A comparison of the fit of cast and machine-milled titanium copings.

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Abstract

A comparison of the fit of cast and machine-milled titanium copings.

Metal-ceramic restorations have been standards in restorative dentistry nowadays. Noble alloys have gradually been replaced by other alternatives due to the high cost and low sag resistance. Titanium has been spotlighted as an alternative for coping material of metal-ceramic restorations. Though titanium has some advantages such as good biocompatibility, high resistance to corrosion, low thermal conduction, high modulus of elasticity, low density, high mechanical strength and reasonable cost, its usage has been limited by the difficulties of fabrication. However, various fabrication methods have been introduced and the investigations for a clinical application are progressing actively.

One major parameter for evaluation of the clinical acceptance of the dental restoration is an adaptability of crown to tooth, which is influenced by coping fabrication. The purpose of present investigation is to compare the adaptabilities of crowns to teeth according to various fabrication methods for titanium. Titanium

copings were fabricated by copy-milling (CAD/CAM) and casting systems. The distances between coping and tooth were measured at margin, axial wall and occlusal fossa areas. In addition, horizontal extensions were measured. Cast nickel-chromium alloys were used as a control group.

Fifteen copings for each group were made and those were cemented onto working dies with cyanoacrylate adhesives. The cemented specimens were sectioned along the longitudinal axis into 4 parts each with 8 surfaces. The distance between coping and die at each surface were measured by image analyzer at x300 magnification. The tendencies of horizontal extension at margin of copings were observed by image analyzer at x50 magnification. The results for each group were analyzed statistically.

The following results may be drawn:

1. The mean marginal gap of machine-milled titanium, cast titanium and Ni-Cr alloy copings were 73.78, 51.57 and 61.07 ㎛, respectively. There were significant differences in the marginal fit among all the test groups, and titanium copings fabricated by machine-milled had the greatest marginal gap.
2. The mean gap at axial wall of Ni-Cr alloy copings was the least value of 47.71 ㎛. That of machine-milled titanium was 59.61 ㎛. Cast titanium which had the least marginal gap showed the

greatest gap at axial wall, 92.79 ㎛. All 3 groups were significantly different from each other.

3. Horizontal overextension, the most frequently observed phenomena for machine-milled titanium copings, was observed in 75.63% of all the machine-milled titanium copings.

Further technical improvements in CAD/CAM system for cp-titanium are needed to acquire more accurate fit, even though the current CAD/CAM system appears to provide acceptable marginal adaptation, 120 ㎛ and possibility with the clinical application.

Key words: copy-milled titanium, cast titanium, marginal fit, image analyzer

A comparison of the fit of cast and machine-milled titanium copings.

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I. INTRODUCTION

Metal-ceramic restorations that have both strength of metal itself and esthetic of porcelain, have been standards in restorative dentistry nowadays (Lin et al. 1998). Recently, noble alloys have gradually been replaced by base metal due to the high cost and low sag resistance. Although base metal alloys have some superior mechanical properties, they were not used widely because of following reasons; low biocompatibility, low corrosion resistance and discoloration of porcelain (Lin et al. 1998. Leong and Chai, 1994). There have been several reports of incident of nickel sensitivity in patients, and beryllium toxicity is a possible problem to dental technician because it is released during casting and polishing procedures (Leong and Chai, 1994).

Some alternatives have been invested. Titanium has been spotlighted as an alternative for coping material of metal-ceramic restorations. Already titanium has been considered as important biomaterials like dental implants. This is because of the unique characteristics of titanium alloys, such as high biologic compatibility, high resistance to corrosion, low thermal conduction, high modulus of elasticity, low density, high mechanical strength and reasonable cost (Oruç and Tulunoglu, 2000. Boening et al. 1992).

Nowadays, there are various methods to deal with titanium. Cast titanium just like conventional lost-wax technique and CAD/CAM system has been introduced. Titanium has a difficulty in obtaining precise casting and bonding to conventional porcelain. Titanium has a high melting-point and reacts well with oxygen, nitrogen and hydrogen during melting, resulting in decreased ductility and changes in strength (Lautenschlager and Monaghan, 1993). In addition, it is affected easily by the ceramic crucible during melting, so in 1982 Ida et al. reported on a casting machine equipped with a high-temperature heating source, inert argon atmosphere (later developed used with 20 psi helium environment), and a durable copper of graphite crucible (Leong and Chai, 1994. Ruiz Contreras and Pessanha Henriques, 2002).

The other method is the computer-aided design and manufacture (CAD/CAM) system. Several CAD/CAM systems for dental use have been described in the literatures. Following systems are included in theses systems; the Cerec® (Siemen, Bensheinm Germany), the Duret® (Sopha Bioconcept Inc., Los Angeles, Calif), Denti-CAD® (BEGO, Bermen. Germany), Procera® (Nobelpharma, Nobel Ind, Goteborg, Sweden), etc. These systems have different methods (modes of collection and production) and applications (Samet and Resheff, 1995. Nakamura and Dei, 2003).

In 1989, Andersson et al. reported the results of a clinical study of titanium crowns and fixed partial dentures fabricated by a precision copy milling technique in combination with spark erosion, known as Procera® system. Outer form is milled and the inner cavity of the crown is processed by spark erosion by the graphite electrode (Boening et al. 1992). Metal copings are fabricated by the data, such as thickness of coping, space for luting agent, and metal collar, read to computer. It reported excellent or satisfactory results in marginal integrity (99.5%), anatomic form (98.9%), and surface & color (96.8%) (Lin et al. 1998, Andersson et al. 1989).

One of the other systems is a DC-Titan system (DCS® Dental AG, Gewerberstrasse, Allschwil, Germany) we used for this investigation. This is a further development and improvement of the DUX® system (AG, Basel, Switzerland). DC-Titan system is composed of three parts; the Preciscan laser scanning system, which is characterized by touchless contact-free measurement, Dentform software and the Precimill milling system. There has been much improvement of the application of computer-controlled fabrication methods for restorative dentistry to make more precise dental restorations (Samet and Resheff, 1995. Besimo and Jeger, 1997).

The computer-controlled systems available today are differentiated by the methods of data collection. However, fabricating processes, like mathematical processing and milling, are quite similar each other. They have same steps from accurate impression to get master die. There are three main steps: (1) digitizing data from the die surface (surface modeling), (2) mathematical processing of data to program the computerizing mill (screen display), and (3) milling or production of copings (automatic milling machine) (Samet and Resheff, 1995. Duret 1988).

One major parameter for evaluation of the clinical acceptance of the dental restoration is a marginal fit (Mitchell et al. 2001). Marginal fit has an influence on tooth itself and periodontal tissues. Intraoral degradation of cements by marginal opening of the restoration can lead to pumping saliva or plaque and cause secondary dental caries. The accumulation of plaques initiates gingival inflammatory reaction that may result in deterioration in soft tissue with periodontal disease (Mitchell et al. 2001. Ushiwata and de Moraes, 2000. Felton et al. 1991).

The purpose of present investigation was to compare the adaptability of crown to tooth made by various fabricating methods using alternative materials, titanium and base metal with a nickel chromium alloy as a control group. Two working hypotheses were stated to evaluate the sensitivity and quality of the gaps according to its fabrication method and location (margin, axial wall, occlusal fossa area). In this study we considered the marginal gap defined as a vertical gap, perpendicular to coping and prepared tooth and compared the number of horizontal overlap (margin over/underextended) as shown below.

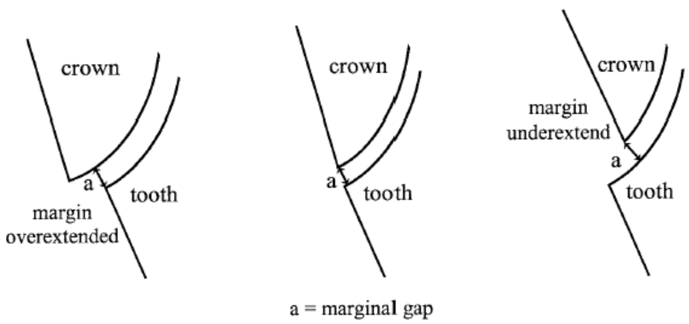


Fig 1. Schematic illustration of measurement of marginal gap and margin over/under-extended according to Holmes et al. (1989).

II. MATERIAL AND METHODS

Master model and die preparation

A maxillary first premolar ivorine tooth was prepared as a master die using a round-end diamond bur in a handpiece mounted in a parallelometer. A tooth was prepared as following features. A total convergence angle is 10 degrees. A buccal shoulder finish line has a 1.5 mm depth, mesial / distal proximal finish lines have approximately 1.0mm depth and lingual 0.5mm depth chamfer margin. Its axial wall height is about 6.5mm.

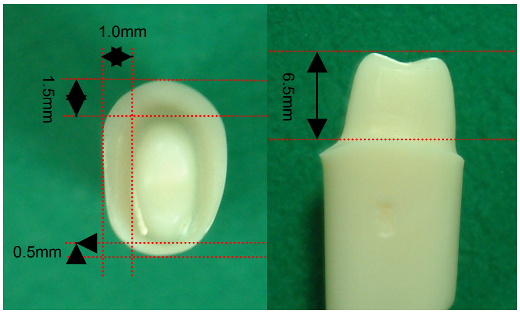


Fig. 2. View of the prepared master die.

Forty-five impressions of master die were made using polyvinyl siloxane impression material in individual trays. A total of 90 stone dies was divided into 3 groups, that is to say 30 for each group. Among them, 15 are for laboratory work and the rests for measurement work.

Table I. Materials used for experiment

Group	Material	Manufacturer
Ni-Cr alloy	Rexillium® III	Jeneric/Pentron incorporated. Wallingford, CT, USA
Cast titanium	Biotan®	Schultz Dental GmbH, Rosbach, Germany
Milled titanium	Cp-Titanium	Austernal Inc. 4104 West 5 Chicago, Il, USA

Coping fabrication

In case of nickel-chromium alloy and cast titanium, 2~3 layers of the die spacer (NICE FIT®, Shofu Inc. Kyoto, Japan) were coated over the entire preparation except 1mm above the margin with the total thickness of 25 ㎛ indicated by the manufacturers. Wax copings (IQ COMPACT® Grey, YETI Dentalproduke GmbH, Engen, Germany) were produced by a combined wax bath, to ensure 0.5mm standard thickness, and wax-additive procedure. Labial surface of teeth were marked with a thin line, and all wax patterns were sprued from their labial cusp area aligned with the thin line to ensure proper orientation of crowns to tooth preparations. The marginal 2mm of each wax coping were removed and remade with Inlay Wax Hard, Grey (GC Corporation, Tokyo, Japan) to minimize the wax distortion at marginal area during spruing and investing procedures.

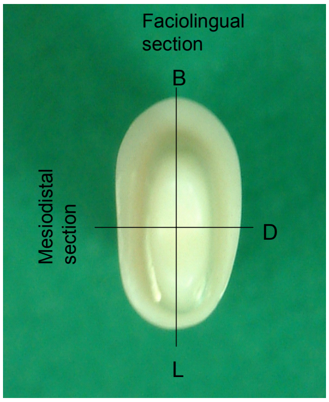
The wax patterns were invested with dental investment (CB-30 MicroFire® Crown and Bridge Investment, Ticonium co., Albany, NY, USA) and cast in nickel-chromium alloy (Rexillium® III, Jeneric/Penton incorporated. Wallingford CT, USA) using conventional centrifugal casting machine, and finished on the working die (Figure 3).

Wax patterns for titanium were invested (Biotan®, Schultz Dental GmbH, Rosbach, Germany) and cast using cast machine (Doramatic®, Schultz Dental GmbH, Rosbach, Germany) under the atmosphere of 1750℃ and argon pressure by the method recommended by Lautenschlager and Monaghan (1993).

Fig. 3. Proximal view of the 3 copings and measurement dies. From left, copy-milled titanium, cast titanium and nickel-chromium alloy.

In this experiment, DC-Titan system (DCS® Dental AG, Allschwil, Germany) was used. In accordance with the DC-Titan system, no die spacer was applied to the milled titanium(TM) group. It was indicated by the manufacturers that space for a cement is created during setting the DC-Titan procedure, equivalent to that created by application of die spacer, 30㎛ on entire surface except 1mm above the margin. These die sent to laboratory that has DCS system with the standards of titanium copings as follows; cement space mentioned above and the thickness of metal was 0.5mm. To minimize the underseating occurred by premature contact with the inside of coping, 10㎛ of cement space were relieved at till 1mm from the margin. As a result, 10㎛ of cement space was allowed to the point 1mm from the margin while 30㎛ was allowed in the rest area. The dies and corresponding titanium copings were returned. The coping were not modified intentionally or externally by investigator.

Copings and dies were set with cyanoacrylate adhesive under a constant load of 49N in a static pressure for keeping coping from underseating on measuring die caused by the film thickness of the luting agents. Jorgensen (1960) concluded that forces above 50N had no significant effect on reducing film thickness. All specimens were embedded in the epoxy resin blocks and sectioned faciolingually and mesiodistally with a slow-speed diamond saw (Metsaw-LS®, R & B Inc. Daejun, Korea) (see figure 4), so each specimen was sectioned in 4 parts and 8 surfaces as shown in figure 5. When cutting was done from the metal coping to the die, the margin could be hidden. The cutting blade was directed toward the coping from die during sectioning to prevent the erratic formation of a lip of burnished metal at the interface (Eames and O'Neal 1978). Sectioned surfaces were sandblasted with 50 ㎛ alumina (Hi Alumina® for Hi Blaster, Shofu, Kyoto, Japan) to eliminate flash and trashes.



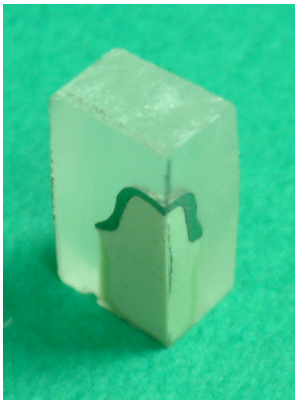
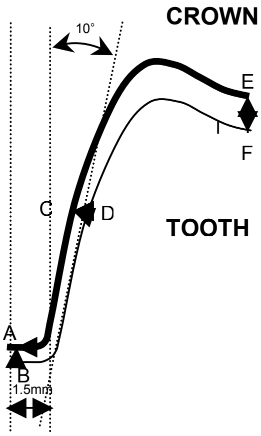


Fig. 4. Instruction of sectioning
- 4 sections were obtained by making mesiodistal and faciolingual sections.

Fig. 5. View of the sectioned specimen.



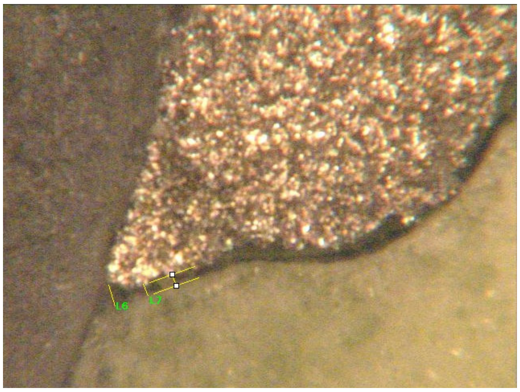


Fig. 6. (left above) Schematic representation of the frontal view of coping (thick dark line) and crown. Measurement points for evaluation of fit.
AB, Fit at finish line. CD, Fit at center point of axial wall. EF, Fit at occlusal fossa.

Fig. 7. (right above) View of sectioned surface of titanium coping and crown by an image analyzer at x300 magnification.

Measurement of Gaps

An image analyzer (Image-Pro® Plus, Media Cybernetics, Inc. 8484 Georgia Avenue, Silver Spring, MD, USA) was used to measure the distance between the coping and tooth. As shown in figures 6 and 7, the distance at 3 parts; the marginal area (A-B), center point of axial wall (C-D) and the occlusal fossa area (E-F), of each sectioned specimen were measured by image analyzer at x300 magnification. Each point was measured 3 times and the average value from the data was taken. We compared the tendencies of the horizontal extension at margin of copings by the methods of the fabrication.

Statistic analysis

After calculating the mean value and the standard deviation of each group, a one-way analysis of variance (ANOVA) was used to evaluate the differences between the groups for measuring points at a statistical difference of $P<0.05$. If differences were found, a LSD post hoc test was then applied to identify those differences. A 2-way analysis of variance (ANOVA) was done to determine the significance of the materials used and the regions involved and to further understand the interaction between gaps at the margin areas and axial walls, a correlation test was performed.

III. RESULTS

The entire fit of Ni-Cr copings (66.28 μm) was better than the other two groups and the differences were significant ($p<0.05$), while the entire gap of titanium copings were not different significantly ($p>0.05$, Table IV). As for marginal fit, cast titanium copings had better fit than the control group, along with milled titanium copings had the greatest marginal gap. At the axial wall and occlusal fossa area, the Ni-Cr group had less internal gaps than the titanium group, and the differences were significant as shown statistically Tables VI and VII ($p<0.05$). One-way ANOVA (Table V, VI, VII) revealed that the differences between groups at each regions were significant ($p<0.05$). Figure 8 shows the different values by material at each region; finish line, axial wall, occlusal fossa.

Table II. Basic statistics for test groups. (μm)

	Ni-Cr	Titanium Casting	Titanium Miling
Finish line	61.07 (25.86)	51.57 (24.46)	73.78 (32.31)
Axial wall	47.71 (24.93)	92.79 (35.36)	59.61 (29.70)
Occlusal fossa	93.69 (40.51)	123.09 (42.47)	139.13 (41.70)

The number in parenthesis is a standard deviation.

Table III. Inscription of abbreviations

	Ni-Cr	Cast Titanium	Milled Titanium
Finish line	NCF	TCF	TMF
Axial wall	NCA	TCA	TMA
Occlusal fossa	NCO	TCO	TMA

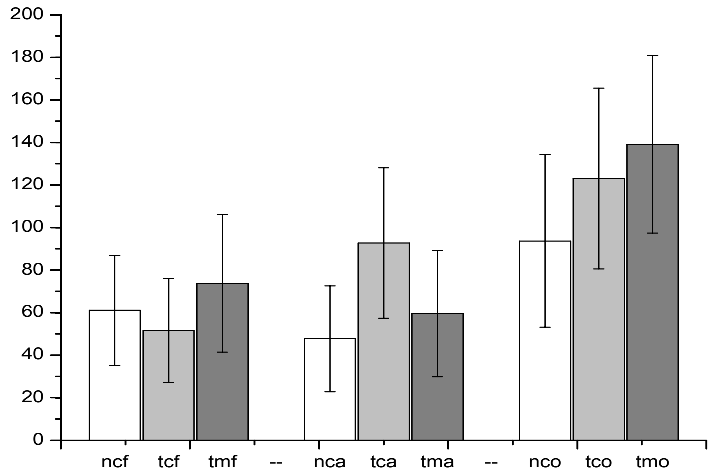


Fig. 8. Fit of all materials at each region.
X axis = materials and regions, Y axis = gap (㎛).

Table IV. Comparison by materials regardless of regions

Material	Material	Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Ni-Cr	Ti-Casting	-22.0385*	2.12445	.000	-26.2037	-17.8733
	Ti-Mililing	-24.9317*	2.11675	.000	-29.0818	-20.7816
Ti-Casting	Ni-Cr	22.0385*	2.12445	.000	17.8733	26.2037
	Ti-Mililing	-2.8932	2.12561	.174	-7.0607	1.2743
Ti-Mililing	Ni-Cr	24.9317*	2.11675	.000	20.7816	29.0818
	Ti-Casting	2.8932	2.12561	.174	-1.2743	7.0607

* The mean difference is significant at the .05 level.

Table V. Comparison of marginal fit by materials

Material	Material	Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Ni-Cr	Ti-Casting	9.5058*	2.18789	.000	5.2124	13.7991
	Ti-Milling	-12.7023*	2.13022	.000	-16.8826	-8.5221
Ti-Casting	Ni-Cr	-9.5058*	2.18789	.000	-13.7991	-5.2124
	Ti-Milling	-22.2081*	2.15595	.000	-26.4388	-17.9774
Ti-Milling	Ni-Cr	12.7023*	2.13022	.000	8.5221	16.8826
	Ti-Casting	22.2081*	2.15595	.000	17.9774	26.4388

* The mean difference is significant at the .05 level.

Table VI. Comparison of internal fit at axial wall by materials.

Material	Material	Mean Difference	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Ni-Cr	Ti-Casting	-45.0762*	2.50772	.000	-49.9984	-40.1540
	Ti-Milling	-11.9037*	2.55646	.000	-16.9216	-6.8859
Ti-Casting	Ni-Cr	45.0762*	2.50772	.000	40.1540	49.9984
	Ti-Milling	33.1724*	2.62148	.000	28.0269	38.3179
Ti-Milling	Ni-Cr	11.9037*	2.55646	.000	6.8859	16.9216
	Ti-Casting	-33.1724*	2.62148	.000	-38.3179	-28.0269

* The mean difference is significant at the .05 level.

Table VII. Comparison of internal fit at occlusal fossa area by materials.

Material	Material	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Ni-Cr	Ti-Casting	-29.3979*	3.34156	.000	-35.9539	-22.8420
	Ti-Milling	-45.4434*	3.35218	.000	-52.0202	-38.8666
Ti-Casting	Ni-Cr	29.3979*	3.34156	.000	22.8420	35.9539
	Ti-Milling	-16.0455*	3.26051	.000	-22.4424	-9.6485
Ti-Milling	Ni-Cr	45.4434*	3.35218	.000	38.8666	52.0202
	Ti-Casting	16.0455*	3.26051	.000	9.6485	22.4424

* The mean difference is significant at the .05 level.

The results of 2-way ANOVA showed that both materials and regions were associated with the adaptation of the coping to the die, especially the marginal area and the axial wall showed contrasting results (Table VIII, Fig. 9), correlation tests revealed that a linear relationship exists in the Ni-Cr group within a 95% confidence level (Table IX).

Table VIII. Tests of the effect between material and region (2-way ANOVA)

Source	F	Sig.
MATERIAL*	61.165	.000
REGION*	11.287	.001
MATERIAL x REGION*	179.640	.000

* The mean difference is significant at the .05 level.

Table IX. Correlation of gaps at finish line and axial wall level

	NCF-NCA	TCF-TCA	TMF-TMA
Pearson correlation	-0.114	-0.039	0.110
Sig.	.045*	.512	.078

* The relationship is significant at 95% confidence level.

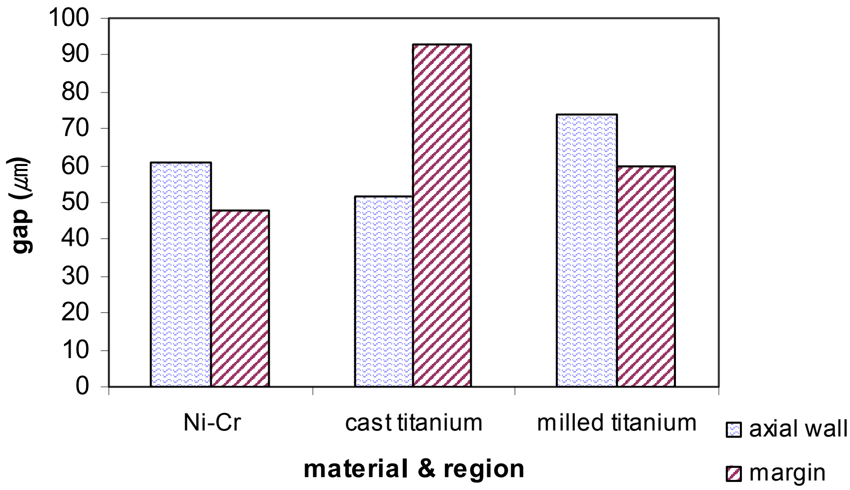


Fig. 9. Comparison of gap at margin and axial wall area by materials

We considered the tendency of the horizontal extension as shown below Table X. In 75/110 (68.19%) of cast Ni-Cr alloy copings and 80/118 (67.80%) of cast titanium copings, no horizontal extension was observed. In addition, overextension and underextension was observed in 27/110 (24.55%) of Ni-Cr alloy and 28/118 (23.73%) of cast titanium respectively. Machine-milled titanium for which margin finishing was done manually, overextension was observed in 90/119 (75.63%) of the case while underextension was observed in 4/119 (3.36%) of the case.

A, B, C in figure 10 is the picture of the specimens observed by the image analyzer at x50 magnification, and D shows the tendency of the overextension.

Table X. Number of Horizontal extension

	No extension	Overextension	Underextension
Ni-Cr	75(68.19%)	27	8
Titanium casting	80(67.80%)	10	28
Titanium milling	25	90(75.63%)	4

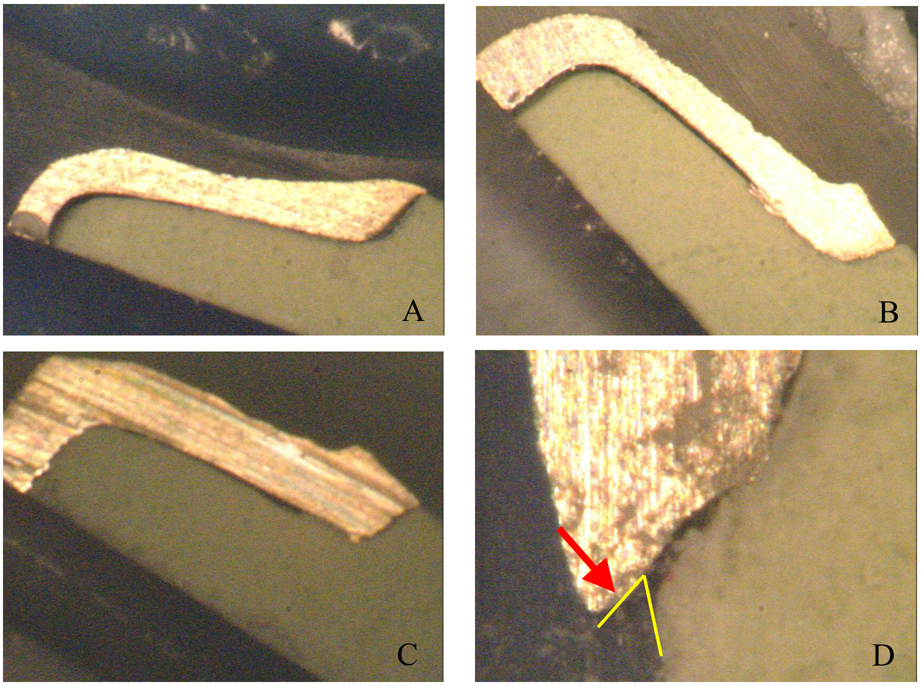


Fig. 10. View of coping and die by image analyzer at x50 (A, B, C) and x300 (D) magnification showing the tendencies of gap at margin, axial wall and occlusal fossa area. A; milled titanium, B; cast titanium, C; Ni-Cr alloy, D; over-extension of milled titanium coping at margin area. The arrow indicates the horizontal overextension.

IV. Discussion

The fit of a casting can be defined best in terms of the "misfit" measured at various points between the casting surface and the tooth. Holmes et al. (1989) defined a casting misfit terminology. We investigated the marginal gap, which was defined as a perpendicular distance from internal surface of the casting to the margin of the prepared tooth.

If the marginal adaptation of a crown and tooth was less than 25 ㎛, which is within the range of ADA specification No.96, the cement thickness of current luting agents would preclude castings from being fully seated. Felton et al. (1991) said that postcementation casting/margin irregularities less than the maximum film thickness of 25 ㎛ were probably rare. When castings are cemented with luting agents, additional errors could be introduced. For this reason, we did not use luting agents in order to exclude the influence of film thickness which affects underseating of copings.

Eames and O'Neal (1978), McLean and von Fraunhofer (1971), Valderrama et al. (1995) concluded that a marginal discrepancy of less than 50 ㎛ is considered clinically acceptable for cast restorations. McLean and von Fraunhofer (1971) showed metallographic cross-sections of an unused and a 3 week-old explorer tip and a 40 ㎛ human hair. Though the radius of a new one was similar to that of human hair, the old one showed a larger radius. This suggests that gaps of less than 80㎛ could be relatively difficult to detect under average clinical conditions. Also he concluded that marginal gaps and film thickness of cement less than 120 ㎛ are clinically acceptable (McLean and von Fraunhofer 1971).

As we mentioned in instruction, the use of nickel-chromium alloys as substitutes for gold has been much attention in fixed prosthodontic procedures. According to the investigation of Duncan, that showed there were no significant different between gold alloy and nickel-chromium alloy and both of them were within the clinically acceptance level (Duncan, 1982). Based on these facts, we used nickel-chromium alloy as a control group.

Two gypsum replicas were then made from each of these impressions using a type IV high-strength dental stone, because during laboratory adjustment of castings, abrasion of stone dies may occur. These make, on a clinical try-in, a suitable marginal fit on the stone die not to be apparent on tooth preparation (Ushiwata and de Moraes, 2000).

As usual, cast distortion and following greater occlusal gap between coping and tooth can result from the uneven metal shrinkage by different wax bulk at the occlusal surface (Ushiwata and de Moraes, 2000). Thick wax portion on occlusal area were carved to prevent this phenomenon.

Before performing the measurement of gaps, we did a sample test to confirm the absence of bias. The sample tests were performed as follows; choose one specimen and measure the same site ten times with a time interval. Result of a one-way ANOVA revealed that every p-value exceeded 0.05, so we could conclude there was reliability, repeatability and no bias.

In our study, we evaluated the discrepancies of milled titanium copings on their inner and outer surfaces. There have been experiments on the casting system and the Procera system, but the investigations of CAD/CAM system for titanium were few. Basic statistics are shown in Table II and Fig. 8. The abbreviations used in Fig. 8 are described in Table III. The average marginal gaps of titanium milled in our study are 73.78 ㎛ with a standard deviation of 32.31 ㎛ and 51.57 ±24.46 ㎛ in cast titanium alloys. They were different significantly ($p<0.05$). The mean marginal opening of the cast titanium was similar to those observed by Blackman et al. (1992) and Leong and Chai (1994). The marginal gap of milled titanium had slightly higher values than those reported by other investigations. We found the significant differences of gaps caused by materials and regions by 2-way ANOVA (Table VIII), and the values of gaps at each region showed opposite tendencies (Fig. 9). Pearson correlation coefficients were checked, and as shown in Table IX, there were interactions between gaps at the finish lines and axial walls in the Ni-Cr groups. Though the values of the correlation coefficient range of both group (low absolute values of -0.114) were not relatively close to 1 or -1, and this indicated that they were not correlated linearly each other but they had some kind of relationships. The TMF-TMA and TCF-TCA groups were not linearly related.

In the comparison of marginal gaps between the coping and teeth, cast titanium copings showed the smallest marginal discrepancies (51.57 ± 24.46 ㎛), whereas milled titanium coping ranked the highest in that 73.78 ± 32.31 ㎛. The accuracy of a coping is the result of the sum of errors at individual steps from tooth preparation to build-up of porcelain, any of which it can lead to a failure of the crown. In this investigation, we could compare the conventional casting system with a machine-milled system. As shown in results, the casting technique of Ni-Cr alloy and titanium were better than the CAD/CAM system of titanium. As shown in figure 9, the coping of milled titanium and die had a smaller space at axial wall area compared to that of the cast titanium group. The binding of the coping and the die caused by this less space could result in the underseating of the metal coping. The marginal gap of 10 ㎛ exists theoretically though the coping is fully seated because 10 ㎛ space were relieved at 1mm above the margin, and these gap might lead to the unstable seating of the coping. The greater value of standard deviation of milled titanium group than those of other two groups fortifies the fact of the unstable seating. In the investigation of May et al. (1998), they also concluded that the larger axial gap dimension suggested that further seating could be possibly occurred, which leaded to smaller marginal gap. These two reasons could explain the fact that the milled titanium group had a greater marginal gap. Another reason is as following; assuming that tooth preparation and master die fabrication were the same, the difference between the two systems could result from the coping fabrication (or design and milling) procedure, in other words, the limitation of the accuracy of the milling machine.

Though the mean value of milled titanium was ≤ 120㎛, as it was the greatest one, the study for the improvement of the accuracy of CAD/CAM system might be performed.

Compared to other investigations, there have been many researches on the marginal adaptation of titanium coping and tooth. Oruç and Tulunoglu (2000) reported on average marginal gap of 47 to 61 ㎛. Besimo and Jeger (1997) investigated the marginal adaptation of titanium frameworks produced by CAD/CAM techniques. Out of 10 total test specimens, 1475 sites were measured and the mean value for all crowns was 47.0 ± 31.5㎛. The results, by Leong and Chai (1994), of marginal fit of machine-milled and cast titanium were 54㎛ and 60㎛, respectively. Harris and Wickens (1994) compared the fit of spark-eroded titanium copings and cast gold alloy copings. 47 ㎛ ~ 95 ㎛ according to the shape of the finish line were recorded. The results above and in those of our study are within the range of a clinically acceptable value of 120 ㎛.

Nakamura and Dei (2003) reported marginal fit and internal fit of Cerec 3 CAD/CAM all-ceramic crowns under three different luting spaces, from 10 ㎛ to 30 ㎛. The range of marginal fit was 53 ~ 95 ㎛, and they recommended 30 ㎛ for luting space. In Nakamura's investigation the lowest marginal gap was found in the luting space of 30 ㎛. In addition, Nakamura suggested that 30 to 50 ㎛ of luting space could offset the influence of the convergence angle of an abutment. On the base of Nakamura's research we set the luting space of the titanium copings to 30 ㎛ and got a mean value of 73.78 ± 32.31 ㎛ at finish line level.

As for horizontal extension, just fit was observed in 68.19% of the Ni-Cr alloy copings and 67.80% of cast titanium copings, which showed the best results. However, horizontal overextension, the most frequently observed phenomena for machine-milled titanium copings, was observed in 75.63% of the cases. This was probably caused during die adaptation procedure when marginal finishing had to be done with the naked eye, using a microscope or not, by the technician, and the inability to do just finishing for fear of damaging the die. 24.55% of overextension and 23.73% of underextension observed in Ni-Cr alloy and cast titanium respectively are assumed to be an error caused by the technician during margin wax application.

As CAD/CAM system develops and applied in a variety of fields, more researches are underway for each system. Unlike the Procera system for which a lot of researches have been focused, we used the DC-Titan system which mills both internal and external surface of copings by scanning the die with linear laser and the results were in clinically acceptable range. However, marginal gap was statistically significantly larger compared to the cast samples, and horizontal overextension was more frequently observed. More technical researches need to done to minimize these. This investigation was a limited study, because we didn’t use permanent cements used in actual clinical situation, and only the precision of fabrication was compared omitting the procedures of porcelain firing and cementation with luting agents. More researches which reflect clinical situations need to be done.

V. CONCLUSION

This study compared internal fit and adaptation of base metal and titanium which was fabricated by casting and machine-milling. A total of 90 dies were made and divided into 3 subgroups. In each subgroup15 were used for making copings and the others were used for measurement after sectioning. Measurements were made at three regions; finish line, middle of axial wall and center of occlusal fossa.

Within the limitations of the study design, the following results may be drawn:

1. The mean marginal gap of machine-milled titanium, cast titanium and Ni-Cr alloy copings were 73.78, 51.57 and 61.07 ㎛, respectively. There were significant differences in the marginal fit among all the test groups, and titanium copings fabricated by machine-milled had the greatest marginal gap.
2. The mean gap at axial wall of Ni-Cr alloy copings was the least value of 47.71 ㎛. That of machine-milled titanium was 59.61 ㎛. Cast titanium which had the least marginal gap showed the greatest gap at axial wall, 92.79 ㎛. All 3 groups were significantly different from each other.

3. Horizontal overextension, the most frequently observed phenomena for machine-milled titanium copings, was observed in 75.63% of all the machine-milled titanium copings.

Further technical improvements in CAD/CAM system for cp-titanium are needed to acquire more accurate fit, even though the current CAD/CAM system appears to provide acceptable marginal adaptation, 120 ㎛ and possibility with the clinical application.

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Abstract in Korean

주조 및 기계 절삭 타이타늄 코핑의 적합도 비교

금속-도재관은 현재까지도 심미적 수복물의 표준으로 사용되고 있다. 코핑 재료로는 주로 귀금속이 사용 되어 왔으나, 고가 및 낮은 굽힘 저항성 등의 단점으로 다른 대체제가 연구 되어 왔다. 그 중 현재 타이타늄이 신소재로 각광을 받고 있으며, 타이타늄은 우수한 생체 친화성 및 부식 저항성, 낮은 열 전도도, 높은 기계적 강도 그리고 적당한 가격 등 의 장점을 가지고 있으나, 성형 및 가공 방법의 어려움으로 인해 그 사용이 제한되어 왔다. 하지만 최근 타이타늄의 가공법이 여러 가지로 제안 되어 왔으며, 이의 임상 적용에 대한 연구가 활발히 진행되고 있다.

보철 수복물의 임상적 성공의 한가지 요인으로 수복물과 지대치의 적합성을 들 수 있으며, 이는 코핑 재료의 가공성에 직접 영향을 받게 된다.

본 실험은 코핑 재료로서 타이타늄의 적합성을 기존의 비귀금속 재료에 의한 코핑과 비교하고자 하였다. 실험군인 타이타늄은 기계 절삭 (CAD/CAM)과 주조 방법 등으로 가공하였으며, 변연부, 축 (axial), 교합면 부위에서 금속 코핑과 모형간의 거리를 측정하였고, 추가적으로 수평 피개 정도를 관찰하였다. 대조군으로는 비귀금속인 니켈-크롬 합금을 사용하였다.

각 군당 15 개의 시편을 제작한 후, 코핑과 작업 모형을 시아노 아크릴레이트 접착제를 이용하여 접착하였다. 접착된 시편을 치아 장축을 따라 근원심, 협설측 방향으로 4 등분으로 절단 하여 총 4 개의 시편, 8 개의 절단면을 얻었다. 각 절단면은 image analyzer 를 통하여 300 배의 배율 하에서 그 간격을 측정하고 각 군간의 측정값을 비교 분석하였으며, 50 배의 배율 하에서 코핑의 수평 피개 정도를 분석하였다.

다음과 같은 결과를 얻을 수 있었다.

1. 기계절삭 타이타늄, 주조 타이타늄, 주조 니켈-크롬 합금 코핑의 변연부 틈새는 각각 73.78 ㎛, 51.57 ㎛ 그리고 61.07 ㎛이었다. 모든 군들은 통계학적 유의성을 보였으며, 기계 절삭 타이타늄 코핑이 가장 큰 변연부 틈새를 보였다.
2. 측벽에서의 평균 틈새는 니켈-크롬 합금, 기계절삭 타이타늄, 주조 타이타늄이 각각 47.71 ㎛, 59.61 ㎛ 그리고 92.79 ㎛이었으며 군 간에 통계학적 유의성을 보였다.
3. 수평 과연장은 기계 절삭 타이타늄 코핑에서 75.63%로 가장 빈번하게 관찰되었다.

비록 CAD/CAM system 이 임상적으로 허용할 만한 범위 (120 ㎛)의 변연부 적합도를 제공하나, 좀 더 정확한 적합을 위한 연구가 더 필요하리라 사료된다.

핵심되는 말 : 기계절삭 타이타늄, 주조 타이타늄, 변연 적합도, 이미지 어날라이저