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The Significance of Marginal Gap and Overextension Measurement in the Evaluation of the Fit of Complete Crowns

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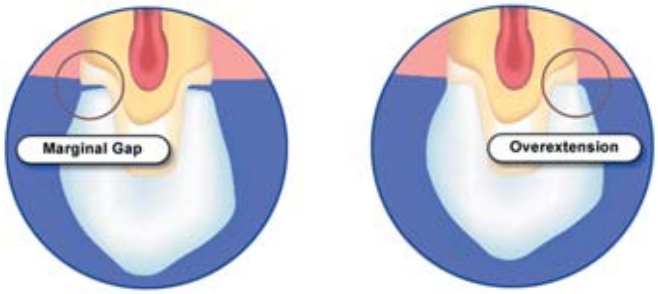

Abstract

Introduction: An important criterion for the success of a crown is marginal fit. However, in the patient's mouth fit can only be evaluated by subjective methods. This study describes the correlation between objective marginal fit and its subjective evaluation by dentists and dental technicians.

Materials and Methods: Thirty human premolars and molars were randomly divided into six groups and prepared with a shoulder. For each of the six groups, complete crowns were made of different alloys and technologies (casting: AuAgCu, AuPdPt, PdAgAu, CoCrMo, and Ti; milling: Ti). The crowns were cemented with provisional cement. Ten dentists and 10 technicians were asked to evaluate the fit of the crowns with a new dental explorer. The crowns were then cleaned and cemented with a zinc-oxide-phosphate-cement. The marginal gap and a possible overextended margin of the crowns were examined under a special 4x light microscope with a magnification level of 560 X. The means of the gaps and the overextended margins were calculated for each group. Significances were detected by analysis of variance (ANOVA) and the post-hoc-test (Bonferroni, $p<0.05$). Correlations between objective measuring and subjective evaluation were evaluated using the Pearson test. The influence of the measured values on the subjective evaluation was determined by regression analyses.

Results: Crowns made from different alloys and technologies showed partly significantly ($p<0.05$) different marginal gaps (mean ranging from 35µm to 92µm) and significantly ($p<0.05$) different overextended margins (mean ranging from 40µm to 149µm). There were significant correlations ($p<0.05$) between subjective findings and objective data. Significant correlations ($p<0.01$) were also found between the subjective findings of dentists and technicians. Compared to the marginal gap, only the overextended margin had a significant influence ($p=0.00$) on the subjective evaluations of the clinicians.

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Conclusion: Crowns from different alloys and technologies showed differences in marginal fit. Marginal gap and the overextension of the crowns significantly correlated with the subjective evaluation of their fit by dentists and dental technicians. For the decision of the clinicians, whether a crown is acceptable, overextension was more important than marginal gap.

Keywords: Complete crown, marginal gap, overextended margin, correlation, cement width, marginal fit, dental explorer

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Introduction

Fit is an important factor for the success of a crown, and deficiencies can result in damage of the tooth and its periodontal tissues.[1-3] Retention of plaque leads to marginal inflammation as well as gingival recession.[4] Insufficient marginal fit can cause caries and secondary caries below the margins of the crown.[5, 6] These defects are frequent reasons for the failure of restorations.[4, 6-8]

Fit of a restoration can be defined best in terms of "misfit" measured at various points between the casting and the tooth. Measurements between the casting and the tooth can be made from points along the internal surface of the margin or on the external surface of the casting. Clinically important measurements are the marginal gap, which is the distance from the internal surface of the casting to the axial wall of the preparation at the margin, and overextension, which is the distance from the marginal gap to the castings margin[9] (Figure 1).

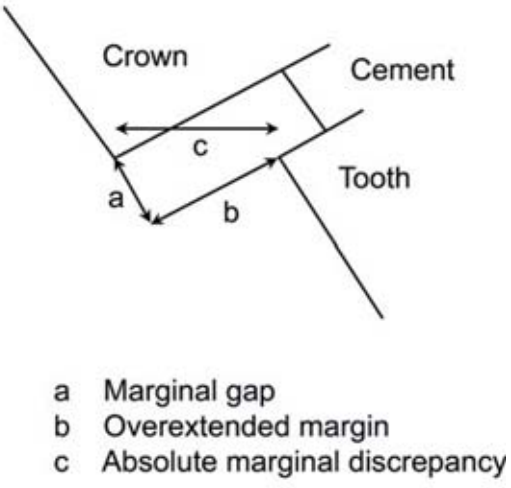

Figure 1. Casting misfit terminology.

Despite careful attention to waxing, investing, and casting, marginal discrepancies are inevitable. It is one of the tasks of luting cements to close these discrepancies. But cement can be washed out under the margins if the gap is too large.[10-12] Saliva increasingly influences the dissolution of the cement in marginal gaps wider than 150µm.[12] However, even if the cement width is only a few micrometers, it can cause irritation of the marginal periodontium.[13]

Published data on clinically acceptable marginal gaps vary between 30µm and 200µm.[2, 14-24] A gap between the tooth and the crown must not be increased by the luting agent but can be ruined because of incomplete seating during cementation.[25] However, one study[26] indicated an increased marginal gap of 43µm to 63µm when crowns were cemented with glass ionomer or zinc phosphate. Other clinical studies have shown marginal gaps ranging between 70µm and 647µm.[17, 27, 28]

Compared to marginal gap, investigations discussing overextended margins are rare.[29-33] However, overextensions of up to 482µm were described.[34] The rate of cast crowns with overextensions range between 26%[7] and 50%.[17, 34, 35] An overextended margin promotes supragingival as well as subgingival plaque and periodontal disease.[2, 33, 36] Thus, the periodontal response to crowns appears to relate mainly to overextensions than to insufficient marginal gaps.[3]

The data on clinically deficient marginal fit of different kinds of crowns fluctuate between 34%[7] and 56%[35] according to different surveys. Up to 95% of these single crowns showed clinical pathological changes.[35]

In the dental laboratory technicians can evaluate the fit under a microscope. But microscopes are not regularly used and they do not give relevant information of the final fit of a cemented crown.[19] Thus, the problem of determination of fit under in vivo conditions is not yet resolved.[27, 37] A fundamental difficulty is the exact identification of the marginal topography.[9, 37, 38] The use of special dental explorers in vivo replicate methods; the evaluation of the margins under a microscope can help, but true reliable findings can only be based on the examination of extracted teeth.[38] Even with X-rays only a vague prediction can be made.[2, 19, 20]

In the daily routine the evaluation of marginal fit is assessed by the dentist.[2] Besides the visual examination[27] the margin of the crown is checked with a dental explorer.[2, 20, 27, 39] When both methods are compared, only insignificant differences can be found.[27]

The data on clinically visual recognizable widths of gaps range from 5µm to 90µm in contrast to differences of 10µm to 119µm when an actual explorer is used.[27] It has to be considered a tip of a new and unused dental explorer has a diameter of approximately 70-80µm.[20, 32] So, a dull probe is dubious of detecting gaps less than 80µm opening for uncemented castings.[20]

Marginal gaps on uncemented crowns of less then 95µm[15] and 200µ[20] could only vaguely be detected with a dental explorer. The subgingival position of the margin of a crown even increases uncertainty.[14, 20, 27, 39, 40] Marginal gaps between 10µm and 160µm were found in crowns which had been clinically accepted.[20] This refers to measuring marginal gaps with a fluctuation of ± 10µm for both repeated measuring by one examiner as well as different examiners.[37, 41] In an experimental study a corresponding result of 75% could be proven by experienced practitioners regarding the estimated overextension and size of marginal gaps of crowns and their actual widths.[27]

In one study[14] a group of dentists evaluating cast restorations with an explorer rejected discrepancies greater than 40µm on accessible margins, but they accepted subgingival margins with 120µm discrepancies. Care had to be taken that the point of the used dental explorer had a diameter of approximately 70µm. Compared to marginal gaps with the same width, overextensions of more than 100µm were reliable to identify by dental explorer.[27] Another study[20] compared radiographic and clinical findings. Radiographically, margin discrepancies less than 80µm were difficult to detect. With the use of an explorer in a clinical examination, a 200µm discrepancy was barely discernible. Regardless of all the studies published and methods to evaluate marginal gaps, there is no defined or accepted reference value to evaluate the fit of crowns.[16]

This study evaluated the correlation between the exact marginal gaps, the overextended margins of crowns made from different alloys and technologies, and the subjective evaluation of their fit by dentists and technicians.

Materials and Methods

Thirty extracted premolars and molars were randomly divided into six groups and were prepared with a shoulder with internal rounded line angles.[42] After tooth preparation, impressions were made (Impregum, 3M ESPE, Seefeld, Germany). To avoid a possible side effect of a special restoration material or a special technology for the production of complete crowns on the decision of the clinicians, five complete cast crowns of five different alloys and metals were made following the instructions of manufacturers using suitable casting techniques for each of the five groups (Table 1). An

Table 1. Alloys and technologies used for fabrication of the investigated restorations.

Alloy	Technology	Tradename	Batchnumber	Manufacturer
PdAgAu	cast	Degupal G	10015442	DeguDent, Hanau, Germany
Ti	cast	Tritan 4	687221	Dentaurum, Ispringen, Germany
AuAgCu	cast	Degulor M	10012784	DeguDent, Hanau, Germany
CoCrMo	cast	Remanium 2000	11610	Dentaurum, Ispringen, Germany
AuPdPt	cast	Degutan	10013942	DeguDent, Hanau, Germany
Ti	milled	Everest	151770	KaVo, Biberach, Germany

additional five titanium crowns were milled using a special cad/cam-technology (Table 1). Because the effect of the porcelain firing on marginal fit should not be investigated, no porcelain was fired onto the restorations.[43-45] Although some of the alloys used were alloys for porcelain fused to metal technology.

To prevent a change in vertical position and to achieve a standardized fit for all examiners, the crowns were cemented on the prepared teeth using a minimum amount of temporary cement (TempBond, Kerr, Orange, CA, USA). To avoid any access of cement, only a small portion of Ø1 mm was placed by a dental brush into the top of the crown.[37]

To evaluate a difference between the practical experience of the dentists and technicians[37], ten experienced dentists and ten experienced technicians evaluated the fit of the crowns with a dental explorer (EXS3A6, Hu-Friedy, Chicago, IL, USA). All of the dentists were experienced staff members of the Department of Prosthodontics at the Martin-Luther-University Halle and all technicians were qualified and long time workers in a professional dental laboratory (Xental Ltd., Grosskugel, Germany). The point of the new explorer had a diameter of 70µm according to the manufacturer, which is in accordance to the literature.[20, 32] The size was confirmed by our own measurements using a light microscope with special measuring software (VMZM40, TV-tubus 1.6-Objectives 2,0-Screenlevel 4,0x, Metrona Software, 4H JENA engineering, Jena, Germany). The examiners were informed the tip of the new dental explorer had a diameter of approximately 70µm. No time limit was given to the examiners. Since explorers are subject to hardening and aging[20, 32] , a new explorer was used for each examiner. The examiners were not informed about the kind of alloys and technologies used for the crowns. The examiners had to answer a questionnaire with a "yes" or a "no." There were two questions: 'Can the marginal fit be accepted?' and 'In consideration of the marginal fit quality, would you cement the crown into a patient's mouth?' The crowns were then carefully removed from the prepared teeth, cleaned, and permanently cemented. Zinc-oxide phosphate-cement (Harvard Cement, Richter & Hoffmann Harvard Dental Ltd., Berlin, Germany) was mixed according to manufacturers' instructions. A load of 5kg was put on the crowns for five minutes. Forces above that weight have no significant effect on reducing film thickness and forces for more than this time have no effect.[20] After setting, the excessive cement was removed with a dental explorer. Because the absolute marginal discrepancy is a geometrical combination of the marginal gap and the overextension, the marginal gaps and the overextended margins were separately measured for all crowns after cementing[9, 37] (Figure 1).

A light microscope was used at a magnification level of 560 X along with special measurement software (VMZM40, TV-tubus 1.6-Objectives 2,0-Screenlevel 4,0x, Metrona Software, 4H JENA engineering, Jena, Germany). Fifty measurements were taken on each crown.46 The statistic analyses were performed by using the program SPSS (SPSS Inc., Chicago, IL, USA). Descriptive analyses were accomplished by Kolmogorov-Smirnov-test on normal distribution followed by analysis of variance (ANOVA) and post-hoc test (Bonferroni). Correlations between the measured values and the subjective evaluations (results of the questionnaires) were determined by the Pearson test. Finally, regression analyses about the influences of the measured values on the clinical decisions were carried out.

Results

Means and significant differences were calculated for each group (Figure 2). Marginal gaps and overextended margins were found in all groups of investigated crowns (Figures 3-8).

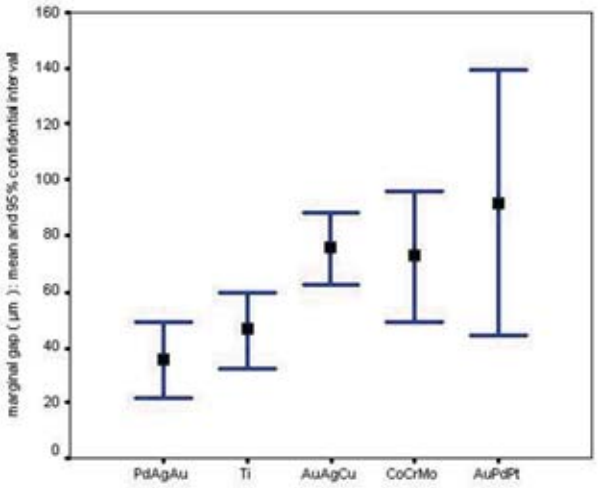

Figure 2. Arithmetical mean and confidential interval of the marginal gaps and overextended margins.

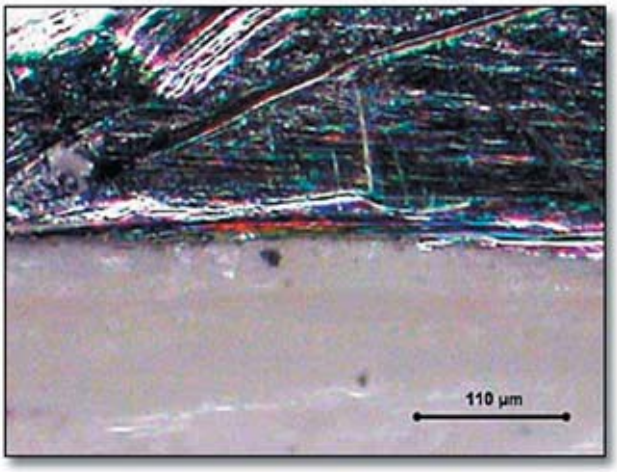

Figure 3. Marginal fit of a PdAgAu-crown.

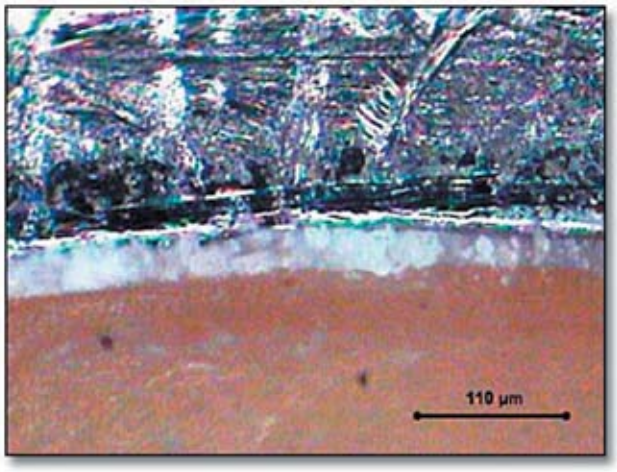

Figure 4. Marginal fit of a Ti-cast crown.

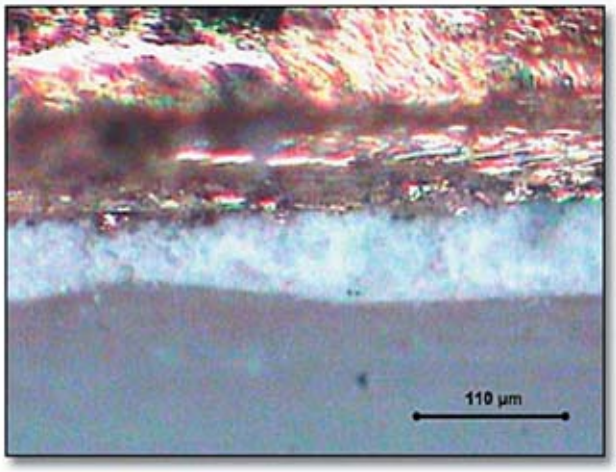

Figure 5. Marginal fit of a AuAgCu-crown.

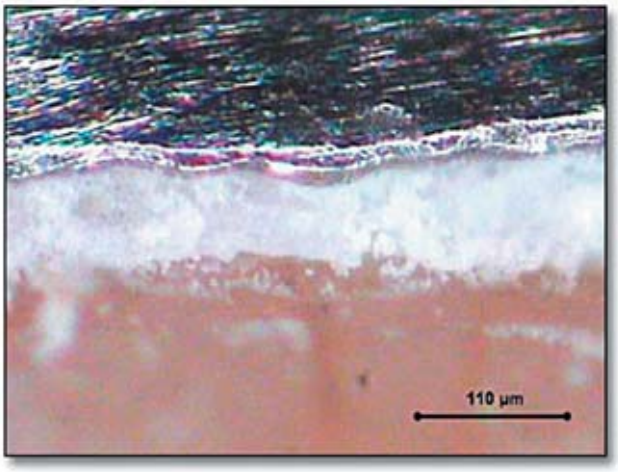

Figure 6. Marginal fit of a CoCrMo-crown.

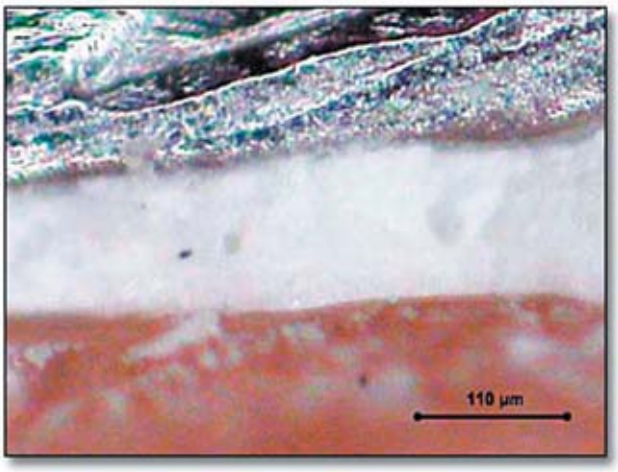

Figure 7. Marginal fit of a AuPdPt-crown.

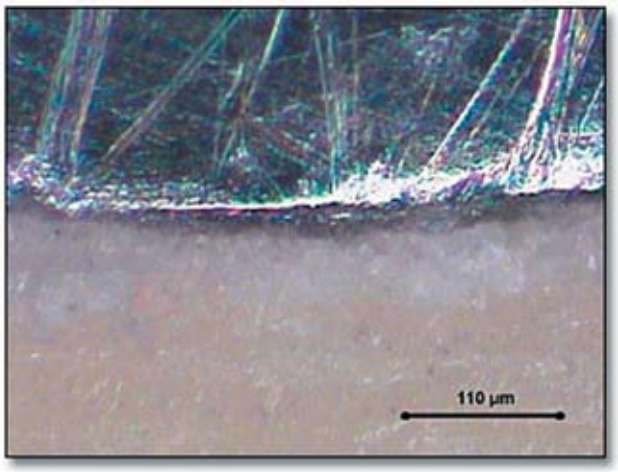

Figure 8. Marginal fit of a Ti-milled-crown.

The smallest marginal gaps were found for PdAgAu crowns. The greatest marginal gap of 92µm was found for crowns of AuPdPt alloy (Figure 2, Table 2). Significant differences are shown in Table 3.

Significant differences among the groups were also found when measuring the size of the overextended margin. The lowest overextended margin of 40µm mean was found for PdAgAu-crowns. The greatest marginal overextension of 149µm was found for crowns of AuPdPt alloy (Figure 2, Table 4). Significant differences are shown in Table 5.

The overall correlations between measured gaps and their subjective evaluation were calculated using the Pearson test (Table 6). It revealed marginal gaps and overextended margins correlated highly significantly ($p<0.01$) with their subjective evaluation of the marginal fit as well and with the perceived clinical acceptability among the dentists and technicians. Only the correlation of the dentist's evaluation of the marginal fit and the measured gaps was significant on the level of 5%. Comparisons of the evaluations of the dentists and the technicians showed a highly significant correlation ($p<0.01$ (Table 7).

Table 2. Arithmetical mean and confidential interval of the marginal gaps.

Margin gap mean						
					95% confidential intervall	
	N	mean	standard deviation	standard error	minimum level	maximum level
PdAgAu	5	35.3240	10.71250	4.79077	22.0227	48.6253
Ti - Cast	5	46.3800	11.03641	4.93563	32.6765	60.0835
AuAgCu	5	75.4540	10.72895	4.79813	62.1323	88.7757
CoCrMo	5	72.6640	18.62406	8.23893	49.5392	95.7888
AuPdPt	5	91.6160	38.39608	17.17125	43.9410	139.2913
Ti - milled	5	59.4774	8.90725	3.98344	48.4176	70.5372
total	**30**	**63.4859**	**26.00480**	**4.74780**	**53.7755**	**73.1963**

Table 3. Differences among the marginal gaps.

Abhängige Variable: marginal gap mean						
Bonferroni						
Mean difference (I-J)						
(I) Alloy	(J) Alloy					
	PdAgAu	Ti - Cast	AuAgCu	CoCrMo	AuPdPt	Ti - milled
PdAgAu		-11.0560	**-40.1300***	-37.3400	**-56.2920***	-24.1534
Ti - Cast	11.0560		-29.0740	-26.2840	**-45.2360***	-13.0974
AuAgCu	**40.1300***	29.0740		2.7900	-16.1620	15.9766
CoCrMo	37.3400	26.2840	-2.7900		-18.9520	13.1866
AuPdPt	**56.2920***	**45.2360***	16.1620	18.9520		32.1386
Ti - milled	24.1534	13.0974	-15.9766	-13.1866	-32.1386	

*mean difference $p<0.05$

Table 4. Arithmetical mean and confidential interval of the overextended margins.

Overextended margin mean						
					95% confidential intervall	
	N	mean	standard deviation	standard error	minimum level	maximum level
PdAgAu	5	40.3330	14.15345	6.32962	22.7592	57.9068
Ti - Cast	5	47.7884	10.89722	4.87338	34.2577	61.3191
AuAgCu	5	135.7500	30.24175	13.52452	98.1999	173.3001
CoCrMo	5	120.9040	21.64357	9.67930	94.0300	147.7780
AuPdPt	5	148.5140	31.48877	14.08221	109.4155	187.6125
Ti - milled	5	63.5636	8.79870	3.93490	52.6386	74.4886
total	**30**	**92.8088**	**48.40386**	**8.83729**	**74.7345**	**110.8831**

Table 5. Differences among the overextended margins.

Abhängige Variable: overextended margin mean						
Bonferroni						
	Mean difference (I-J)					
(J) Alloy	(I) Alloy					
	PdAgAu	Ti - Cast	AuAgCu	CoCrMo	AuPdPt	Ti - milled
PdAgAu		7.4554	95.4170*	80.5710*	108.1810 *	-23.2306
Ti - Cast	-7.4554		87.9616*	73.1156*	100.7256*	-15.7752
AuAgCu	-95.4170*	-87.9616*		-14.8460	12.7640	-72.1864*
CoCrMo	-80.5710*	-73.1156*	14.8460		27.6100	-57.3404*
AuPdPt	-108.1810 *	-100.7256*	-12.7640	-27.6100		84.9504*
Ti - milled	-23.2306	-15.7752	72.1864*	57.3404*	84.9504*	

*mean difference p<0.05

Table 6. Correlation between the measured value and the subjective evaluation.

Pearson correlation test			
		marginal gap mean	overextended margin mean
marginal fit is acceptable (dentists)	Pearson correlation	-.423*	-.616**
	Significance	.020	.000
marginal fit is acceptable (technicians)	Pearson correlation	-.501**	-.668**
	Significance	.005	.000
restoration is acceptable for cementation (dentists)	Pearson correlation	-.552**	-.687**
	Significance	.002	.000
restoration is acceptable for cementation (technicians)	Pearson correlation	-.508	-.707**
	Significance	.004	.000

* Pearson correlation p<0.05 significant
** Pearson correlation p<0.01 significant

Table 7. Correlation among dentists and technicians regarding subjective evaluations.

Pearson correlation test					
		marginal fit is acceptable (dentists)	marginal fit is acceptable (technicians)	restoration is acceptable for cementation (dentists)	restoration is acceptable for cementation (technicians)
marginal fit is acceptable (dentists)	Pearson correlation	1	.751**	.900**	
	Significance		.000	.000	.000
	N	30	30	30	30
marginal fit is acceptable (technicians)	Pearson correlation	.751**	1	.767**	.949
	Significance	.000		.000	.000
	N	30	30	30	30
restoration is acceptable for cementation (dentists)	Pearson correlation	.900**	.767**	1	.844**
	Significance	.000	.000	.000	
	N	30	30	30	30
restoration is acceptable for cementation (technicians)	Pearson correlation	.819**	.949**	.844**	1
	Significance	.000	.000	.000	
	N	30	30	30	30

** Pearson correlation p<0.01 significant

The influence of the measured values on the subjective evaluations was determined by regression analyses. In doing this a possible influence of two independent variables on a depended variable can be detected. The analysis showed the marginal gap had no significant influence on the decision among dentists and technicians regarding the marginal fit of the tested crowns, but the influence of the overextended margin was highly significant (p=0.005, Table 8 and p=0.004, Table 9).

In the evaluation of the perceived clinical acceptability for clinical cementation a significant influence of the marginal gap did not exist, while overextension had a very strong effect on the acceptability among the dentists (p=0.007, Table10) and especially among the technicians (p=0.001, Table11).

Discussion

The results reflect difficulties and problems in the clinical determination of the quality of the marginal fit. By means of currently available methods a statement on the marginal topography can be made only in cases of great marginal discrepancy. All in vivo methods are deficient and often lead to an underestimation of the real discrepancies.[38] Consequently, routine examination with a conventional dental explorer has only a limited reliability.[27] Further problems are the individual tactileness of the investigators, different diameters of explorers, as well as changing positions of the dental explorers during the investigation.[2] However, the investigation of the tested crowns by use of a dental explorer without excessive clinically altering[20, 32] showed acceptable results referring to the literature[14-22, 34] as well as to the measured gaps and overextensions in our study.

Because the aim of this investigation was not to evaluate advantages or disadvantages of alloys and technologies used for full crowns, no recommendations should be made regarding alloys or technologies. But the results showed all crowns meet the general requirements for a clinically acceptable marginal gap fit (30µm-100µm).[14-22] Two groups of restorations had excellent mean widths of gaps between 30µm and 50µm according to Ostlund[21] and Marxkors[19], but experienced clinicians[19] had already stated gaps of this size cannot generally be achieved in the clinical routine.

In contrast to studies of gaps overextensions are rarely investigated. So comparisons with other studies are difficult.[29-33] Compared to the findings of Donath and Roth[34] all crowns had distinctly smaller overextensions than 482µm, but none of the crowns showed small overextensions of at most 29µm as found by White et al.[32]

In contrast to clinical practice these investigations were made under ideal conditions: direct accessibility to the complete marginal area, no time limit, and no disruptive factors or irritations by subgingival margins of crowns, dental calculus, remnants of cement, bleeding, or saliva.[27] The results showed the evaluation of the marginal fit as well as the perceived clinical acceptability of crowns by clinically experienced evaluators correlated to the marginal gaps as well as to the marginal overextensions examined under the microscope. Groten et al.[37] described a different clinical and practical experience referring to the clinical results between dentists and technicians. In the present study no significant difference between the evaluations of dentists and technicians could be found.

Statistical analysis revealed the marginal gap had no significant influence on the clinical decision at all, but it has to be considered marginal misfits of the tested crowns were small. Overextended margins were the only important factor for the evaluation among the dentists and the technicians. This is in contrast to the findings of Groten et al.[37], who showed the external vertical height of the marginal gap is objective and reliable. Kerschbaum et al.[27] showed experienced examiners can more exactly feel deviations of contours than the widths of marginal

Table 8. Influence of the measured values on the subjective evaluation among the dentists if the marginal fit is acceptable.

		non standardized coefficients		standardized coefficients		
		B	standard error	Beta	T	significance
1	(constant))	80.314	9.418		8.527	.000
	marginal gap mean	.177	.229	.193	.772	.447
	Overextended margin (mean)	-.379	.123	*.770	-3.081	.005
2	(constant))	84.489	7.653		11.040	.000
	Overextended margin (mean)	-.303	.073	-.616	-4.134	.000

Table 9. Influence of the measured values on the subjective evaluation among the technicians if the marginal fit is acceptable.

		non standardized coefficients		standardized coefficients		
		B	standard error	Beta	T	significance
1	(constant))	86.053	11.126		7.734	.000
	marginal gap mean	.106	.271	.093	.391	.699
	Overextended margin (mean)	-.454	.145	-.742	-3.119	.004
2	(constant))	88.551	8.968		9.874	.000
	Overextended margin (mean)	-.408	.086	-.668	-4.747	.000

Table 10. Influence of the measured values on the subjective evaluation among the dentists if the restoration is acceptable for cementation.

		non standardized coefficients		standardized coefficients		
		B	standard error	Beta	T	significance
1	(constant))	100.167	6.818		14.692	.000
	marginal gap mean	-.006	.166	-.008	-.033	.974
	Overextended margin (mean)	-.260	.089	-.680	-2.920	.007
2	(constant))	100.037	5.480		18.255	.000
	Overextended margin (mean)	-.263	.053	-.687	-4.998	.000

Table 11. Influence of the measured values on the subjective evaluation among the technicians if the restoration is acceptable for cementation.

		non standardized coefficients		standardized coefficients		
Modell		B	standard error	Beta	T	significance
1	(constant))	97.820	9.720		10.063	.000
	marginal gap mean	-.168	.237	.160	-.711	.483
	Overextended margin (mean)	-.472	.127	-.835	-3.717	.001
2	(constant))	101.790	7.886		12.908	.000
	Overextended margin (mean)	-.400	.076	-.707	-5.291	.000

gaps. Thus, for clinical evaluation of fit, it can be assumed overextensions are safer to detect than gaps.[4-8] White et al.[32] suggested the horizontal measurement protocol probably overestimated the marginal overextension because the measurement plane is perpendicular to the long axis of the tooth, not perpendicular to the flared root or casting surface. However, there is no certainty about the width of a noticeable marginal overextension.[7, 17, 27, 34, 35]

Conclusion

- All crowns showed marginal gaps as well as marginal overextensions.
- All marginal gaps and overextensions were in a clinically acceptable range.
- Objective measurement of marginal gaps and overextended margins correlated significantly with their subjective evaluation by dentists and technicians.
- The findings regarding the marginal gap and the overextended margin correlated significantly with the subjective evaluation of the clinical acceptability of dentists and technicians.
- Evaluations of dentists and technicians showed a significant correlation.
- The marginal gap had no significant influence on the decision among dentists and technicians regarding the marginal fit and the perceived clinical acceptability of the tested crowns.
- Overextended margins had significant effects on the decision of dentists and technicians regarding marginal fit and clinical acceptability of the crowns.

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