Effect of Pattern Elevation on the Fit of Co-Cr Copings Produced for Implant Abutments

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Abstract

Objectives: The study's purpose was to evaluate the efficacy of pattern elevation compared to other methods used for fit manipulation of metal copings produced for implant abutments

Methods: Seventy-seven pattern resin and eleven wax patterns were produced for Friadent 4.5mm diameter straight abutment and were assigned into eight groups. Four resin groups were elevated from the abutment for 250μ, 500μ, 750μ and 1000μ respectively in order to produce a die spacer effect, then were recapped and remargined with resin, one resin group was elevated for 1000μ then was recapped and remargined with wax, while the other two groups were used without any elevation. The patterns were invested and cast with Co-Cr alloy. One resin group (no pattern elevation) was invested separately and followed a different heating cycle prescribed by the manufacturer to produce extra investment expansion.

After casting, the copings were subjected to sequential fitting rounds. The amount of vertical marginal gap was measured after each fitting cycle. And the data were analyzed statistically by ANOVA and Dunnett C Post hoc test.

Results: The 1000 μ-elevated wax recapped and remargined group showed significantly better marginal fit at the beginning of the fitting process and less time needed to reach target marginal adaption zones. Compared to the control group (no elevation-pattern resin), only the wax, and 500 μ elevated groups did also show significantly less fitting time.

Conclusion: Pattern elevation is effective in reducing the fitting time. However, the recapping and remargining process has a significant influence on effectiveness.

Keywords: Marginal fit, Die spacer, Implant, Pattern resin, Pattern elevation, Crown fit.

Introduction

Marginal fit is one of the most important aspects related to the prognosis of fixed prosthetic treatment. Lack of good marginal adaptation in implant supported prostheses may lead to peri-implantitis and loss of marginal bone [1-3]. Despite the lack of sound consensus regarding the maximum allowed marginal gap [4], huge efforts have continuously been spent to improve the fit and eliminate marginal discrepancies [4-28].

To achieve smooth full seating, there should be no interferences between the fitting surface of the prosthesis and the abutment. This is accomplished by the provision of a tolerance space between the two contacting surfaces [5-9]. During the pattern production [10-15], investing [16-18] and the casting steps [18] relevant factors are manipulated to produce metal copings with the

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needed tolerance space.

Thermal shrinkage that happens after metal casting and cooling poses a problem in this regard, especially with high melting point base metal alloys [18]. Therefore, efforts are made to produce an enlarged mold space into which the molten metal is introduced [18]. Conventionally, this is accomplished first by producing the pattern on a die enlarged by die stone expansion [8, 19, 20] and coating with a suitable die spacer [21-23], thereafter a suitable investment material especially formulated to undergo a controlled amount of setting and thermal expansion is used [9, 16, 17, 24]. After casting, the retrieved metal coping is subjected to a fitting process in which the remaining interferences are detected and removed [18].

Resin is commonly used for pattern production made directly over metal abutments for implants. Compared to wax there is less risk of pattern fracture or distortion during manipulation, and this makes it popular among many laboratory technicians [10-15]. However, when resin patterns are produced over metal abutments the conventional die spacers tend to stick and become part of the pattern. Therefore, the only chance left to provide the needed tolerance space would be at the investment and mold heating steps.

However, the investment expansion behavior may also differ depending on the physical and mechanical properties of pattern material's [18]. Besides, investment manipulation should affect both the dimensions of the coping intaglio and the inter-abutment distance [9, 13, 17]. Lack of fit may result if investment expansion leads to inaccuracies in the inter-abutment distances [9, 13, 17]. In comparison die enlargement offers a chance for allowing easier fit at each respective abutment without affecting the inter abutment distances.

The purpose of this study was to introduce pattern elevation as a new method for production of a controlled amount of die spacer. The method is tested on patterns produced for implant abutments and cast in base metal alloy

MATERIALS AND METHODS
Test specimens

Basic casting patterns of 0.5 mm thickness were produced using a specially made duplication mold for friadent 4.5mm diameter straight abutment (Dentsply, Friadent, Mannheim, Germany) (Fig. 1). Seventy-seven resin patterns (Pattern resin LS, GC Corporation, Japan, Lot No. 0512073), and eleven wax patterns were assigned into eight experimental groups. Four pattern resin groups were elevated of the abutment for 250μ, 500μ, 750μ and 1000μ respectively in order to produce a die spacer effect. Then they were recapped and remargined with pattern resin. One pattern resin group was elevated for 1000μ then the patterns were recapped and remargined with wax, while the other two groups were used without any elevation.

By elevating the pattern off the tapered abutment, a proportional amount of space (Die spacer effect) would result between the tapered vertical walls of the abutment and the pattern intaglio (Fig. 2). After that the pattern was locked in the elevated position by recapping and remargining. In this step contact was reestablished between the abutment's horizontal surfaces and the pattern and the occlusal dead space was closed. The amount of space lateral distance could be calculated as:

Lateral Distance (μ m) = Elevation (μ m) * Tan (Unilateral taper angle)

The patterns were invested (Castorit- super C, Dentarum, Germany, Lot No. 120541) and cast with Co-Cr alloy (Remanium star -Co 60.5%, Cr 28%, W 9%-, Dentarum, Germany, Lot No. 230) according to the manufacturer's instructions. Into each casting ring one wax and six resin specimens

were embedded representing seven groups (Fig. 1).

The eighth group (pattern resin, no pattern elevation) was invested separately and followed a different heating cycle prescribed by the investment manufacturer in order to produce more investment expansion. In this group, after holding the mold at 250 C° for 60 minutes, instead of continuing to the final casting temperature, the mold was lift to cool back to room temperature then the temperature was raised to the final casting temperature.

After casting, the copings were divested and cleaned with airborne particle abrasion (100 µm aluminum oxide) at 3 bars. The internal surface was inspected under a stereo microscope and obvious nodules were removed.

Fitting process

The copings were subjected to sequential rounds of fittings under operating microscope - magnification 20X and 40X- (Euromex Arnhem, Germany) after determination of the contact points with suitable marker (Snowman, Japan). In each fitting cycle the contact points were determined for all specimens first. Then the specimens were presented to a blinded single operator sequentially, and the grinding time was measured. The starting specimen was changed systematically in each fitting cycle to exclude any effect of order on the results. The fitting process for each specimen continued until the marginal gap became less than 50 µm.

At the beginning and after each fitting cycle the amount of vertical marginal gap was measured at six representative locations marked on the abutment. Digital images were acquired (MC camera, motic group, China) under microscopic magnification of 50X and 100X (Zeiss, Germany), and analyzed with suitable software (motic images plus 2.0 ML, China) (Fig. 3). The reproducibility of the measurements was ± 5 µm.

And the data were analyzed statistically by ANOVA and Dunnett C Post hoc test.

Retention test

After the fitting process was completed each metal coping was fixed to the abutment with light body silicone (Elite H-D, super light–fast setting, Zhermac, Rovigo, Italy, Lot No. 25116), the marginal gap was measured for the last time, then the assembly was fixed to the testing machine (Autograph AG-IS, 500N, Shimadzu, Kyoto, Japan). Then, a dislodging force was applied through a chain hocked into a ring cast with the metal coping. The crosshead speed was 2 mm/min. and the amount of force needed to cause dislodgment was recorded in grams.

After the test the silicone representing the cement layer was collected and weighed (AW120, Shimadzu, Kyoto, Japan). The weight was divided by the calculated density of the silicone material (1.3304 gm/cm³) to give the cement space volume. Based on direct measurements, digital imaging and sketches provided in the manufacturer's manuals, a three- dimensional model was produced for the test abutment by the use of the preprocessor of FEM computer software (ANSYS 8.0 FEM; ANSYS Inc, Canonsburg, Pa, USA) (Fig.1). The model was used to measure the abutment surface area (91.2 mm²). The average cement layer thickness for each metal coping was calculated by dividing the measured cement space volume by the abutment surface area.

RESULTS

The initial fit of all test groups in the as-cast condition was very unsatisfactory (mean= 1181 µ) signifying the need for fitting before final judgment. In the as-cast condition only the 1000 µ elevated wax recapped and remargined group showed a mean marginal adaptation within 100 µ.

(Table.1). Figure 4 shows the average marginal gap for each group throughout the fitting process.

After seven fitting rounds the global mean became less than 100 μ. When compared to the control group (pattern resin with no pattern elevation nor favored heat expansion), the 1000 μ elevated wax recapped and remargined, the wax, and the 500 μ elevated pattern resin recapped and remargined showed significantly better marginal fit (Table.1).

Table.1 also shows the average marginal gaps in the as-cast condition, after the seventh fitting round, and at the end of the fitting process. At the end of the fitting process there was no significant difference in the marginal adaptation between the eight groups (Fig. 4). Also indicated in the table are the means of the grinding times needed for each specimen to reach a marginal adaptation below 100 μ and below 50 μ. The time was significantly lower in the 1000 μ-elevated wax recapped and remargined, the wax, and the 500 μ elevated groups (Table 1).

According to Tukey post hock test only the 1000 μ-elevated wax recapped and remargined and the wax groups did show significantly different retention force in comparison to the control group, but the difference was minor (Table.1). Also, only the 1000 μ-elevated wax recapped and remargined showed significant but small difference in the average cement space (Table.1).

DISCUSSION

Despite the huge differences in the marginal adaptation in the as-cast condition, there was no significant difference at the end of the fitting process. This indicates that when the pattern is carefully made, meticulous fitting can still lead to acceptable marginal adaptation even if the as-cast result was very unsatisfactory. However, the penalty paid in terms of labor time might be unbearable, and depending on the strictness of the worker, less acceptable marginal adaptation might result.

As compared to many previous investigations[4-28] this study addressed explicitly the fitting process as a comparison criterion, this was paramount since the initial fit was not acceptable for most of the samples, which was in contrary to many previous studies that either used different pattern materials like wax and/or were conducted for none-implant abutments (natural teeth).

In this study the fit was measured at the marginal locations mainly using direct magnified visualization. Alternatively, more elaborate marginal and internal fit measurements were advocated by previous studies[29-32] using micro-computed tomography (micro-CT) and the replica techniques. However, since multiple measurements were needed throughout the fitting process the direct visual measurement method was considered more appropriate.

At the end of fitting process the volume of the internal space was measured and from it the average internal separations between the abutment and the copings were calculated. Therefore, in this study the internal misfit was not measured at different locations as could be done with the micro CT or the replica technique[33]. Nevertheless, it was assumed that such demanding measurements might be more relevant in the case of weaker full ceramic restorations[33].

At the end of the fitting process, the differences in the retention force and average cement space between the groups were marginal. In this study silicone was used instead of conventional cement because it was easier to clean and collect for weight measurement. The retention force recorded may be far away from the real ones when proper cements are used. However, the retention force results combined with the average cement space results may

indicate that the retention forces of the eight groups might be close with no major expected influence of the pattern specifications on the actual retention behavior.

The 1000 μ-elevated wax recapped and remargined group showed the best marginal fit at the beginning of the fitting process. Also, it needed the least amount of time to reach the two target marginal adaptation zones (100 μ and 50 μ). In this group the effect of pattern elevation on fit was the most obvious, signifying the usefulness of this method in fit enhancement. However, when compared to the control group, aside from the 500 μ elevated group which showed statistically significant but only slight improvement, unexpectedly none of the other pattern resin recapped and remargined groups managed to show consistently better marginal adaptation at the beginning of the fitting process nor less time needed to reach the 100 μ and 50 μ zones.

The reason behind lack or reduced efficacy for pattern resin recapped and remargined groups compared to wax remargined recapped group might be due to the phenomenon that was observed at the pattern production step. With the help of operating-microscope it was observed that after elevation, when the patterns were remargined and recapped with pattern resin, there was a tendency for the monomer to flow by capillary attraction into the space created between the pattern and the abutment. This tendency was not observed when wax was used for recapping and remargining. It is expected that some of the polymer particles could have been drifted with the monomer and led to partial obliteration of the space between the pattern and the abutment. The drifted particles also could have led to roughening of the pattern intaglio which might have interfered with smooth wetting of the pattern inside walls by the investment material. This might explain the limitations observed when pattern resin was used for recapping and remargining as compared to wax.

Future studies are recommended to focus on more elaborate specifications for the most appropriate amount of pattern elevation or alternative techniques for remargining and recapping that can still preserve the beneficial die spacer effect while extending the desired stability and strength effect of resin pattern to the marginal areas.

When compared to the resin control group, wax patterns showed significantly better marginal adaptation at the beginning and less fitting time. According to the manufacture's manual, the setting temperature of the investment material was $60^{\circ C}$. At this temperature the wax patterns tend to soften and expand much more than the resin patterns, this would also allow less resistance to the setting expansion of the investment material and more enlargement of the mold space [10-18].

The special heat cycle group didn't show statistically significant difference in terms of less marginal gap nor shorter fitting time when compared to the control group. This indicates the limitation of this method and the special need for a die spacer with resin patterns.

CONCLUSION

Resin patterns even though used for their strength and dimensional stability, when compared to wax patterns proved to be unresponsive to fit enhancement factors integral to the steps of conventional investment and pattern production. When recapped and remargined with wax, pattern elevation proved to be helpful in compensating for that by producing a die spacer effect that was successful in enhancing the fit of the metal copings.

It is suggested that the amount of die spacing can be easily manipulated and tuned by the technician based on the desired ease of fit versus tightness of the copings through controlling the

amount of elevation. This takes advantage from the geometrical fact that the ratio of die spacer lateral distance to the amount of elevation is very low under the low tapper angles common to implant abutments.

However, even though it might be desired after elevation to recap and remargin the patterns with resin this study's results showed that this would reduce the beneficial effect and that further investigations need to be done before such maneuver would lead to the desired level of fit achieved with wax or elevated wax remargined

recapped resin patterns.

Manipulation of the technique to diversify and improve might be a topic of future investigations.

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Table 1: Groups mean and standard deviation (between brackets) of the (as cast, seven rounds and final) marginal gap values -in micrometers-, active grinding time needed to reach a gap below (50 μ and 100 μ) -in seconds-, retention -in gram force- and average cement thickness -in micrometers-. The asterisks indicate significant differences with the control group (pattern resin with no elevation).

| Group	Initial fit- as cast condition (μm)	Seven rounds fit (μm)	Final fit (μm)	Fitting time 100 μm (seconds)	Fitting time 50 μm (seconds)	Retention (grams)	Cement thickness (μm)
0μ -Resin	1494 (378)	96 (34)	30 (7)	443 (68)	778 (123)	1409 (122)	69 (9.4)
250μ - Resin	1569 (546)	89 (40)	32 (11)	452 (99)	746 (170)	1330 (149)	67 (9)
500μ - Resin	1291 (488)	40 (11)*	36 (11)	342 (64)*	498 (99)*	1340 (107)	66 (8.6)
750μ - Resin	1397 (340)	104 (76)	33 (10)	455 (102)	790 (138)	1346 (121)	73 (8.3)
1000μ - Resin	1217 (287)	97 (45)	37 (10)	392 (91)	814 (194)	1263 (92)	78 (8.8)
1000μ - Wax	86 (17)*	39 (8)*	33 (5)	0*	170 (108)*	1556 (93)*	82 (5.7)*
Wax	664 (429)*	40 (13)*	27 (6)	235 (50)*	371 (79)*	1582 (98)*	79 (10.9)
Heat cycle	1731 (411)	59 (44)	36 (7)	397 (109)	655 (185)	1406 (159)	62 (4.6)
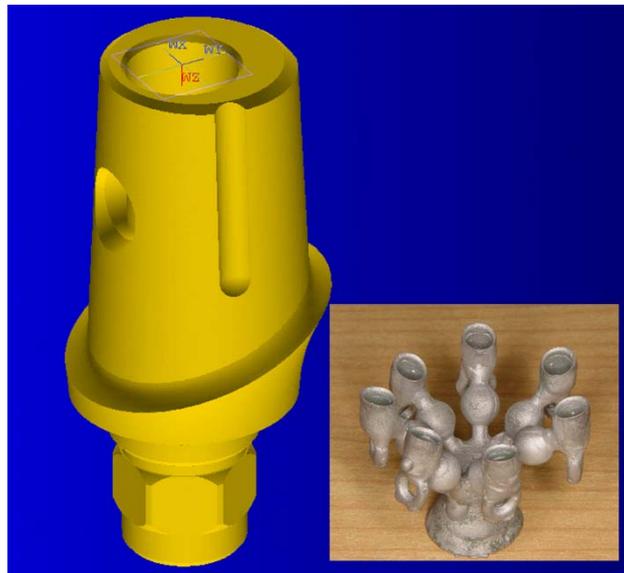
Fig. 1: An image of the abutment used in this study, and seven metal copings each representing a different group after divesting and before sprue cutting.
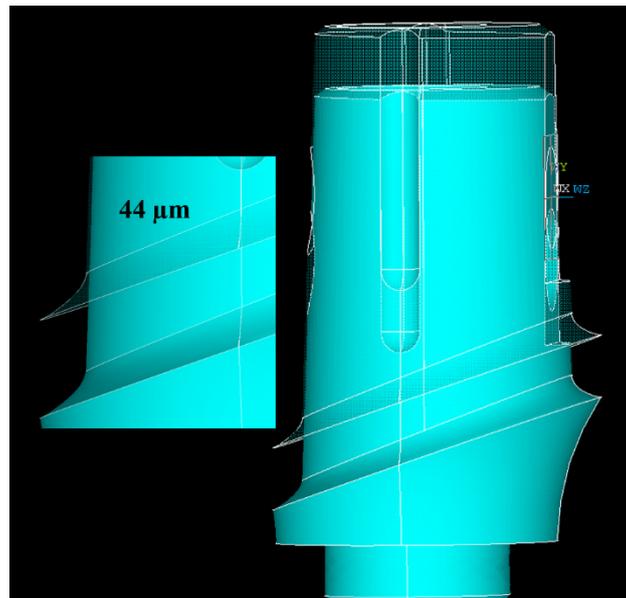
Fig. 2: Effect of pattern elevation on the gap between the vertical walls of the abutment and the pattern. The calculated amount of space lateral distance for the 5.5 degrees tapered abutment used in this study at 1000µ micrometer elevation was 44µ.
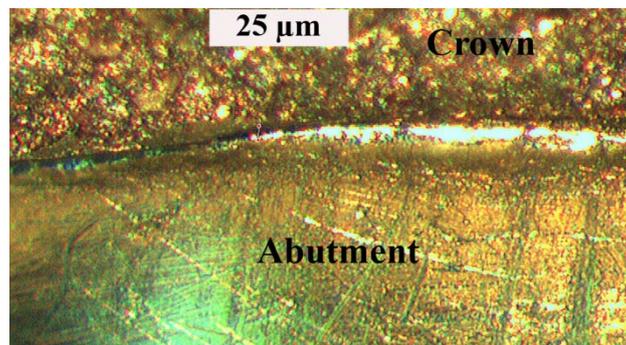

Fig. 3: Abutment-coping interface and gap measurement by analyzing the magnified digital image with Motic Images Plus 2.0 ML software.
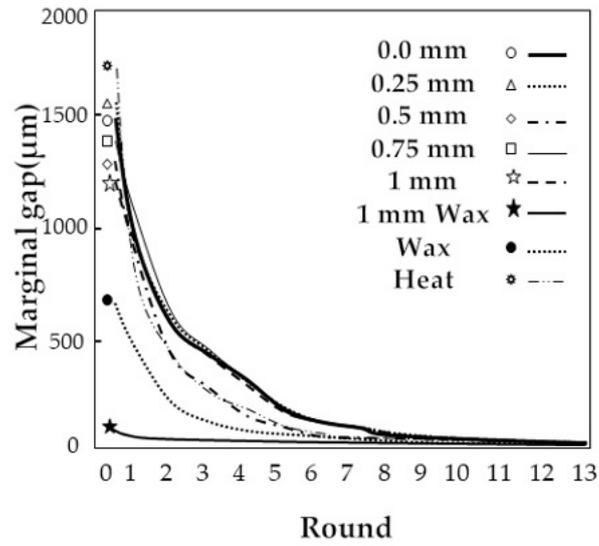
Fig. 4

Fig. 4: The average marginal gap for each group throughout the fitting process

تأثير رفع النموذج على دقة انغلاق الحواف للأغطية المصنعة من الكوبالت كروم لدعامات الغرسات السنية

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الملخص

الأهداف: هدف هذا البحث إلى دراسة مدى فاعلية رفع النموذج على تحسين دقة درجة انغلاق الحواف، وتسهيل تحقيقها مقارنة بالطرق الأخرى المستخدمة لذات الغاية.

المواد وخطوات العمل : تم عمل سبع وسبعين نموذج من الراتنج إضافة إلى أحد عشر نموذجاً من الشمع لدعامة غرسة من نوع فريادنت مستقيمة وذات قطر 4و 5 مم. ومن ثم تم توزيع النماذج على ثمان مجموعات كالآتي: أربعة مجموعات من الراتنج تم معالجتها عن طريق رفعها بمقدار 250، 500، 750 و10000 ميكرون و ذلك لإحداث فراغ بين النموذج، والدعامة، بدرجات متفاوتة حسب كل مجموعة، ومن ثم تم اكمال النموذج إضافة الراتنج، و ذلك لإعادة إغلاق الحواف، واستبدال الجزء العلوي من النموذج، في مجموعة أخرى تم رفع النموذج لمسافة 10000 ميكرون ومن ثم اكماله بالشمع كما وتم استخدام مجموعتي الراتنج المتبقيتين دون رفع أو إضافة، وتم عمل قوالب صب في كل قالب عينة من الشمع و ست عينات تمثل ست مجموعات راتنج، ومن ثم صبها بسبيكة الكوبالت كروم، وتم صب المجموعة الثامنة من الراتنج دون رفع على حدى حيث خضع القالب لدورة تسخين مختلفة حسب تعليمات الشركة الصانعة، وذلك بهدف توسيع القالب بشكل أكبر.

وبعد الانتهاء من الصب تم اخضاع الهياكل المعدنية لدورات تنزيل متتابعة، وتم قياس درجة عدم الانغلاق بعد كل دورة، وتم تحليل النتائج إحصائياً باستخدام انوفا ودنت سي.

النتائج: أظهرت النماذج المرفوعة ل 1000 ميكرون والمكملة بالشمع درجة انغلاق مبدئية أفضل ولزمها وقت أقل للوصول إلى درجات الانغلاق النهائية من الناحية الاحصائية. كما وأظهرت مجموعة الشمع والمجموعة المرفوعة 500 ميكرون وقت تنزيل ذات دلالة إحصائية اقل مقارنة بالمجموعة المرجعية (راتنج بدون رفع او معالجة حرارية مختلفة).

الخلاصة: أظهرت الدراسة فاعلية رفع النموذج في تقليل الوقت الازم للتنزيل وتحقيق انغلاق الحواف، إلا أن ذلك يعتمد وبشكل كبير على الطريقة المتبعة في اكمال النموذج بعد رفعه.

الكلمات الدالة: دقة انغلاق الحواف، نماذج الراتنج، رفع النموذج، الغرسات السنية، دقة التلبيسات.