Available online at www.sciencedirect.com

ScienceDirect

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

Influence of placement instruments on handling of dental composite materials

*Martin Rosentritt, Jana Hartung, Verena Preis, Stephanie Krifka**

UKR University Hospital Regensburg, Department of Prosthetic Dentistry, Franz-Josef-Strauß-Allee 11, 93053 Regensburg, Germany

ARTICLE INFO

Article history:
Received 7 February 2018
Received in revised form
19 June 2018
Accepted 12 November 2018

Keywords:
Composite instrument
Stickiness
Applicability
Plugger
Diameter
Geometry
Coating

ABSTRACT

Objective. Applicability and stickiness of dental composites are influential factors for the properties of those materials and so indirectly affect function, longevity and esthetics of composite restorations in the clinic. Thus, this *in vitro* study aimed for the influence of different placement instruments' diameter, geometries and coatings on the handling of uncured resin composite materials.

Methods. A survey about application technique of resin composites, placement instrument diameter, geometry and coating, and application temperature was answered by 55 German dentists in private practice. Due to these data diverse composite placement instruments were used to perform tensile tests on PMMA plates with application forces of 1 N and 2 N ($v = 35$ mm/min) at 25 and 37 °C. Following the dosing of a certain amount of the composite (nanohybrid, microhybrid) to the tip of the composite placement instrument, unplugging forces were determined after application and unplugging was performed.

Results. Unplugging forces were statistically significant different and varied between 0.27 N and 1.14 N. Stickiness of dental composites was dependent on the composite material itself as well as diameter, geometry and coating of the placement instruments.

Significance. Pre-clinical testing of composite materials' stickiness by unplugging forces facilitates the assessment of its handling properties.

1. Introduction

Resin composites are used in dental practice to directly restore function and esthetic of damaged teeth. Materials' biological, chemical and physico-mechanical properties as well as the handling of the composites influence the clinical longevity of the restorations [1–5]. Although dental materials are characterized by their composition, the dentist manipulates the material during its placement, which may optimize or impair the clinical outcome [7,8]. Inadequate handling of composite materials subsequently results in instability, porosity, bacterial adhesion, discoloration, enhanced wear, marginal leakage and fracture [4,7]. An important factor for clinical handling is materials' stickiness [5], which ideally leads to better adaptation of the composite to the cavity wall. However, stickiness may also cause a lack of applicability, removal and deformation of the composite due to increased adherence of the material to the placement instrument. To support the adaptability of composites a lot of techniques and instruments

Abbreviations: UF, unplugging force; MH, microhyrbid composite; NH, nanohybrid composite; AF, application forces.

* *Corresponding author.*
E-mail address: stephanie.krifka@ukr.de (S. Krifka).

https://doi.org/10.1016/j.dental.2018.11.010

varying in diameter, geometry and coating are available for dentists to overcome difficulties in handling. Besides location and size of the cavity, personal habits and preferences and environmental conditions (temperature, storage, light curing) strongly contribute to the selection how composite materials are applied and shaped [8–10]. Commonly, cost-intensive and time-consuming marketing research helps to develop and improve handling of composites or simplify the workflow. An objective assessment of the handling of composites on the basis of standardized *in vitro* test is not established so far, but a number of reliable methods have been introduced to assess the stickiness of composite materials [6,7,11–13]. These tests utilize either tensile strength or profilometry to analyze the unplugging force (UF), unplugging work or measure the length/area of withdrawn composite (composite flag). Nevertheless, *in vitro* and *in vivo* knowledge about the effect of placement instruments on stickiness of composites is rare. Thus, dentists were questioned about their commonly used composite placement instruments as well as the storage temperature of composites right before application. Based on the results of the survey unplugging forces were determined to measure the stickiness of composite materials *in vitro*.

The hypothesis of this *in vitro* study was that handling of dental composite materials is affected by diameter, geometry and coating of the placement instruments used. The purpose of this study was to analyze the influence on composite placement instruments on stickiness of dental composite materials allowing the prediction of composites' clinical handling.

2. Materials and methods

2.1. Survey

Fifty-five dentists were asked about the clinical applicability of conventional resin composite materials. The questionnaire included five questions, which addressed the method of application (composite dispenser, paddle, plugger, other), instrument geometry (plane, ball, paddle) including the frequency of its use, instrument diameter (0.5–5.0 mm), instrument coating (none, gold, titanium-aluminium-nitride (TiAlN), composite, other) and the storage temperature of the composite material just before application (refrigerator 6 °C, room temperature 25 °C, body temperature 37 °C, other).

2.2. Unplugging force

Materials and methods of the unplugging force (UF) analysis are summarized in Table 1. The dental composite placement instruments were fixed to a universal testing machine (Zwick 1446, resolution 0.001 N, Zwick, Ulm, Germany) using a parallelometer to assure parallelism of each instrument surface. Composite placement instruments differed in diameter (A: 1.6 mm, 2 mm, 2.5 mm), geometry (B: plane, pear-shaped, ball) or coating (C: none, gold, composite, TiAlN). To avoid polymerization during testing, all experiments were conducted under yellow light.

Two commercial dental composites (microhyrbid (MH, Arabesk Top, #1231255); nanohybrid (NH, Grandio, #1608297); both VOCO, Cuxhaven, Germany) were used for the different filler content (MH: 77% w/w; NH: 89% w/w) and material handling properties, of which adaptability and stickiness were previously evaluated *in vitro* and *in vivo* [7]. Identical amount (1.5 mm × 2 mm) of the materials was dosed to the tip of each instrument using the composite-gun tubes 1915 (KerrHawe, Bioggio, Switzerland). Pre-tests identified roughened (1000-P2500 grits) PMMA as a suitable standardized surrogate for human teeth. Therefore, the composite materials were applied to PMMA plates (thickness: 1.5 mm) at room temperature (25 °C) or PMMA plates warmed to 37 °C. Application was performed at a speed of 35 mm/min using two different application forces (AF: 1 N/2 N) and subsequently unplugging was conducted at a speed of 35 mm/min. Parameters were selected according to earlier baseline investigations [7]. Unplugging forces (UF) in N were determined (n = 20 per group). Mean and standard deviation were calculated. Data were statistically analyzed by SPSS 21 (SPSS Inc., Chicago, IL, USA) using one-way ANOVA and multi-variant comparison (Bonferroni Post Hoc). The level of significance was set to 0.05. The effect of the different parameters was analyzed by the error-rates method (ERM). The level of significance was adjusted to $\alpha^*(k) = 1 - (1 - \alpha)1/k$, where k represents the number of pairwise tests to be performed.

3. Results

3.1. Survey

A composite applicator (55%) paddles (49%) and pluggers (38%) were frequently utilized to apply the composite material. Only in rare cases other dental placement instruments (5%) were used to apply the materials (Fig. 1).

A ball burnisher was usually utilized (53%) by dentists to condense the materials into the cavity, whereas dentists infrequently adapt composites by using pluggers (28%) or other composite placement instruments (20%). The diameter of the used plugger ranged from 0.8 mm up to 5.0 mm, but in the majority of the cases pluggers with a diameter of 2.0 mm (29%), 1.5 mm (16%), 1 mm (16%) and 4 mm (15%) were used.

71% of the dentists utilized none-coated instruments to directly restore lost tooth structure with composite. TiAlN — (20%), gold — (9%), composite — coated instruments (7%), or other coatings (4%) were rarely used for handling and shaping. Composite materials were usually (93%) stored at room temperature (25 °C) right before their use, but a few (16%) dentists stored composites at 4 °C or at other temperatures (2%) previous to application.

3.2. Unplugging force

The results of unplugging forces (UF) are displayed depending on instrument diameter (Fig. 2), geometry (Fig. 3) and coating (Fig. 4) using two application forces (AF: 1 N/2 N) at room temperature (25 °C) or body temperature (37 °C). Diameter, geometry and coating of composite placement instruments generally affected unplugging forces (ERM: $p = 0.000$). UF of MH was higher than UF of NH in all cases. An increase of application temperature slightly reduced the UF. Only for MH with 1 N with the 2 mm and 2.5 mm placement instruments

Table 1 – Unplugging forces: materials and methods.

No	Material (1.5 × 2 mm)	Placement instrument	Diameter (mm)	Coating	Temperature storage/application	Application force (N)	Speed (mm/min)	Substrate
A	Grandio nanohybrid composite Arabesk Top microhybrid composite	Plane plugger	1.6 2 2.5	None	25 °C/25 °C 25 °C/37 °C	1 2	35	Roughened PMMA (1000-P2500 grits)
B	Grandio nanohybrid composite Arabesk top microhybrid composite	Plane plugger Pear-shaped plugger Ball burnisher	2.5	None	25 °C/25 °C 25 °C/37 °C	1 2	35	Roughened PMMA (1000-P2500 grits)
C	Grandio nanohybrid composite Arabesk top microhybrid composite	Plane plugger	2.5	None Gold Composite NiTiN	25 °C/25 °C 25 °C/37 °C	1 2	35	Roughened PMMA (1000-P2500 grits)

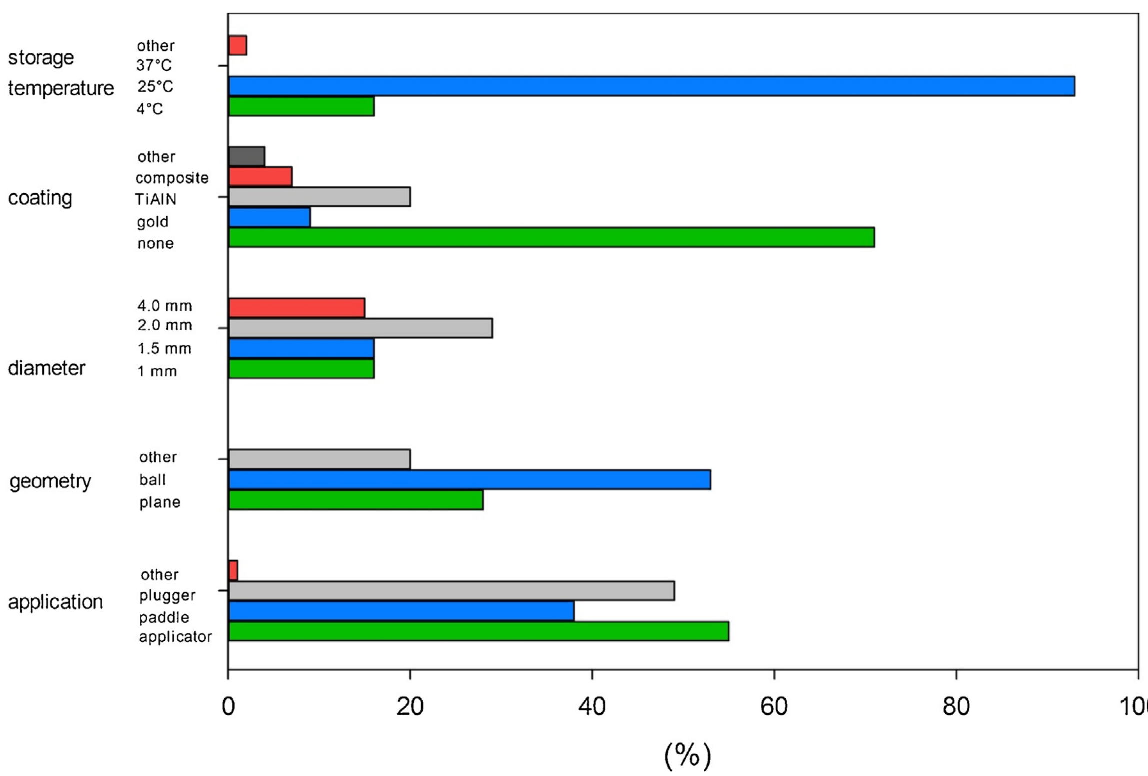

Fig. 1 – Survey of clinical composite application (percent share, n = 55) using different placement instruments and storage temperature (4 °C, 25 °C, 37 °C, other). Placement instruments varied in geometry (plane, ball other) diameter (1.0 mm, 1.5 mm, 2.0 mm, 4.0 mm) and coating (none, gold, TiAlN, composite, other).

an increase of UF was found. The increase of AF from 1 N to 2 N only enhanced UF for MH.

A. Instrument diameter

Application force 1 N: *The UF* ranged from 0.27 ± 0.05 N to 0.74 ± 0.11 N (Fig. 2). For NH, pluggers with a diameter of 1.6 mm (25 °C: $p = 0.015$; 37 °C: $p = 0.000$) and 2.0 mm (25 °C: $p = 0.043$; 37 °C: $p = 0.000$) showed statistically lower results in comparison to data of 2.5 mm pluggers. For MH at 37 °C, statistically significant lower results were found of 1.6 mm and 2.0 mm ($p = 0.020$) than of 2.5 mm ($p = 0.003$) pluggers.

Application force 2 N: UF varied between 0.22 ± 0.03 N and 1.09 ± 0.05 N. For NH, UF were statistically different lower with 1.6 mm/2.0 mm compared with 2.5 mm pluggers at 25 °C ($p = 0.000/p = 0.000$) and 37 °C ($p = 0.000/p = 0.000$). For MH, pluggers with a diameter of 1.6 mm (25 °C: $p = 0.000$; 37 °C: $p = 0.000$) and 2.0 mm (25 °C: $p = 0.001$; 37 °C: $p = 0.000$) provided statisti-

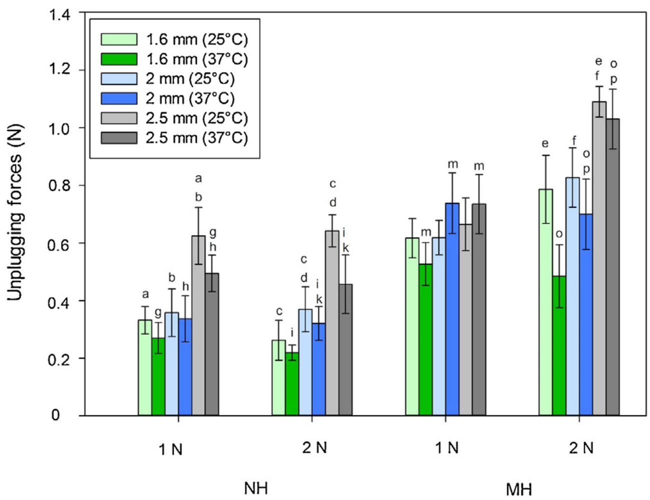

Fig. 2 – Unplugging forces (UF, mean + standard deviation) of two composite materials (NH: nanohybrid composite, MH: microhybrid composite) using different diameters of none coated plane pluggers (1.6 mm, 2 mm, 2.5 mm) and application forces (1 N/2 N) at two application temperatures (25 °C, 37 °C); significant differences are indicated by identical letters.

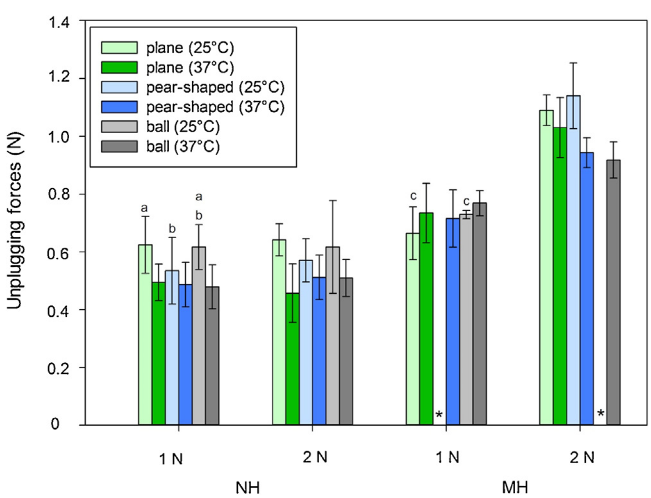

Fig. 3 – Unplugging forces (mean + standard deviation) of two composite materials (NH: nanohybrid composite, MH: microhybrid composite) using different none coated composite instrument geometries (plane, pear-shaped, ball; diameter: 2.5 mm) and application forces (1 N/2 N) at two application temperatures (25 °C, 37 °C); significant differences are indicated by identical letters; * = non-valid experiments.

cally significant lower UF than pluggers with a diameter of 2.5 mm.

B. Placement instrument geometry

Application force 1 N: *UF* varied between 0.48 ± 0.08 N and 0.77 ± 0.04 N (Fig. 3). Both, the plane plugger and the ball burnisher, provided statistically significant higher UF in comparison to the pear-shaped plugger ($p = 0.000$/$p = 0.000$) when

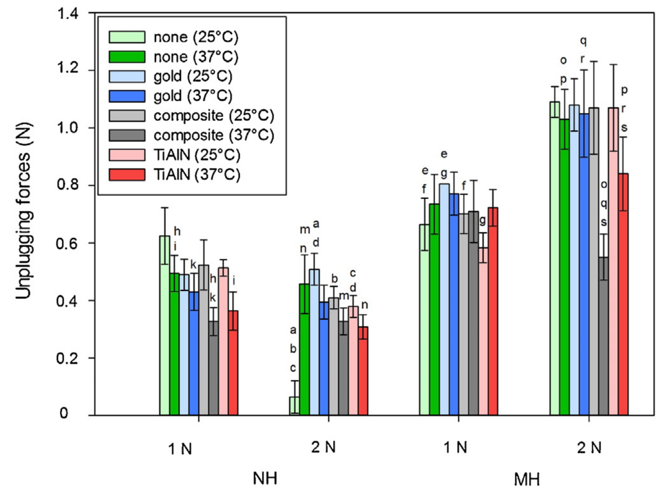

Fig. 4 – Unplugging forces (mean + standard deviation) of two composite materials (NH: nanohybrid composite, MH: microhybrid composite) using differentially coated plane composite pluggers (none, gold, composite, NiAlN; diameter: 2.5 mm) and application forces (1 N/2 N) at two application temperatures (25 °C, 37 °C); significant differences are indicated by identical letters.

NH was unplugged at 25 °C. For MH the plane plugger provided statistically significant lower results compared to the ball burnisher at 25 °C ($p = 0.000$). No valid experiments were obtained with the pear-shaped plugger and MH at 25 °C, because the composite did not adhere to the PMMA.

Application force 2 N: UF varied between 0.46 ± 0.07 N and 1.14 ± 0.11 N. For NH and MH no statistically significant differences were found. No valid experiments were obtained with the ball burnisher and MH at 25 °C, because the composite did not adhere to the PMMA.

C. Placement instrument coating

Application force 1 N: *UF* ranged from 0.33 ± 0.05 N to 0.81 ± 0.05 N (Fig. 4). For NH at 37 °C, the none-coated plugger showed statistically significant higher results in comparison to the composite-coated plugger ($p = 0.000$) and the TiAlN-coated plugger ($p = 0.001$). For the gold-coated plugger statistically significant higher UF was found compared to the composite-coated plugger ($p = 0.030$). For MH were statistically significant lower UF of none-coated plugger than UF of the gold-coated plugger ($p = 0.000$) and the composite-coated plugger ($p = 0.000$) at 25 °C. For MH at 25 °C, the gold-coated plugger provided statistically significant higher UF than the TiAlN-coated plugger ($p = 0.004$).

Application force 2 N: UF varied between 0.33 ± 0.05 N and 1.09 ± 0.05 N. For NH, UF was statistically lower for the application with a non-coated plugger in comparison to application with the gold-coated ($p = 0.007$), composite-coated ($p = 0.000$) and the TiAlN-coated pluggers ($p = 0.000$) at 25°. At 25 °C the gold-coated pluggers provide statistically significant higher results compared to the TiAlN-coated plugger ($p = 0.008$) unplugging NH. Only at 37 °C UF were statistically higher with the none-coated plugger than with the composite-coated ($p = 0.000$) and the TiAlN-coated plugger ($p = 0.006$) when MH was unplugged. TiAlN-coated pluggers data were statistically significant lower compared with data from the gold-coated ($p = 0.001$), but statistically significant higher compared to the composite-coated plugger ($p = 0.000$). There was a statistically significant lower result of the gold-coated than the composite-coated plugger ($p = 0.000$) when AT was unplugged at 37 °C.

4. Discussion

Numerous investigations about composite focus on their physico-mechanical, biological or esthetical characteristics and clinical longevity, but only a small number of studies aim to investigate composite handling. The present study based on a previously published study [7] using a pressure/tensile test to measure unplugging work (unplugging force × length of the adhesive flag), which has been related to a clinical evaluation of adaptability and stickiness. The unplugging work has been considered as a reliable method to measure stickiness of composites [5]. Roughened PMMA plates were regarded as suitable substrate and alternative to tooth hard tissues for testing [6,7]. However, no standardized protocol for *in vitro* or *in vivo* testing of composite materials' stickiness has been established so far.

Ideally, an uncured composite flows into nooks, properly adapts to the cavity during placement and is easily shaped, but should not stick to the placement instruments [6,12]. Stickiness of composites is considered to strongly impact the quality and clinical performance of composite restorations. Sticky composites may detach from the cavity wall and diminish the clinical success of the restoration. An increase of filler loading usually results in a decrease of stickiness [13]. Thus, the nanohybrid composite with a filler content of 89% w/w, and the microhybrid composite with a filler content of 77% w/w, were selected to present different degrees of stickiness in this investigation.

The hypothesis of this study that handling of dental composite materials is affected by diameter, geometry or coating of the placement instruments used could be confirmed. Both, most of the pairwise comparisons of data and comparison on the basis of the error-rates method showed that stickiness, in general, is affected by diameter, geometry and coating of the placement instrument. To our best knowledge, these are the first experiments directly comparing different diameters, geometries and coatings of placement instruments by means of unplugged force testing. Ertl et al. [6] found significant differences between steel, dentin and bonded dentin in stickiness of composite materials, reporting higher stickiness to steel than to bonded dentin. They recommended the evaluation of potential materials (titanium or ceramic) optimized for lower stickiness characteristics. The results of the present study showed that composites are less sticky to a plugger with a diameter of 1.6 mm and 2 mm than to a plugger with a diameter of 2.5 mm. The enlarged surface of more than 2 mm clearly increases the adherence of composite materials to the facial side of the plugger. Interestingly, stickiness to placement instruments with different geometries (plane, pear-shaped, ball) varies slightly. Once, the microhybrid composite did not stick to the pear-shaped plugger, another time it did not stick to the ball burnisher (non-valid experiments). Based on the results of the present study, no explicit placement instrument could be recommended to apply and shape the uncured composite. The choice of the placement instrument falls to personal habits and preferences of the dentist. Other than results about instrument geometry, the results about how different coatings of placement instruments affect composite stickiness revealed statistically significant differences. Altogether, composite materials are less sticky to composite- and TiAlN-coated instruments than to none- or gold-coated placement instruments.

Looking at the materials used, the nanohybrid composite (0.27–0.64 N) was less sticky than microhybrid (0.52–1.14 N), indicating superior handling of the nanohybrid material. These results coincide with an individual evaluation of practitioners (stickiness and adaptability) combined with laboratory adaptability and stickiness testing [7]. It has been reported that the amount of filler particles, filler particle size and morphology affect composite handling [11,13]. The rising of application temperature (37 °C) noticeably reduced the stickiness of both composites, most likely caused by increased movability of polymer chains, which results in increased viscoelasticity and decreased stickiness of composite materials [14,15]. These data confirm earlier tests [7], which investigated the stickiness of five composites on PMMA- or tooth-slices at different storage and application temperatures (6 °C, 25 °C, 37 °C). Moreover, the results of the present study are in agreement with Al-Sharaa and Watts [13], who also showed the decrease of stickiness, when application temperature increased. Kaleem et al. [11] found no significant influence of temperature (at 25 °C, 37 °C) on stickiness of experimental composites varying in filler particle size and morphology. In contrast to the present study Ertl et al. [6] reported an increase of composite stickiness with an increasing temperature (23 °C, 37 °C) on steel rod or bovine dentin slices with/without bonding. Also, Kaleem et al. [12] found, that the stickiness of six composites except Grandio increases when the temperature increases (26 °C, 37 °C). Results may be influenced by the experimental set-up, such as material, surface condition or speed of testing. It can be assumed that moist dentin or a smear layer may further impede the placement of composite materials and their adhesion to the cavity wall. Increased application force to 2 N additionally enhanced stickiness of the microhybrid composite in the present investigation, which has been reported for the microhybrid composite and other composites before [7]. Deeper impression of the instrument caused by higher force into a composite may result in enhanced attachment to the instrument sides. Speculations about former difficulties in dosing of the applied composite [7] were eliminated by applying an equal amount of both composites.

5. Conclusions

Diameter, geometry and coating of composite instruments influence the handling of dental composites. Stickiness is mostly affected by the coating of the instrument. Within the limitations of this *in vitro* investigation, unplugging forces may be used to easily assess the stickiness of dental composite materials in order to characterize clinical handling of these materials.

Acknowledgement

Thanks to Voco for providing the materials.

REFERENCES

[1] Schultz S, Rosentritt M, Behr M, Handel G. Mechanical properties and three-body wear of dental restoratives and their comparative flowable materials. Quintessence Int 2010;41:e1–10.

[2] Schweikl H, Buchalla W, Krifka S. Cell responses to cariogenic microorganisms and dental resin materials-Crosstalk at the dentin-pulp interface. Dent Mater 2017;33:514–24.

[3] Pinna R, Usai P, Filigheddu E, Garcia-Godoy F, Milia E. The role of adhesive materials and oral biofilm in the failure of adhesive resin restorations. Am J Dent 2017;30:285–92.

[4] Lempel E, Lovász BV, Meszarics R, Jeges S, Á Tóth, Szalma J. Direct resin composite restorations for fractured maxillary teeth and diastema closure: a 7 years retrospective evaluation of survival and influencing factors. Dent Mater 2017;33:467–76.

[5] Ferracane JL, Hilton TJ, Stansbury JW, Watts DC, Silikas N, Ilie N, et al. Hickel R Academy of dental materials guidance — resin composites: part II-technique sensitivity (handling, polymerization, dimensional changes). Dent Mater 2017;33:1171–91.

[6] Ertl K, Graf A, Watts D, Schedle A. Stickiness of dental resin composite materials to steel, dentin and bonded dentin. Dent Mater 2010;26:59–66.

[7] Rosentritt M, Buczovsky S, Behr M, Preis V. Laboratory tests for assessing adaptability and stickiness of dental composites. Dent Mater 2014;30:963–7.

[8] Kalman L, Xian A. Preliminary study of a novel dental hand instrument for restorative procedures. J Dent Res Dent Clin Dent Prospects 2017;11:195–9.

[9] Dentist training manual for military dentists, Chapter 4, Operative dentistry. vol. 2, 90.

[10] Evans TE, Lucaccini LF, Hazell JW, Lucas RJ. Evaluation of dental hand instruments. Hum Factors 1973;15:401–6.

[11] Kaleem M, Satterthwaite JD, Watts DC. Effect of filler particle size and morphology on force/work parameters for stickiness of unset resin-composites. Dent Mater 2009;25:1585–92.

[12] Kaleem M, Satterthwaite JD, Watts DC. A method for assessing force/work parameters for stickiness of unset resin-composites. Dent Mater 2011;27:805–10.

[13] Al-Sharaa KA, Watts DC. Stickiness prior to setting of some light cured resin-composites. Dent Mater 2003;19:182–7.

[14] Silikas N, Watts DC. Rheology of urethane di-methacrylate and diluent formulations. Dent Mater 1999;15:257–61.

[15] Mesquita RV, Geis-Gerstorfer J. Influence of temperature on visco-elastic properties of direct and indirect dental composite resins. Dent Mater 2008;24:623–32.