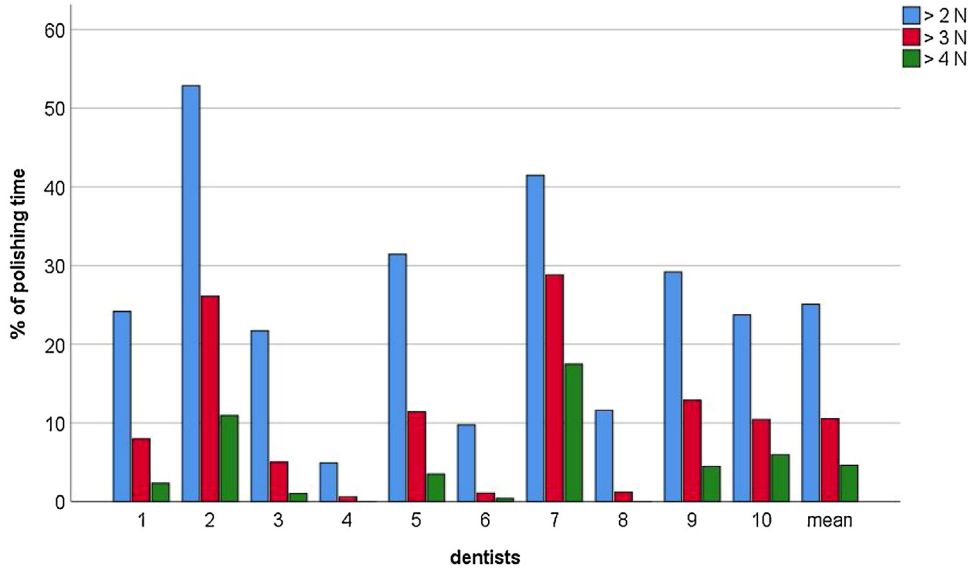

Fig. 8 – Bar diagram of the percentage of total polishing time with press-on force above 2 N/3N/4 N in relation to the dentist (1–10) and mean percentage across all dentists (mean).

session was made prior to the application of the polishing system, using an electronic laboratory scale to measure the force applied during the various polishing steps [44]. The use of uncontrolled force during polishing can be the cause for the different results when the same composite resin is polished with the same polishing instruments. The polishing force can effectively be controlled in the laboratory by means of e.g. a device that uses air pressure as a counterbalance for a defined force in the range of 1 N–10 N, as has been demonstrated in two laboratory studies by the principle author of this study [17,38].

Some dentists intuitively exert higher forces as they think that higher forces result in smoother surfaces and that these surfaces can be accomplished in a shorter period of time. However, there is no direct correlation between press-on force and polishing quality. The press-on force seems to be less critical for flexible discs like the Sof-Lex discs, as they bend and counteract the increase in pressure. However, rubber discs and polishing cups are stiffer and do not compensate for higher pressure. One study revealed a statistically significant influence of the press-on force on the surface roughness of hybrid composites, as a higher pressure resulted in less smooth surfaces with increased roughness [38]. The surface roughness of the microfilled composite specimens was less affected by the variance in forces in that study. With ceramic and metal materials higher press-on forces result in higher gloss [38,45]. There is, however, no evidence from laboratory studies to support the choice for nanofill or submicron composites over traditional

microhybrids based on better surface smoothness and/or gloss after polishing [46].

The findings are based on tests with only one-dimensional force, usually a handpiece with a polisher onto which a balance or force gauge was pressed. Especially when polishing fissures and cusps, the horizontal part is under pressure from the vertical direction by which the polishing force is applied and the cusp slopes are under pressure from the horizontal or oblique direction of the force. Therefore, a series of measurements should be performed using a 3D force sensor onto which the tooth to be polished is placed to determine the pressure forces that are effectively acting on the surfaces in a procedure that is as realistic as possible.

Another factor was the type of shapes used for polishing. In this respect, the large flames and cups were conducive to higher forces than the small flames and lenses. Interestingly, only 3 out of the 10 dentists used all 4 shapes for polishing the restoration, and 4 used only two (2) shapes. The shapes most used were the small and large flames followed by the cups and discs, which is in line with the results of the above-mentioned US survey amongst 655 general practitioners [13]: 57% used points for occlusal surfaces, 36% used cups and 31% used discs for facial and lingual surfaces; only about 3–4% used spirals.

5. Conclusions

The press-on forces during polishing varied significantly between dentists and within the same dentist. In about 25% of the polishing time, the forces applied exceeded 2 N — a value that is recommended by some manufacturers as the maximum polishing force. Test institutes and manufacturers should evaluate the polishing performance of polishing instruments with various press-on forces.

All four hypotheses were confirmed:

(1) The press-on force varied significantly amongst the 10 dentists.
(2) The type of polishing shape influenced the press-on force.
(3) The press-on force was above 2 N during a considerable period of polishing time.
(4) The preferences of shapes varied largely between the dentists.

REFERENCES

[1] Morgan M. Finishing and polishing of direct posterior resin restorations. Pract Proced Aesthet Dent 2004;16:211–7.
[2] Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. Dent Mater 1997;13:258–69.
[3] Jones CS, Billington RW, Pearson GJ. The in vivo perception of roughness of restorations. Br Dent J 2004;196:42–5.
[4] Reis AF, Giannini M, Lovadino JR, Ambrosano GM. Effects of various finishing systems on the surface roughness and staining susceptibility of packable composite resins. Dent Mater 2003;19:12–8.
[5] Willems G, Lambrechts P, Braem M, Vuylsteke-Wauters M, Vanherle G. The surface roughness of enamel-to-enamel contact areas compared with the intrinsic roughness of dental resin composites. J Dent Res 1991;70:1299–305.
[6] Waheeb N, Silikas N, Watts D. Initial polishing time affects gloss retention in resin composites. Am J Dent 2012;25:303–6.
[7] Quirynen M, Bollen CM, Papaioannou W, Van Eldere J, van Steenberghe D. The influence of titanium abutment surface roughness on plaque accumulation and gingivitis: short-term observations. Int J Oral Maxillofac Implants 1996;11:169–78.
[8] Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. J Adhes Dent 2001;3:45–64.
[9] Krämer N, Lohbauer U, Frankenberger R. Adhesive luting of indirect restorations. Am J Dent 2000;13:60D–76D.
[10] Meijering AC, Creugers NH, Roeters FJ, Mulder J. Survival of three types of veneer restorations in a clinical trial: a 2.5-year interim evaluation. J Dent 1998;26:563–8.
[11] Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent 2000;28:163–77.
[12] Heintze SD, Rousson V. Clinical effectiveness of direct Class II restorations — a meta-analysis. J Adhes Dent 2012;14:407–31.
[13] Clinicians Report. Polishing up your Class II technique. Clin Rep 2017;10:2–3.
[14] Daud A, Gray G, Lynch CD, Wilson NHF, Blum IR. A randomised controlled study on the use of finishing and polishing systems on different resin composites using 3D contact optical profilometry and scanning electron microscopy. J Dent 2018;71:25–30.
[15] Dental Advisor. Finishing and polishing, 33; 2016. p. 2–7.
[16] GFK. Politur nicht nur Kür, sondern Pflicht. Dent Mag 2017;35:39.
[17] Heintze SD, Forjanic M. Polishing performance of multiple-use silicone rubber-based polishing instruments with and without disinfection/sterilization. Am J Dent 2008;21:288–94.
[18] Janus J, Fauxpoint G, Arntz Y, Pelletier H, Etienne O. Surface roughness and morphology of three nanocomposites after two different polishing treatments by a multitechnique approach. Dent Mater 2010;26:416–25.
[19] Jung M, Brügger H, Klimek J. Surface geometry of three packable and one hybrid composite after polishing. Oper Dent 2003;28:816–2824.
[20] Erdemir U, Sancakli HS, Yildiz E. The effect of one-step and multi-step polishing systems on the surface roughness and microhardness of novel resin composites. Eur J Dent 2012;6:198–205.
[21] Senawongse P, Pongprueksa P. Surface roughness of nanofill and nanohybrid resin composites after polishing and brushing. J Esthet Restor Dent 2007;19:265–73.
[22] Türkün LS, Türkün M. The effect of one-step polishing system on the surface roughness of three esthetic resin composite materials. Oper Dent 2004;29:203–11.
[23] Paravina RD, Roeder L, Lu H, Vogel K, Powers JM. Effect of finishing and polishing procedures on surface roughness, gloss and color of resin-based composites. Am J Dent 2004;17:262–6.
[24] Baseren M. Surface roughness of nanofill and nanohybrid composite resin and ormocer-based tooth-colored restorative materials after several finishing and polishing procedures. J Biomater Appl 2004;19:121–34.
[25] Lu H, Roeder LB, Powers JM. Effect of polishing systems on the surface roughness of microhybrid composites. J Esthet Restor Dent 2003;15:297–303.
[26] Setcos JC, Tarim B, Suzuki S. Surface finish produced on resin composites by new polishing systems. Quintessence Int 1999;30:169–73.

[27] Kakaboura A, Fragouli M, Rahiotis C, Silikas N. Evaluation of surface characteristics of dental composites using profilometry, scanning electron, atomic force microscopy and gloss-meter. J Mater Sci Mater Med 2007;18:155–63.
[28] Kameyama A, Nakazawa T, Haruyama A, Haruyama C, Hosaka M, Hirai Y. Influence of finishing/polishing procedures on the surface texture of two resin composites. Open Dent J 2008;2:56–60.
[29] Silikas N, Kavvadia K, Eliades G, Watts D. Surface characterization of modern resin composites: a multitechnique approach. Am J Dent 2005;18:95–100.
[30] Tate WH, DeSchepper EJ, Cody T. Quantitative analysis of six composite polishing techniques on a hybrid composite material. J Esthet Dent 1992;4:30–2.
[31] Watanabe T, Miyazaki M, Moore BK. Influence of polishing instruments on the surface texture of resin composites. Quintessence Int 2006;37:61–7.
[32] Yap AU, Yap SH, Teo CK, Ng JJ. Finishing/polishing of composite and compomer restoratives: effectiveness of one-step systems. Oper Dent 2004;29:275–9.
[33] Korkmaz Y, Ozel E, Attar N, Aksoy G. The influence of one-step polishing systems on the surface roughness and microhardness of nanocomposites. Oper Dent 2008;33:44–50.
[34] Ozel E, Korkmaz Y, Attar N, Karabulut E. Effect of one-step polishing systems on surface roughness of different flowable restorative materials. Dent Mater J 2008;27: 755–64.
[35] Ergücü Z, Türkün LS. Surface roughness of novel resin composites polished with one-step systems. Oper Dent 2007;32:185–92.
[36] Jung M, Hornung K, Klimek J. Polishing occlusal surfaces of direct Class II composite restorations in vivo. Oper Dent 2005;30:139–46.
[37] Ergücü Z, Türkün LS. Clinical performance of novel resin composites in posterior teeth: 18-month results. J Adhes Dent 2007;9:209–16.
[38] Heintze SD, Forjanic M, Rousson V. Surface roughness and gloss of dental materials as a function of force and polishing time in vitro. Dent Mater 2006;22:146–65.
[39] Krejci I, Lutz F, Boretti R. Resin composite polishing–filling the gaps. Quintessence Int 1999;30:490–5.
[40] Roulet-Mehrens T, Roulet JF. Smoke stain accumulation on restorative dental materials and hard tooth tissues after polishing with prophylaxis pastes. Schweiz Monatsschr Zahnheilkd 1982;92:487–96.
[41] Roulet J-F, Roulet-Mehrens TK. The surface roughness of restorative materials and dental tissues after polishing with prophylaxis and polishing pastes. J Periodontol 1982;53:257–66.
[42] Van Dijken JW, Ruyter IE. Surface characteristics of posterior composites after polishing and toothbrushing. Acta Odontol Scand 1987;45:337–446.
[43] Hoelscher DC, Neme AM, Pink FE, Hughes PJ. The effect of three finishing systems on four esthetic restorative materials. Oper Dent 1998;23:36–42.
[44] Wilder Jr AD, Swift Jr EJ, May Jr KN, Thompson JY, McDougal RA. Effect of finishing technique on the microleakage and surface texture of resin-modified glass ionomer restorative materials. J Dent 2000;28:367–73.
[45] Silva TM, Salvia AC, Carvalho RF, Pagani C, Rocha DM, Silva EG. Polishing for glass ceramics: which protocol? J Prosthodont Res 2014;58:160–70.
[46] Kaizer MR, de Oliveira-Ogliari A, Cenci MS, Opdam NJ, Moraes RR. Do nanofill or submicron composites show improved smoothness and gloss? A systematic review of in vitro studies. Dent Mater 2014;30:e41–78.