Report

Marginal behaviour of composite resin restorations in Class I and V cavities
placed with *FL Bond II and FL Bond III* in combination with *Beautifil II*
in vitro after thermocycling.

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Marginal behaviour of composite resin restorations in Class I and V cavities placed with *FL Bond II and FL Bond III* in combination with *Beautifil II* in vitro after thermocycling.

1 Summary

In extracted human teeth, stored in 0.1 % thymol solution, eight Class I and eight Class V cavities per group were prepared and filled with the composite resin *Beautifil II* using the self-etching adhesive systems *FL Bond II and FL Bond III*. After finishing and water storage for 21 days, replica were taken before and after thermocycling and a quantitative margin analysis in the SEM was performed at a magnification of 200X using four defined criteria.

The evaluation of the marginal adaptation of the Class V restorations after thermocycling showed for both adhesive systems rather high amounts of margin quality "continuous margin" in dentin (median value 94.1 and 95.0 %) and in enamel (median value 97.1 and 96.9 %).

At the Class I restorations the evaluation of the marginal adaptation in enamel after thermocycling showed for *FL Bond II* statistically significant ($p<0.05$) higher amounts of margin quality 1 (median value of 87.4 %) than for *FL Bond III* (median value 56.6 %).

The results of this in vitro test show efficient marginal adaptation in enamel and dentin even after thermocycling when *FL Bond II* or *FL Bond III* were used at Class V cavities. The marginal adaptation in enamel at Class I cavities using *FL Bond III* is less effective than in combination with *FL Bond II*.

Project leader

Dr. U. Blunck

Berlin, January, 3rd 2008

2 Introduction

Adhesive systems are used to improve the marginal seal of composite resin restorations at the interfaces of the composite to enamel and dentin. The bonding between enamel or dentin and composite must be effective enough to resist the polymerization shrinkage and stresses created by different coefficients of expansion of tooth structures and filling materials during thermal stress.
Available adhesive systems can be classified as dentin conditioning adhesive systems with selective acid etching on enamel, etch-and-rinse systems, necessitating phosphoric acid etching and rinsing of enamel/dentin prior to applying multi-bottle or one-bottle adhesives, and self-etching systems that contain acid monomers which can condition both enamel and dentin simultaneously with no rinsing [10]. Self-etching adhesive systems can be applied in two consecutive steps or as so-called all-in-one adhesives. The latter are available in two forms: those that require mixing and those that do not. In order to reduce the handling time and to avoid the time consuming etch&rinse technique, self etching adhesive systems were developed. They combine the etching effect by their acidity and the ability of the primer to penetrate into the simultaneously etched tooth surface. A certain disadvantage of self etching systems so far was the reduced storage time caused by the inherent acidity. Therefore some systems require mixing of two components immediately before the application. The most recently launched adhesive systems are one-bottle all-in-one-adhesives containing all ingredients to establish bonding to enamel and dentin and avoiding the mixing procedure. Self-etching adhesive systems create a bonding to the tooth substrate by dissolving hydroxyapatite during the application. This effect is depending on the acidity of the solution and how easily the acidic primer is neutralized by the hydroxyapatite. The effectiveness in dissolving hydroxyapatite might be influenced by the application technique depending on whether the adhesive is applied with or without agitation.
The effectiveness of adhesive systems can be tested in vitro by bond strength measurements of various kinds, by penetration tests of Class V/II fillings with different substances and by evaluating the margin quality of Class I/II/V or cylindrical fillings under a microscope [4]. In this study, evaluation was performed with the scanning electron microscope (SEM) which is used for identification and quantification of different margin qualities [9]. This method has several distinct advantages such as the high level of detail revealed and marked accuracy, allowing it to be used for evaluating the same margins at substantially different times. This is particularly useful for testing the effects of water storage or stressing of the same specimens. The effectiveness of adhesive systems can be tested by evaluating in the SEM the marginal adaptation of Class V restorations with margins both in dentin and in enamel simulating a clinical situation and at Class I restorations with margins only in enamel.

The purpose of this in vitro investigation was to evaluate the effectiveness of the self-etching all-in-one adhesives ***FL Bond II*** with mixing and ***FL Bond III*** without mixing in improving the marginal adaptation of composite resin restorations placed with ***Beautifil II*** in dentin and enamel in Class V restorations and in enamel in Class I restorations.

3 Materials and Methods

3.1 Cavity preparation

Class I cavities

Per group 8 class I cavities were prepared in extracted teeth with a diamond bur[1, 2] at high speed using water as a coolant. The preparation was approximately 3 mm deep, 6 mm wide in mesio-distal direction, and 4 mm wide in buccal-oral direction. The extension of the occlusal cavity included most of the fissures which otherwise would cross the margin of the cavity. The enamel portions were bevelled with a finishing diamond bur[3].

Class V cavities

Per group 8 Class V cavities were prepared in extracted teeth with a diamond bur[1] at high speed using water as a coolant. The oval preparation was approximately 1.5 mm deep, 3 mm wide, and 4 mm high (2 mm were apical to the cementoenamel junction). The enamel portions were beveled with a finishing diamond bur[3] and the cavosurface margins in dentin were finished[2] to a 90 degree angle.

3.2 Application of the adhesives

FL-Bond II

Primer was applied on bevelled enamel and on dentin of the cavity and left undisturbed for 10 s; then it was dried with gentle air flow. *Bond* was applied and carefully distributed in the entire cavity and light cured[4] for 10 s.

FL-Bond III

Primer was applied on bevelled enamel and on dentin of the cavity and left undisturbed for 10 s; then it was dried with gentle air flow for 5 s and finally dried with strong air pressure for another 5 s. The adhesive was then light cured[4] for 10 s

The Class V cavities were filled with the composite resin ***Beautifil II*** in two incremental insertions starting at the cervical margin and each increment was light-cured[4] for 40 s.
The Class I cavities were filled in three increments, starting at the cavity floor with one horizontal layer of 1 mm followed by two oblique layers which each were light-cured[4] for 20 s separately.

3.3 Additional treatment

After polishing[5, 6, 7], the teeth were stored for 21 days in water (18 to 22 °C) and then thermocycled for 2000 cycles between +5 ^{o}C and +55 ^{o}C. Before and after the thermocycling procedure, impressions were taken with a polyvinylsiloxan impression material[8] and replicas were produced by casting the impressions with an epoxy resin[9] and by coating with gold in a sputter device[10].
The margins at the enamel/composite interface of the Class I restorations and at the enamel/composite and dentin/composite interfaces at the Class V restorations were examined and quantified with a scanning electron microscope[11] (SEM) at a magnification of 200X using defined criteria (Tab. 1) to assess the margin qualities. The amount of length for the different defined criteria were summarized in percent of the total margin length in enamel and dentin respectively for each cavity.

The statistical evaluation was performed with the SPSS statistical software[12] using non parametric tests.

Table 1 Criteria for the marginal examination in the SEM at a magnification of 200 X

Margin-quality	Definition
1	Margin not or hardly visible No or slight marginal irregularities; No gap
2	No gap but severe marginal irregularities
3	Gap visible (hairline crack up to 2 μm) No marginal irregularities
4	Severe gap (more than 2 μm) slight and severe marginal irregularities
	the term "marginal irregularities" means porosities, marginal restoration fracture, bulge in the restoration

4 Materials and devices used

1 Diamond bur No. 838/314/014; Gebr. Brasseler GmbH D-32657 Lemgo, Germany
2 Finishing diamond bur No. 8838/314/012; Gebr. Brasseler GmbH D-32657 Lemgo, Germany
3 Composhape H-15 Finierdiamant; Intensiv CH-6962 Viganello-Lugano, Switzerland
4 Astralis 10, Lightcuring unit; Ivoclar Vivadent GmbH, D-73471 Ellwangen, Germany
5 Sof-Lex Pop-on Nr. 1981 SF/F/M/C; 3M Espe, St. Paul, MN, USA
6 Brownie and Greenie Polishing system; Shofu Dental, D-40878 Ratingen
7 Occlubrush, Kerr GmbH, D-76437 Rastatt
8 Silagum light body, DMG D-22547 Hamburg, Germany
9 Stycast 1266 Part A + B; Emerson and Cumming B-2431 Westerlo-Oevel, Belgium
10 Sputter device SCD 030; Balzers Union FL-9496 Balzers, Liechtenstein
11 Scanning electron microscope AMRAY 1810; Amray Inc., Bedfort Ma. 01730, USA
12 SPSS/PC+ Version 2.0; SPSS GmbH Software D-80538 München, Germany

4.1 Batch Nr.

Material	Lot number		
Beautifil II	010716		2009-12
FL-Bond II	Primer: Bond:	080710 080714	2010-07 2010-07
FL-Bond III (SI-R20603)	787T2060712		

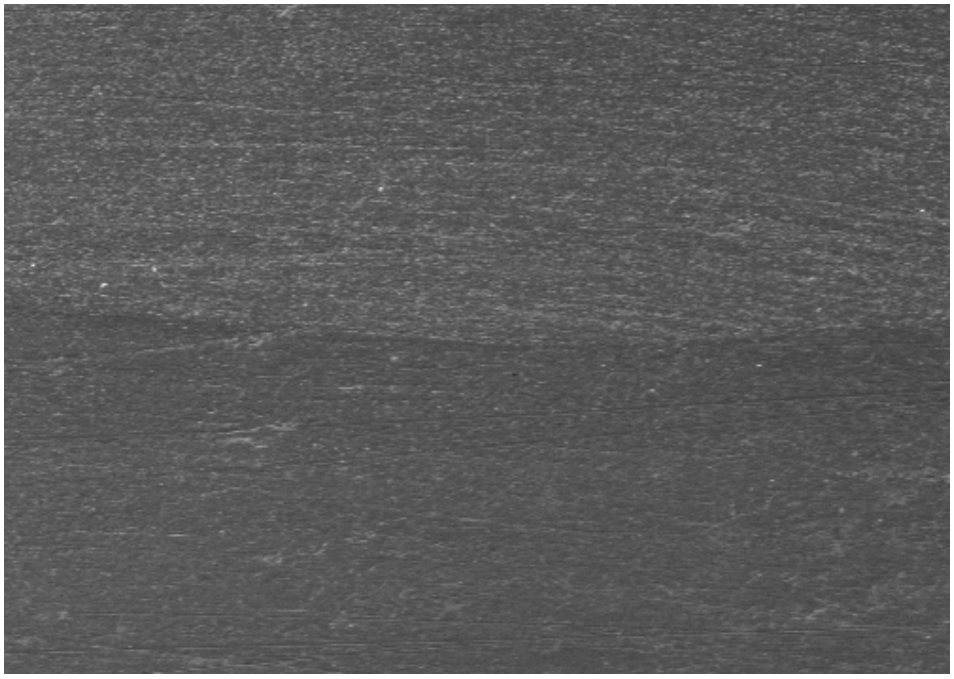

Fig. 1 Example for margin quality 1 in the SEM at a magnification of 200 X

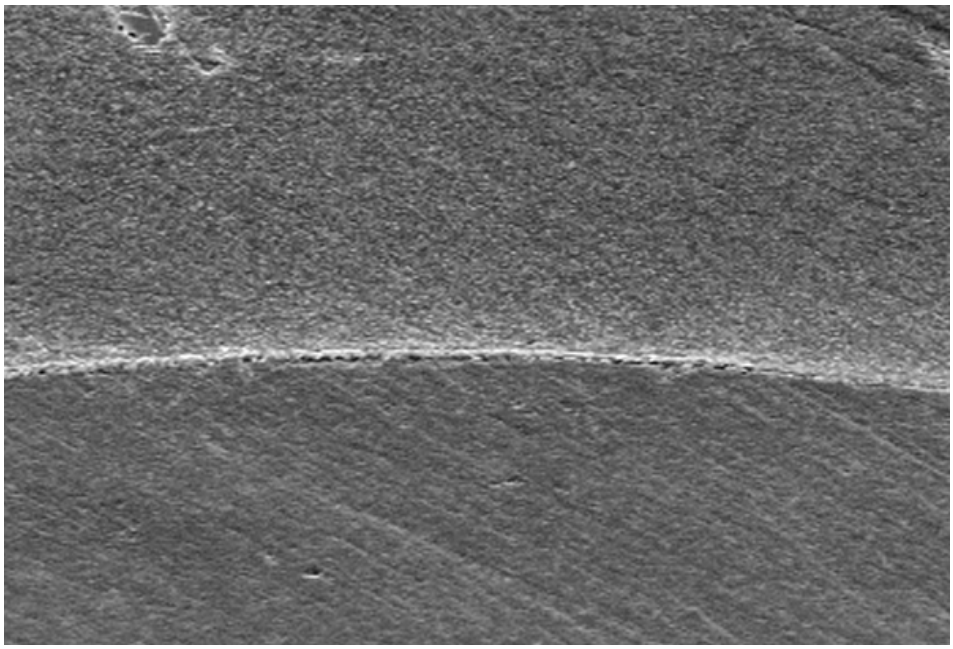

Fig. 2 Example for margin quality 2 in the SEM at a magnification of 200 X

Fig.3 Example for margin quality 3 in the SEM at a magnification of 200 X

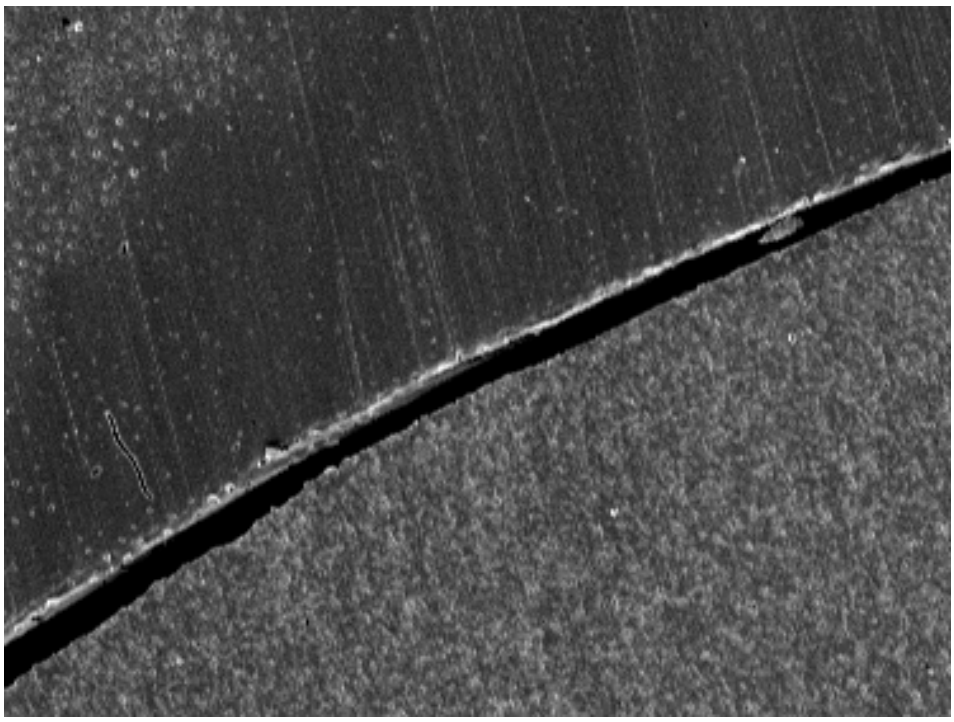

Fig. 4 Example for margin quality 4 in the SEM at a magnification of 200 X

5 Results

The results for the tested materials are summarized in table 2 and 3 and shown as graphs in figure 5 and 6 for the evaluation in enamel and in dentin at the Class V restorations and in table 4 and figure 7 for the evaluation in enamel at the Class I restorations.

Table 2 Results of the quantitative margin analysis in the SEM **in dentin of Class V restorations** at a magnification of 200 X
TM1 = before, TM2 = after thermocycling, StDev = standard deviation, MQ = margin quality

Materials	TM		MQ 1	MQ 2	MQ 3	MQ 4	gap
Shofu FL-Bond II / Beautifil II	1	Median	98,6	1,4	0,0	0,0	0,0
		Mean	97,4	1,9	0,5	0,2	0,7
		St-Dev	3,4	2,2	1,4	0,5	1,9
	2	Median	94,1	5,9	0,0	0,0	0,0
		Mean	87,2	7,1	0,2	5,5	5,7
		St-Dev	17,3	4,6	0,7	14,5	14,5
Shofu FL-Bond III / Beautifil II	1	Median	98,9	1,1	0,0	0,0	0,0
		Mean	98,4	1,6	0,0	0,0	0,0
		St-Dev	1,8	1,8	0,0	0,0	0,0
	2	Median	95,0	5,0	0,0	0,0	0,0
		Mean	95,1	4,9	0,0	0,0	0,0
		St-Dev	5,0	5,0	0,0	0,0	0,0

Table 3 Results of the quantitative margin analysis in the SEM **in enamel of Class V restorations** at a magnification of 200 X
TM1 = before, TM2 = after thermocycling, StDev = standard deviation, MQ = margin quality

Materials	TM		MQ 1	MQ 2	MQ 3	MQ 4	gap
Shofu FL-Bond II / Beautifil II	1	Median	100,0	0,0	0,0	0,0	0,0
		Mean	99,2	0,8	0,0	0,0	0,0
		St-Dev	1,4	1,4	0,0	0,0	0,0
	2	Median	97,1	2,9	0,0	0,0	0,0
		Mean	96,8	3,2	0,0	0,0	0,0
		St-Dev	2,7	2,7	0,0	0,0	0,0
Shofu FL-Bond III / Beautifil II	1	Median	100,0	0,0	0,0	0,0	0,0
		Mean	99,1	0,9	0,0	0,0	0,0
		St-Dev	1,2	1,2	0,0	0,0	0,0
	2	Median	96,9	3,1	0,0	0,0	0,0
		Mean	95,6	4,4	0,0	0,0	0,0
		St-Dev	4,5	4,5	0,0	0,0	0,0

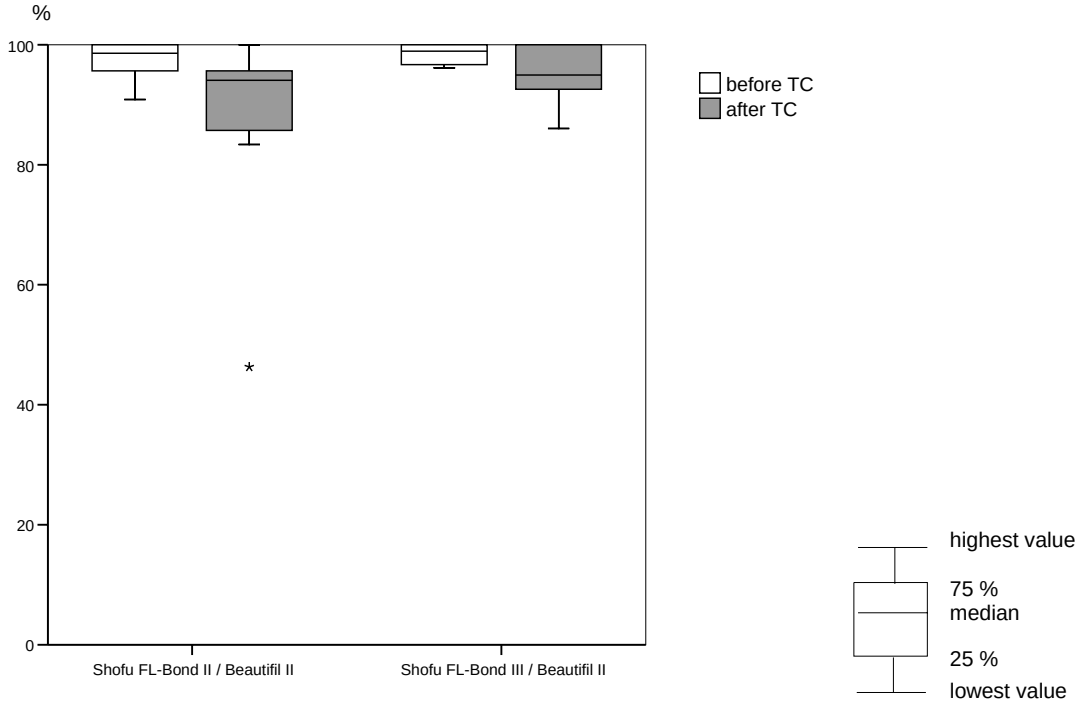

Fig. 5 Amount of margin quality 1 in % of the entire margin length in **dentin of Class V restorations** for the tested adhesive systems before and after TC.

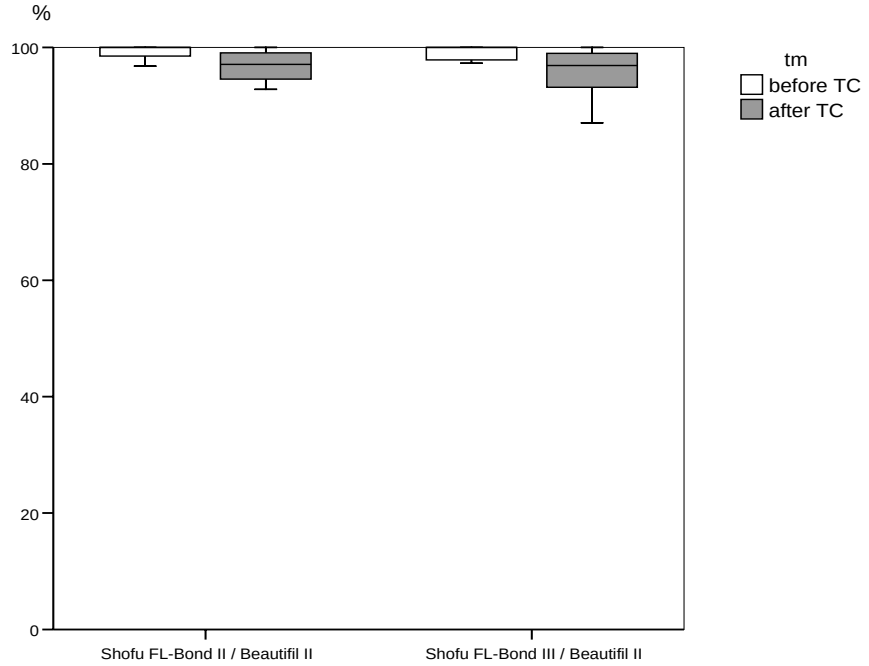

Fig. 6 Amount of margin quality 1 in % of the entire margin length in **enamel of Class V restorations** for the tested adhesive systems before and after TC.

Table 4 Results of the quantitative margin analysis in the SEM **in enamel in Class I Cavities** at a magnification of 200 X
TM1 = before, TM2 = after thermocycling, StDev = standard deviation, MQ = margin quality

Materials	TM		MQ 1	MQ 2	MQ 3	MQ 4	gap
Shofu FL-Bond II / Beautifil II	1	Median	95,2	3,8	0,0	0,0	0,2
		Mean	95,4	3,9	0,2	0,5	0,7
		St-Dev	1,6	1,1	0,3	1,0	1,0
	2	Median	87,4	8,3	0,3	0,1	1,6
		Mean	87,3	9,8	0,9	2,0	2,8
		St-Dev	6,5	4,6	1,1	3,5	3,6
Shofu FL-Bond III / Beautifil II	1	Median	89,4	7,4	0,0	2,9	4,8
		Mean	85,0	8,5	4,1	2,3	6,5
		St-Dev	9,1	7,3	6,9	2,1	7,3
	2	Median	56,6	25,0	0,0	18,9	18,9
		Mean	57,2	24,8	2,4	15,6	18,0
		St-Dev	19,3	15,4	3,7	9,4	9,8

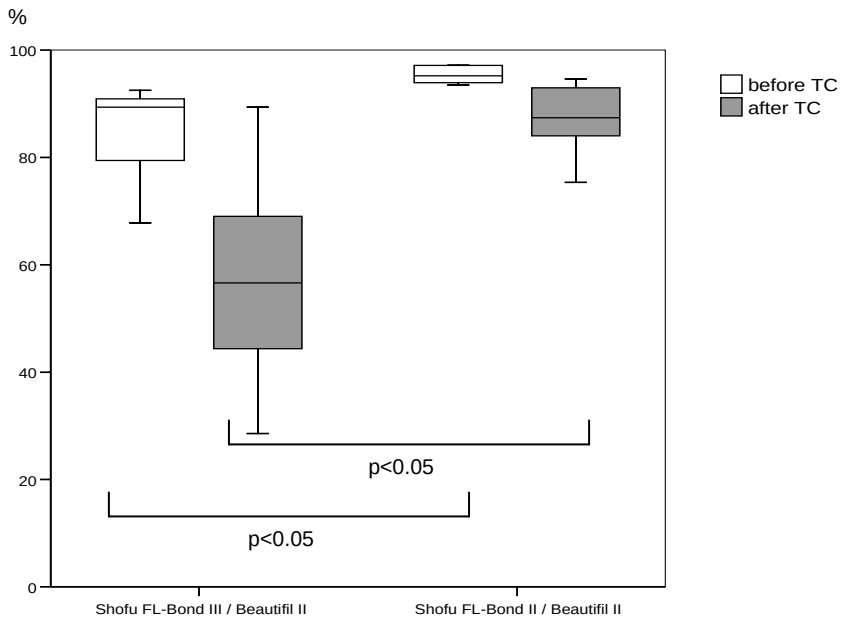

Fig. 7 Amount of margin quality 1 in % of the entire margin length in **enamel of Class I restorations** for the tested adhesive systems before and after TC.

The evaluation of the marginal adaptation in the SEM at the Class V restorations showed rather high amounts of margin quality “continuous margin” in enamel and also in dentin after thermocycling with median values between 94.1 % and 97.1 % at margins in enamel and in dentin for both tested adhesive systems ***FL Bond II*** and ***FL Bond III***. The statistical evaluation showed no significant differences in the amount of margin quality “continuous margin”.
However, the evaluation of the enamel margins of the Class I restorations placed in combination with ***FL Bond II*** showed after thermocycling significantly higher amounts of margin quality 1 (median 87.4 %) than with ***FL Bond III*** (median 56.6 %).

Typical examples for the marginal adaptation after thermocycling in enamel and dentin at the Class I and Class V restorations are shown in Fig. 8 to 11.

6 Discussion

Effectiveness of adhesive systems can be generally judged by the marginal adaptation of composite resin restorations at the interface with the tooth substrate. Marginal adaptation is affected by many different parameters. These might be greatly influenced by the inherent properties of the restorative material such as shrinkage and shrinkage stress [8], the chemistry of the adhesive system used, the size of the cavity, the c-factor [3], the insertion technique and the polymerization protocol [1].
In this study a high resolution quantitative marginal analysis method was used to evaluate the marginal adaptation of composite resin restorations over a period of water storage followed by TC. This quantification method relies on imaging of precision replicas of restored teeth with a scanning electron microscope (SEM) followed by quantitative quality analysis of the entire margin length. The replica technique is non-destructive to the natural-tooth samples and thus the margins can be assessed and marginal defects detected and compared at different times and after applying different stresses to the tooth specimens. The high sensitivity of this method, due to the SEM's excellent detail reproduction, is a great advantage for the evaluation of such bonding of adhesive systems [2] [9].

The evaluation for both tested adhesives showed rather high amounts of excellent margins of Class V restorations in dentin and enamel after thermocycling. However, in Class I cavities with a higher c-factor [3] the bond strength of ***FL Bond III***, the self-etching all-in-one adhesive without mixing, to enamel obviously is less effective than ***FL Bond II***, the self-etching all-in-one adhesive with mixing. It has been shown that bond strength to enamel of self-etching adhesives is not directly depending on the pH value of the applied mixture of monomers [7]. Obviously the composition and the mechanical strength of the primer-adhesive mixtures effect the bond strength more than the acidity itself [5]. The application mode of the adhesive, applied with or without agitation, also showed effect on bond strength to enamel [6]. An active application mode, e.g. agitation during the application in the cavity, and a prolonged application time might increase the marginal adaptation of Class I restorations when ***FL Bond III*** is used.

From the results of this in vitro investigation it can be concluded that the tested self etching adhesive ***FL Bond II*** is effective in the marginal adaptation in dentin and enamel. The effectiveness of ***FL Bond III*** in Class V cavities is as good as that of ***FL Bond II***, however, in Class I cavities ***FL Bond III*** seems not to be effective enough for the recommended application procedure.

7 References

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8 Results of the statistical evaluation with SPSS for Windows

Statistical differences between the two tested groups

Class V Cavities
Kruskal-Wallis-Test

	MQ1
Chi-Square	,016
df	1
Asymptotic Significance	,898

TM = 1, margin in enamel

	MQ1
Chi-Square	,050
df	1
Asymptotic Significance	,822

TM = 1, margin in dentin

	MQ1
Chi-Square	,179
df	1
Asymptotic Significance	,672

TM = 2, margin in enamel

	MQ1
Chi-Square	,630
df	1
Asymptotic Significance	,427

TM = 2, margin in dentin

Class I Cavities
Kruskal-Wallis-Test

	MQ1
Chi-Square	11,294
df	1
Asymptotic Significance	,001

TM = 1, margin in enamel

	MQ1
Chi-Square	8,040
df	1
Asymptotic Significance	,005

TM = 2, margin in enamel

9 SEM-pictures of margins

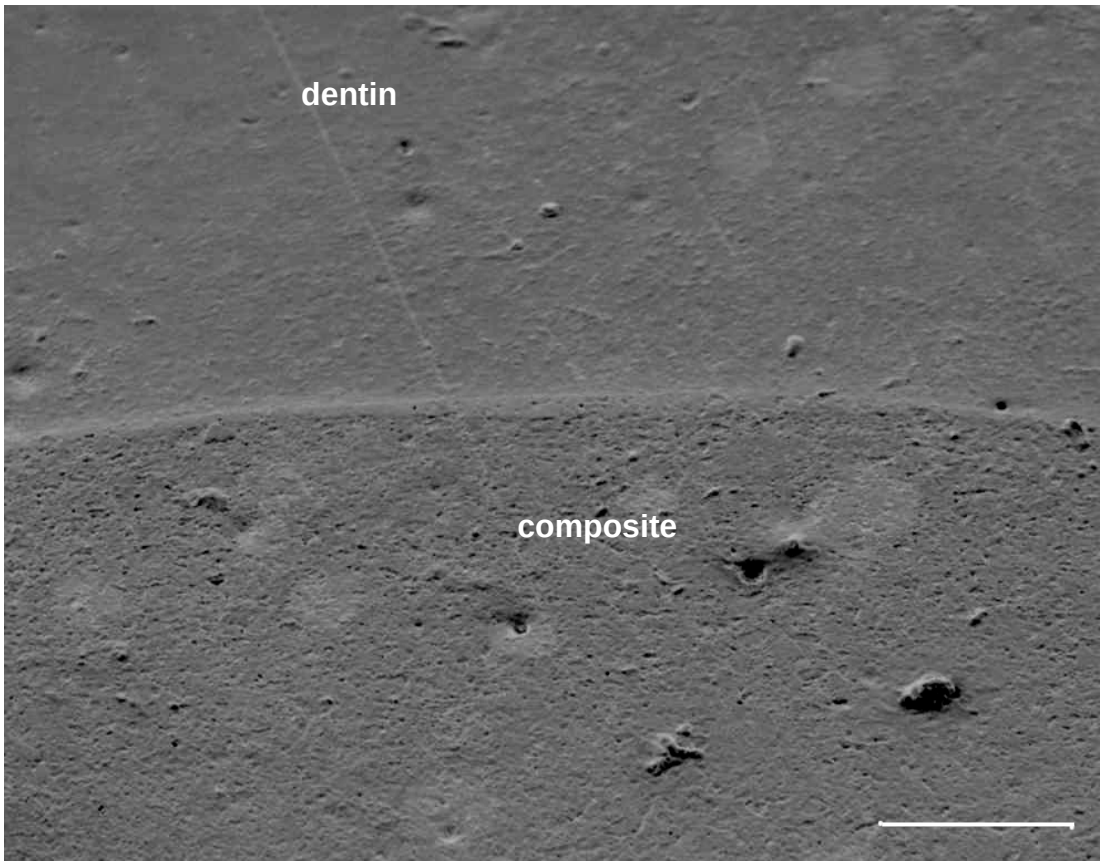

Fig. 7 Marginal situation in **dentin at Class V restorations**, adhesive system: ***FL Bond II*** margin quality 1 (original magnification: 200X), (white bar = 100 μm)

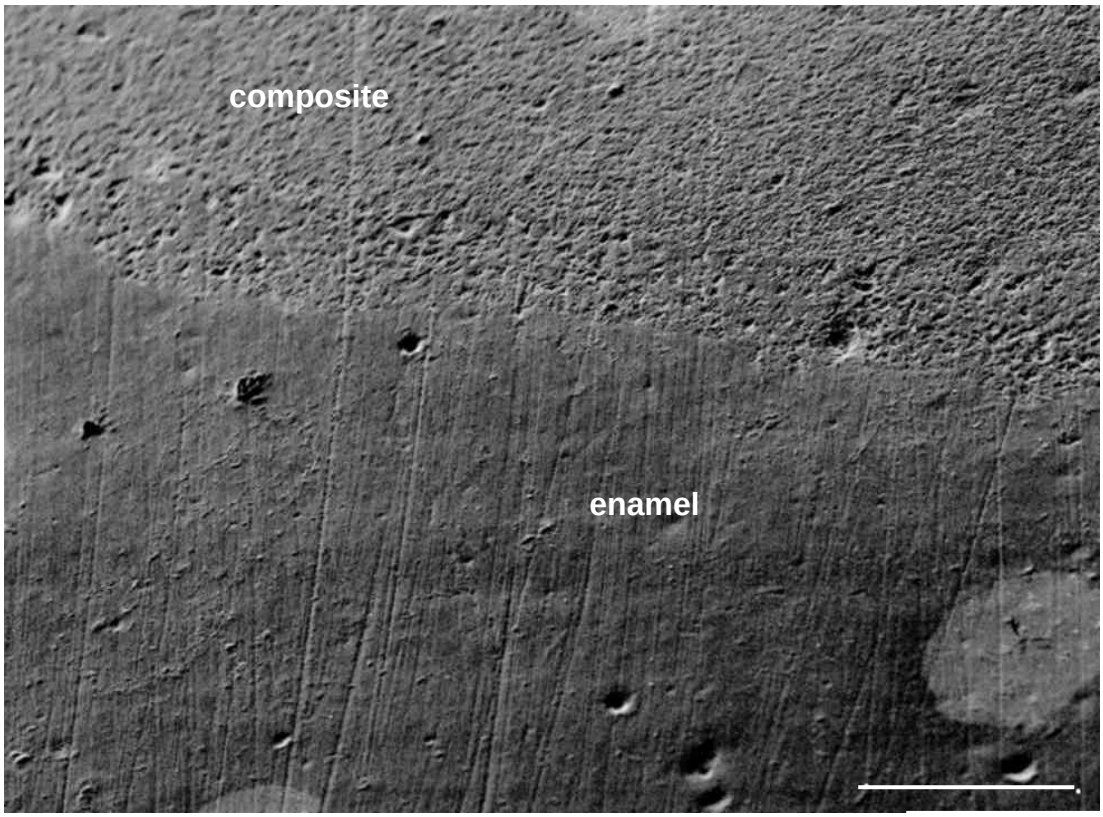

Fig. 8 Marginal situation in **enamel at Class V restorations**, adhesive system: ***FL Bond II*** margin quality 1 (original magnification: 200X), (white bar = 100 μm)

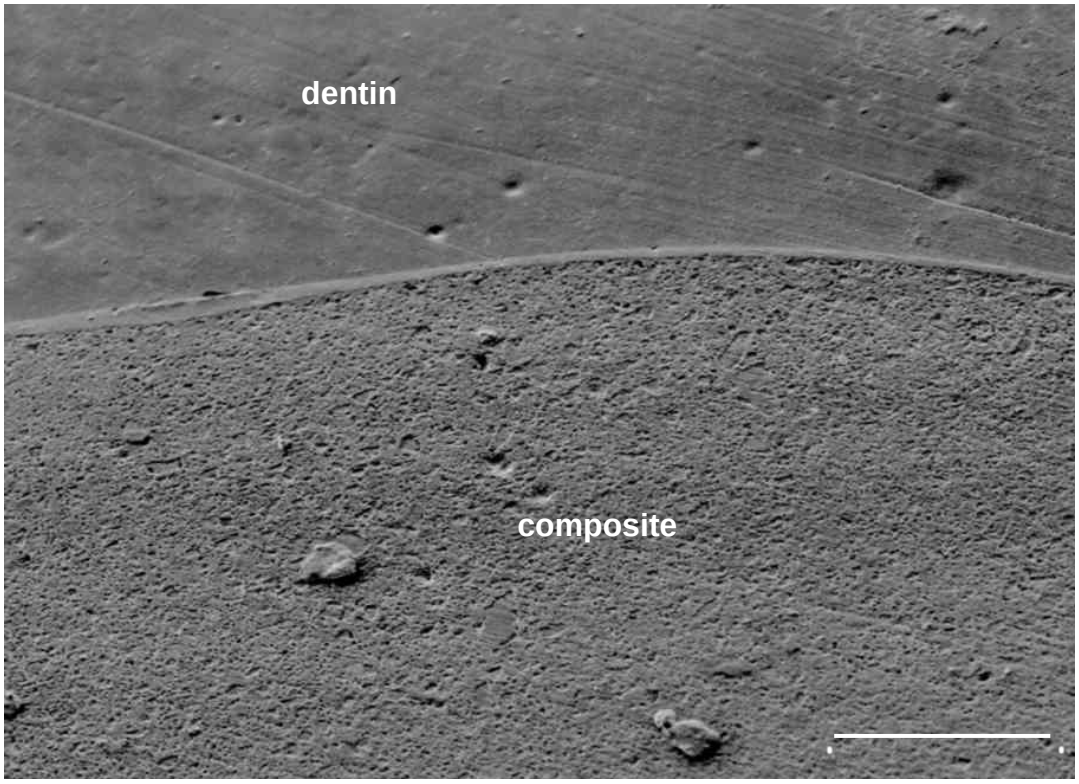

Fig. 9 Marginal situation in **dentin at Class V restorations**, adhesive system: ***FL Bond III*** margin quality 1 (original magnification: 200X), (white bar = 100 μm)

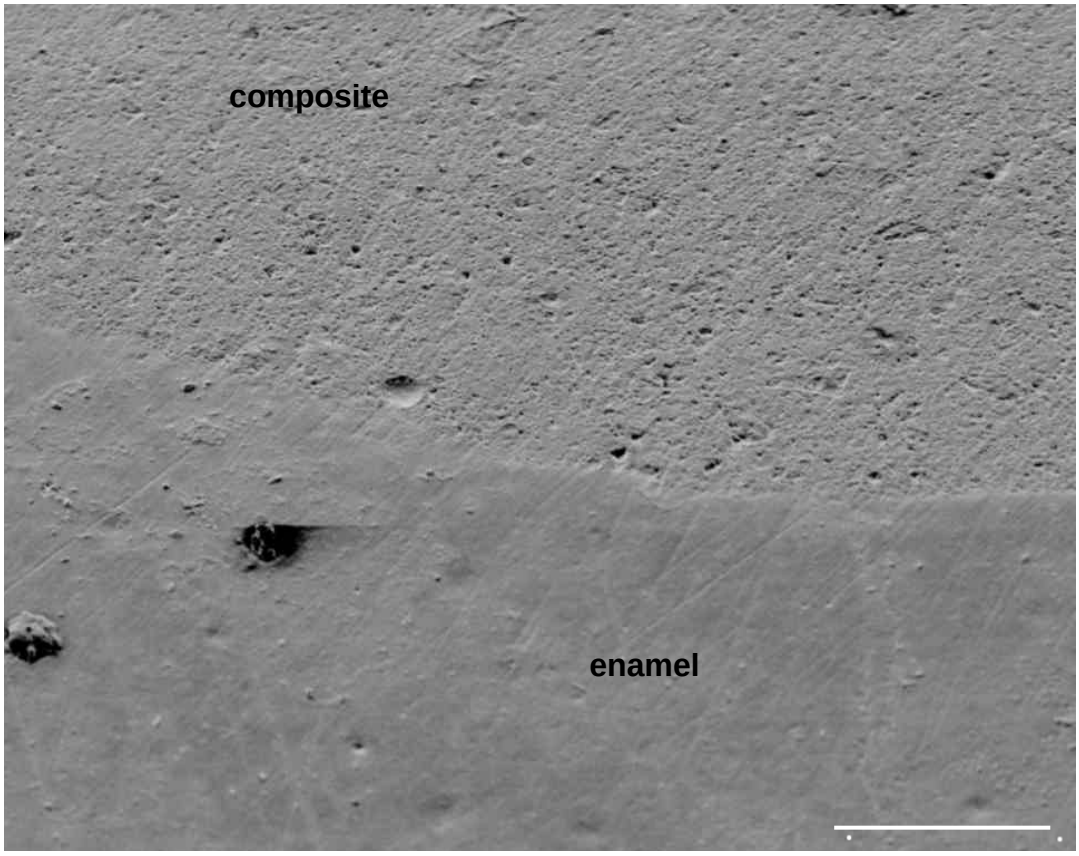

Fig. 10 Marginal situation in **enamel at Class V restorations**, adhesive system: ***FL Bond III*** margin quality 1 (original magnification: 200X), (white bar = 100 μm)

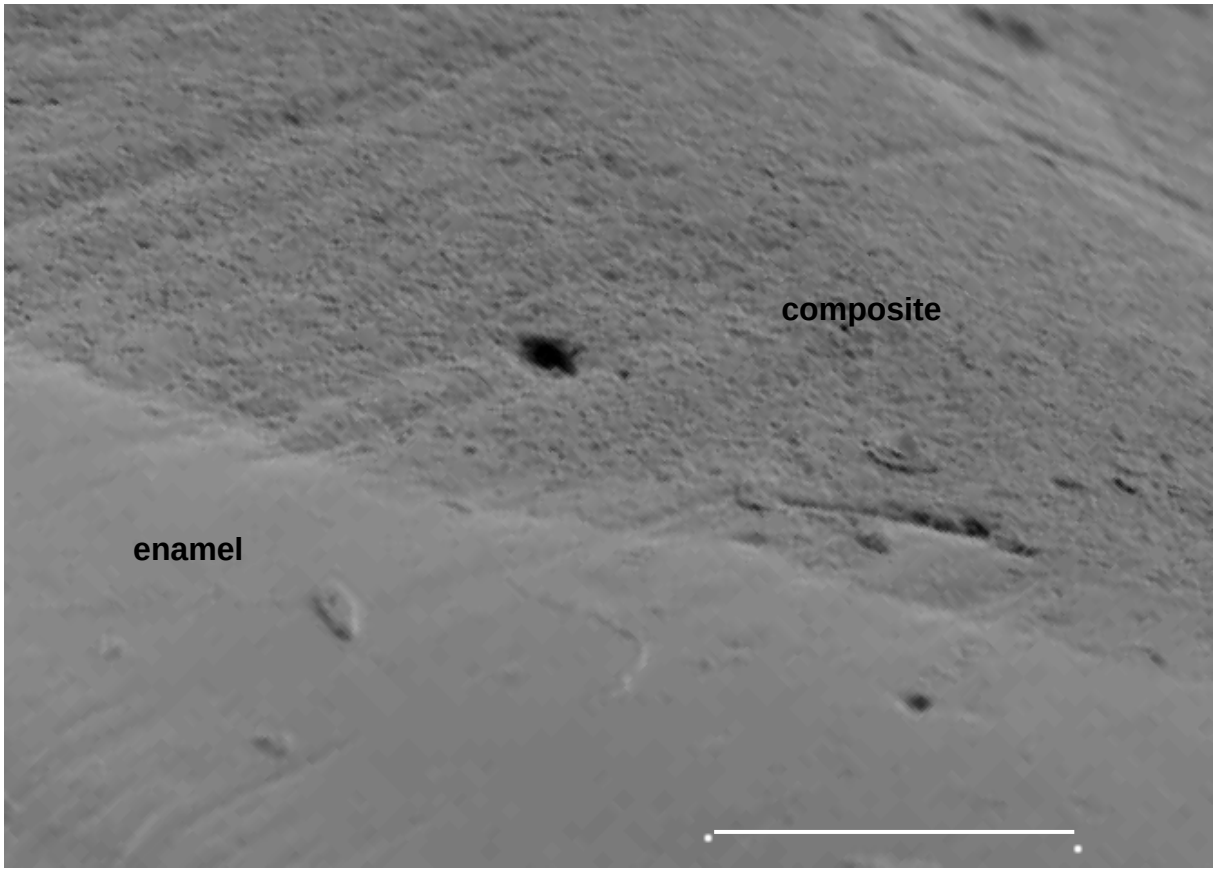

Fig. 11 Marginal situation in **enamel at Class I restorations**, adhesive system: ***FL Bond II*** margin quality 1 (original magnification: 200X), (white bar = 100 μm)

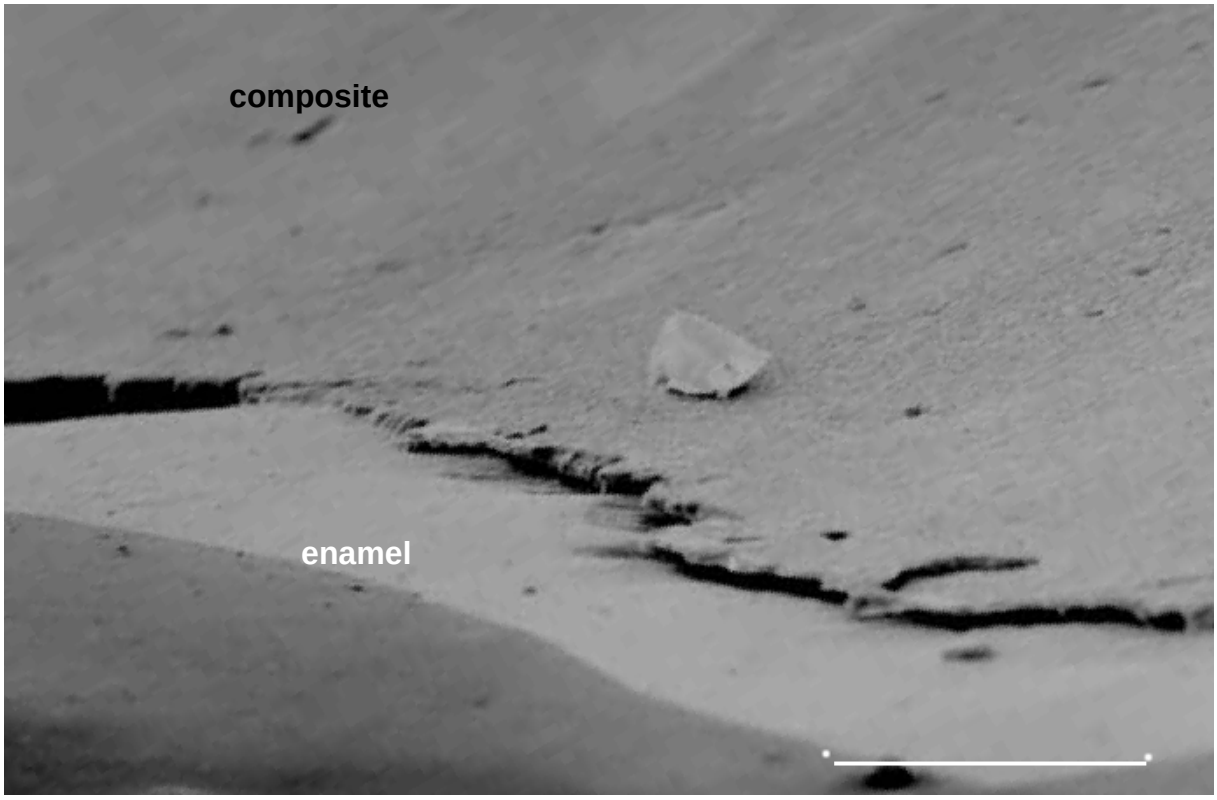

Fig. 11 Marginal situation in **enamel at Class I restorations**, adhesive system: ***FL Bond III*** margin quality 4 (original magnification: 200X), (white bar = 100 μm)