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Original Article

A Comparative In Vitro Study Evaluating the Marginal Adaptation of Zirconium Computer-Aided Design/Computer-Aided Manufacture and Press-ceramic Veneers

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Abstract

Introduction: One method to evaluate the clinical success of cemented restorations is measuring the marginal adaptation. There is a correlation between the fitting of the restoration and problems caused by clinically undetectable passage of bacteria between the tooth structure and the veneer.

Aim: To evaluate in comparison the marginal adaptation of veneers produced via CAD/CAM and press technique.

Materials and methods: 32 extracted incisors are divided into two equal-number groups (n=16) according to the production technique – CAD/CAM zirconium veneers and press-ceramic veneers. Cut sections are examined under a SEM magnification. Marginal accuracy is measured as the distance between the finish line of the tooth and the margin of the veneer at eight fixed locations.

Results: The mean values of marginal gap of group 1 are: external adaptation – 79.88±3.71 μm; internal adaptation – 79.14±15.70 μm; cervical adaptation – 82.39±28.55 μm; incisal adaptation – 86.85±21.72 μm. The mean values of marginal gap of group 2 are: external adaptation – 100.31±2.16 μm; for internal adaptation – 101.01±12.51 μm; cervical adaptation – 91.55±3.31 μm; incisal adaptation – 93.76±2.54 μm.

Conclusions: Veneers produced via CAD/CAM technology have better fit at the external and internal marginal wall. There is no statistically significant difference between the gaps at the cervical and the incisal areas.

Keywords

CAD/CAM veneers, marginal adaptation, zirconium veneers

INTRODUCTION

One of the most commonly used methods to evaluate the clinical success of cemented restorations has been by measuring the marginal adaptation.[1] In case of all-ceramic restorations, microleakage has been correlated with a loss of integrity of the bond to tooth structure. This has been associated with problems such as plaque accumulation staining, postoperative sensitivity, secondary caries, pulpal inflammation, chipping and fractures. This is due to the clinically undetectable passage of bacteria, fluids, molecules and ions between tooth structure and the cemented veneer. Marginal adaptation is a term defining the accuracy of the veneer according to the prepared tooth structure. It can be external – the distance between the edge of the veneer and the edge of the tooth structure, and internal – the gap between the labial surface of the tooth and the inner side of the veneer (it corresponds to the amount of cement used). Most of the scientists measure this gap as more than 100 μm.[2,3] Keeping in mind that the diameter of *Streptococcus mutans* is approximately 0.75 μm[4], the result will be a continuous disintegration of the cementing layer and penetration of bacteria between the veneer and the tooth structure.

AIM

The aim of the study was to compare the marginal adaptation of veneers produced via the new CAD/CAM technology and the "golden standard" for veneers – the press technique.

MATERIALS AND METHODS

For in vitro test specimens, 32 natural freshly extracted upper incisors were preserved in thymol solution 0.02 wt/% for 6 months.[5] Each tooth was fixed on acrylic lower jaw base of Phantom Head. The preparation was performed via turbine and turbine burs according to the following requirements – 1 mm reduction of the incisal edge and 0.5 mm buccal reduction **(Fig. 1)**. The specimens are randomly divided into two groups (n=16) according to the veneer production technique – group 1 – CAD/CAM zirconium veneers and group 2 – press-ceramic laminate veneers.

Specimens from group 1 are scanned using a laboratory scanning device (Wieland Dental, Ivoclar Vivadent Group), a digital design of a veneer is made using computer-aided design software (3 Shape Trios) followed by a milling from an A1 zirconium disk 18 mm Ultra-translucent Multi-layered zirconium KATANA (Kurraray Noritake Dental Inc., Japan) **(Fig. 2)** by computer-aided manufacture VHF (Camfacture AG, Germany). The milled veneers are sintered in a sintering furnace VITA Zyrcomat 6000 MS (VITA, Ivoclar) according to the zirconium manufacturer instructions reaching up 1550°C. An important step in the protocol of veneer preparation is functionalizing of the inner surface of zirconium via aluminium particles (Al_2O_3) with a diameter of 50 μm and pressure of 4 bars. The tooth surface is covered with self-etching tooth primer Panavia V5 (Kurraray Noritake Dental Inc., Japan) for 20 s and then gently dried with air. The inner surface of the veneer is covered with Ceramic Primer containing the monomer MDP (Clearfil Ceramic Primer Plus, Kurraray Noritake Dental Inc., Japan) and then gently dried with air. A thin layer of dual-polymerizing cement is then applied onto the veneer and adapted well to the tooth structure. Excess cement is wiped off. Polymerization with LED- light curing lamp (iLED 1,000-1,200 mW/cm^2, Woodpecker) is performed for 60 s from both the lingual and labial surfaces. The mar-

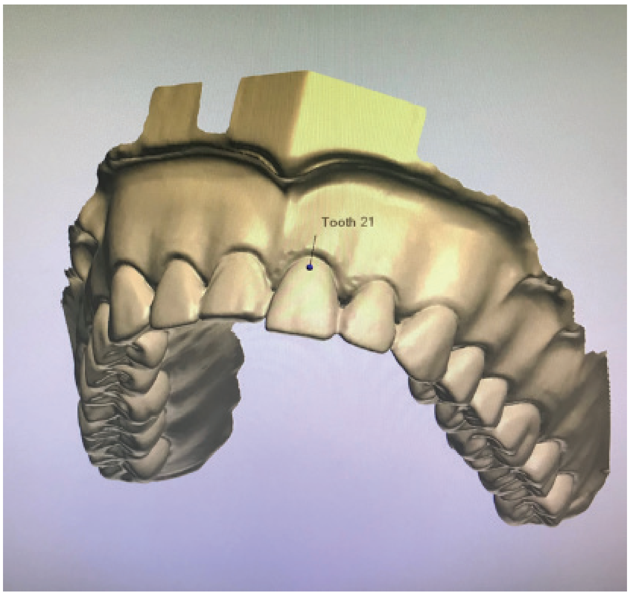


Figure 1. Preparation of teeth – 1 mm reduction of the incisal edge and 0.5 mm buccal reduction.

Figure 2. A zirconium 18 mm, ultra-translucent multi-layered disk KATANA (Kurraray Noritake Dental Inc., Japan)

gins of the veneer are polished with polishing discs (Sof Lex, 3M ESPE).

A dental technician produces a wax-up from the specimens of group 2 and then a press-ceramic veneer is produced. Each ceramic laminate veneer is etched using 9.6% hydro-fluoric acid gel for 30 sec. (Porcelain Etch Gel, Pulpdent Corp., Watertown, MA, USA), cleaned in an ultra-sonic bath of 95% alcohol, dried and finally coated with a ceramic primer (Panavia V5, Kurraray Noritake Dental Inc, Japan). Tooth surface is etched with 37% orthophosphoric etching agent and tooth primer is applied (Panavia V5 Kurraray Noritake Dental Inc., Japan). The same procedure of cementation as CAD/CAM specimens is then applied.

The specimens from both groups are vertically sectioned in a labio-lingual direction with a straight handpiece and a separating diamond disc with depth of 0.3 mm. This sectioning allows us to explore the thickness of the cement layer and the marginal gap on external walls of the veneer.

All specimens are fixed onto an experimental tray and covered with gold through electro-vacuum metallization **(Fig. 3)**.

Figure 3. The specimens fixed onto an experimental tray and covered with gold particles through electro- vacuum metallization.

The cut sections are examined with a scanning electron microscope (FE-SEM JEOL JSM- 6390) at magnification ×300.

On both vertical sections and outline of the tooth, marginal accuracy is measured as the distance between the finish line of the underlying tooth surface and the margin of the ceramic laminate veneer at seven fixed locations: 1 cervical, 1 incisal, 3 points on the inner surface, 3 points on the outer contour of the tooth **(Figs. 4, 5)**.

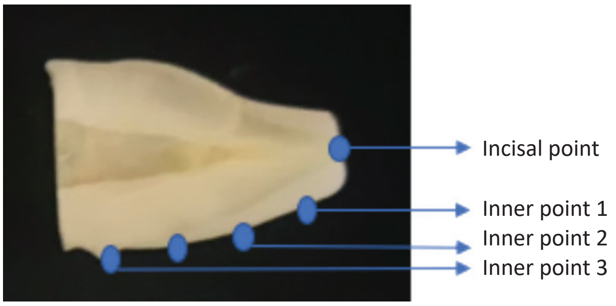


Figure 4. Four inner fixed locations for measurement of the distance between the labial surface of the tooth and the back side of the veneer.

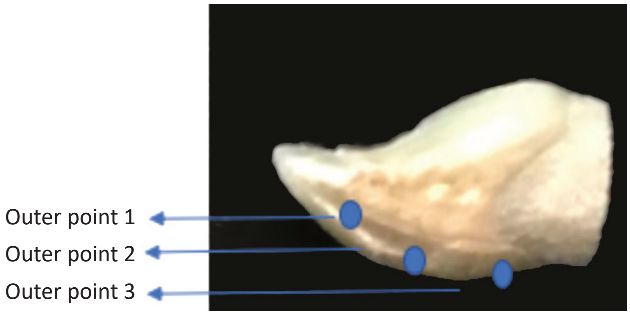


Figure 5. Three outer fixed locations to measure the distance between the labial surface of the tooth and the back side of the veneer.

Statistical analysis

The Saphiro-Wilk test was performed to verify departures from basic assumptions about normality of the data. Normally distributed variables are presented as mean±standard deviation (SD) and non-normal distributed data are presented by using other measurement of central tendency and spread – median (Me) and interquartile range (IQR). Statistical hypothesis testing for difference of arithmetic means were calculated using independent samples t-test and non-parametric Mann-Whitney U test to compare mean ranks. All the statistical analyses were performed using IBM SPSS Statistics v.25 (IBM Corp., Armonk, NY). A p value <0.05 was considered statistically significant.

RESULTS

After the statistical analysis of measurements we obtained the following results:

1. For group 1 **(Fig. 6)**: mean distance for outer wall 79.88±3.71 μm; for inner wall 79.14±15.70 μm, for cervical area 82.39±28.55 μm; for incisal area 86.85±21.72 μm **(Table 1)**.

2. For group 2 **(Fig. 7)**: mean distance for outer wall 100.31±2.16 μm; for inner wall 101.01±12.51 μm; cervical area 91.55±3.31 μm; incisal area 93.76±2.54 μm **(Table 2)**.

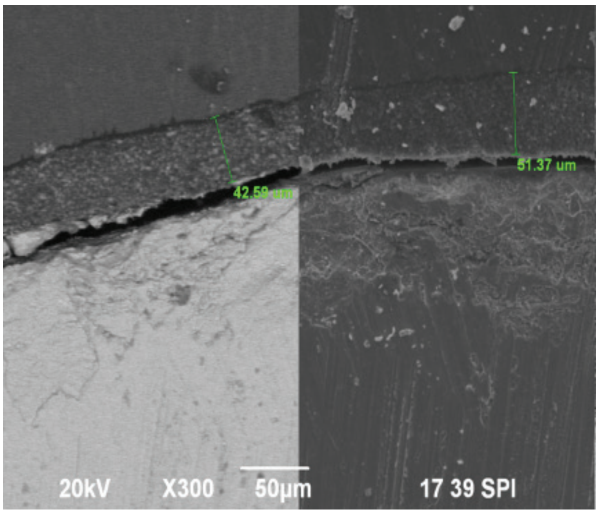
A statistical difference was found between the means of outer distance (t=4.76; *p*=0.000) in group 1 (79.87±14.83 μm) when compared to group 2 (100.37±8.65 μm) and between the mean ranks of inner distance (U=25; *p*=0.000) in group 1 when compared to group 2. There was no statistical difference (*p*=NS) between mean ranks in groups 1 and 2 in the incisal and cervical areas **(Table 3)**.

Table 1. Descriptive analyses of measurements for group 1

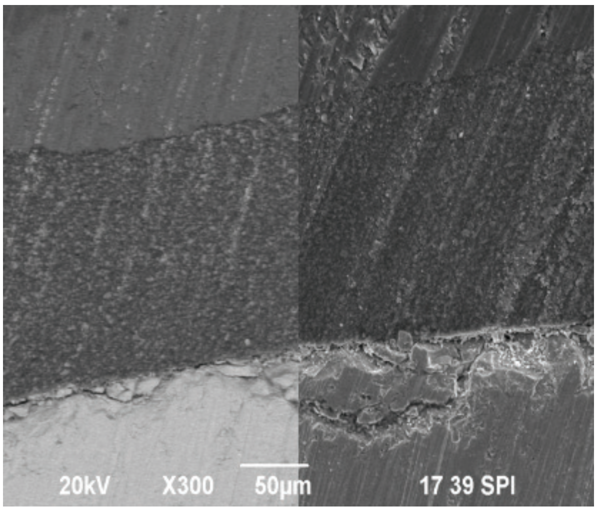
	Outer 1	Outer 2	Outer 3	Outer mean	Inner 1	Inner 2	Inner 3	Inner mean	Cervical	Incisal
Mean	84.43	75.40	79.78	79.87	88.35	82.30	75.33	81.99	86.70	91.77
Mean error	7.96	3.13	3.73	3.71	9.35	6.07	5.52	4.42	9.81	7.80
Mediana	76.99	74.16	85.28	76.02	82.28	76.30	70.73	79.14	82.39	86.85
Standard deviation	31.82	12.51	14.91	14.83	37.39	24.28	22.07	17.68	39.25	31.19
Variation	1012.54	156.50	222.35	219.97	1398.22	589.58	486.87	312.43	1540.91	972.78
Range	137.22	42.53	54.94	62.54	170.54	100.01	92.68	73.85	167.67	122.10
Minimum	56.45	53.81	52.43	60.96	43.59	56.23	56.24	62.23	52.33	43.23
Maximum	193.67	96.34	107.37	123.51	214.13	156.24	148.92	136.07	220.00	165.33

Table 2. Descriptive analyses of measurements for group 2

	Outer 1	Outer 2	Outer 3	Outer mean	Inner 1	Inner 2	Inner 3	Inner mean	Cervical	Incisal
Mean	102.41	100.93	97.59	100.31	107.24	106.98	103.58	105.93	91.55	93.76
Mean error	5.70	2.72	3.31	2.16	4.32	7.17	5.68	4.29	3.31	2.54
Mediana	97.34	99.53	95.03	97.91	101.65	100.67	98.43	101.01	90.60	96.23
Standard deviation	22.79	10.86	13.23	8.65	17.26	28.67	22.73	17.14	13.22	10.16
Variation	519.33	118.00	174.94	74.88	298.04	821.78	516.58	293.94	174.79	103.17
Range	76.16	55.22	57.13	26.24	63.25	122.93	109.57	70.58	45.42	40.73
Minimum	80.60	78.98	78.98	88.35	90.75	78.98	54.67	89.98	70.35	65.01
Maximum	156.76	134.20	136.11	114.58	154.00	201.91	164.24	160.56	115.76	105.74

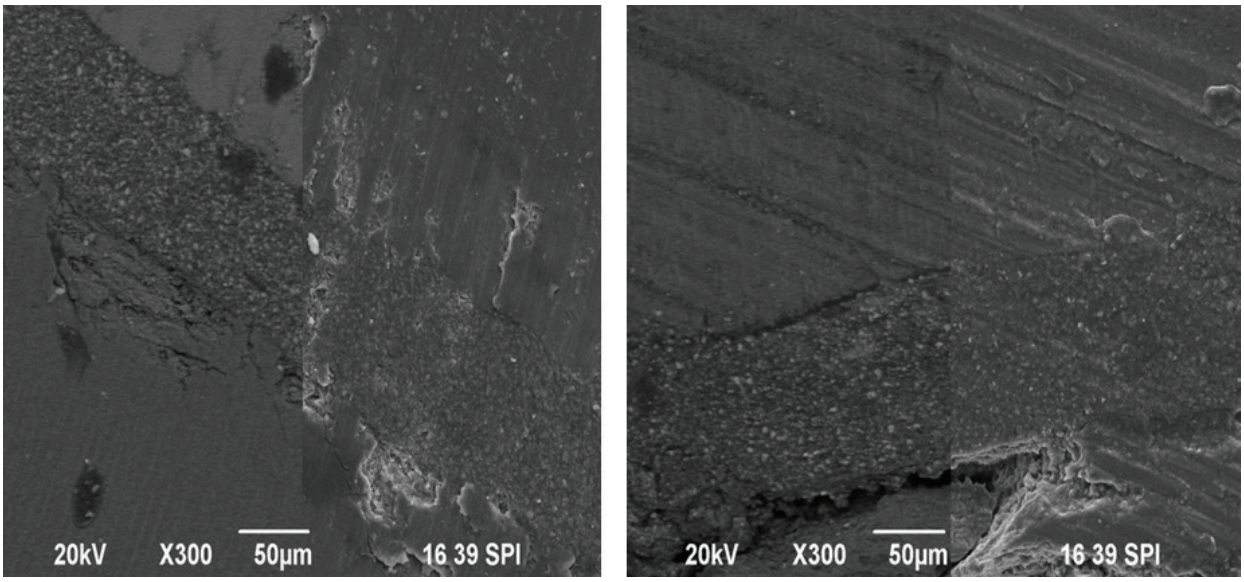


A



B

Figure 6. Images of the cementing layer under a zirconium veneer in a sagittal cut under SEM ×300 – A) backscattered electrons; B) secondary electrons.



A B

Figure 7. Images of the cementing layer under a press-ceramic veneer in a sagittal cut under SEM ×300 – A) backscattered electrons; B) secondary electrons.

Table 3. Statistically significant difference between groups 1 and 2

	Group 1		Group 2		Mann-Whitney U – test	*p* value
	Mean rank	Sum of ranks	Mean rank	Sum of ranks		
Inner	10.06	161.00	22.94	367.00	25.00	0.000
Cervical	13.50	216.00	19.50	312.00	80.00	0.070
Incisal	13.44	215.00	19.56	313.00	79.00	0.065

DISCUSSION

The technical progress of dental industry makes every next generation of CAD/CAM system better and more precise. An example of this evolutionary success is the comparison between three generations of CEREC CAD/CAM systems[6-9] as one of the last data for CEREC III [10] shows distance of marginal fit in the range of 53-162 µm. The results of our *in vitro* study are consistent with it and are even better. To the best of our knowledge, the CAD/CAM system we used has never been investigated in this kind of study before. This fact means that contemporary digital systems, no matter the manufacturer, have common satisfactory accurateness of the product.

In an *in vitro* study of Lin et al., the adaptation of ceramic restorations produces via CAD/CAM technology show a gap of 51±34 µm in the cervical area[11] which is slightly different from what we have found (82.39±28.55 µm).

Scientists define 'closely-located margins' as a gap in the range of 100 µm – 120 µm.[2,3] So the results of our study may be classified as excellent, because all the parameters we have are less than 100 µm.

Press-technology in manufacturing ceramic veneers is said to be a 'gold standard'. There are a lot of studies to examine the marginal adaptation in comparison between this 'gold standard' and the new CAD/CAM technology. The aim of these studies is to investigate if the digital matter is even comparable. Basel et al. measure 45 µm as a gap between the tooth surface and the restoration for the CAD/CAM group and 38 µm for the press-ceramic group.[12] The conclusion that press-ceramic veneers have a better adaptation is confirmed by many other authors.[13] We, on the contrary, have different results. According to the statistical analysis we did, the CAD/CAM restorations have better fitting and lower marginal gap than the comparative group. It is worth noting, though, that the devices we used have a serious effect on the results, the human role in the production process of press-ceramic veneers. As far as we know, there has been no other study that evaluates the marginal accuracy when using this specific CAD/CAM system - (laboratory scanning device Wieland Dental; milling device 5-S2 VHF).

Even the results for the press-ceramic technique are worse than CAD/CAM, they still fit into the well-accepted standard for satisfactory marginal adaptation of 100 µm – 120 µm and may be classified as 'closely- located margins'.

CONCLUSION

The SEM measurements of CAD/CAM zirconium veneers show a very thin cementing layer and better marginal adaptation in comparison with press-technology. These excellent results if applied in clinical situation would have long-term success.

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Сравнительное исследование in vitro, оценивающее краевую адаптацию циркониевых виниров, изготовленных с помощью компьютерного проектирования / компьютерного производства и пресс-керамики

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Резюме

Введение: Одним из методов оценки клинического успеха цементированных восстановительных конструкций является измерение краевой адаптации. Существует корреляция между установкой восстановительных конструкций и проблемами, вызванными клинически необнаруженным проходом бактерий между структурой зуба и виниром.

Цель: Оценить и сравнить краевую адаптацию виниров, изготовленных с использованием CAD / CAM и пресс-керамики.

Материалы и методы: 32 извлечённых резца были разделены на две группы с одинаковым количеством (n=16) в соответствии с технологией производства – CAD / CAM циркониевые виниры и виниры из прессс-керамики. Срезы исследовали с увеличением SEM. Краевая точность измеряется как расстояние между препарированной кромкой зуба и кромкой винира в восьми фиксированных местах.

Результаты: Средние значения краевого просвета по группе 1: внешняя адаптация – 79.88±3.71 μm; внутренняя адаптация – 79.14±15.70 μm; шейная адаптация – 82.39±28.55 μm; резцовая адаптация – 86.85±21.72 μm Средние значения краевого просвета группы 2: внешняя адаптация – 100.31±2.16 μm; внутренняя адаптация – 101.01±12.51μm; шейная адаптация – 91.55±3.31 μm; резцовая адаптация – 93.76±2.54 μm.

Заключение: Виниры, изготовленные по технологии CAD / CAM, имеют лучшее крепление к внешней и внутренней краевой стене. Не существует статистически значимой разницы между просветами шейных и резцовых областей.

Ключевые слова

CAD/CAM виниры, краевая адаптация, циркониевые виниры