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Research Article / Araştırma Makalesi

The Effect of Different Angled Abutments With Peripheral Groove and Vent Hole on the Retention of Cement Retained Implant – Supported Restorations

Simante İmplant Üstü Restorasyonlardaki Farklı Açılar Uygulanmış Abutmentlerde Çevresel Oluk ve Deliğin Tutuculuğa Etkisi

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ABSTRACT

Background: The purpose of this study was to analyze the effect of vent hole or peripheral groove on retention of differently angled (15° and 30º) abutments in cement retained implant supported restorations.

Methods: A total of sixty standard implant abutments were used. Abutments were divided into two groups at 15° and 30° angles on CNC. According to the modification, each group were divided into 3 subgroups; (1) no modifications, (2) with peripheral groove and (3) with vent hole. Sixty metal frameworks were prepared using laser sintering to fit all abutments. All laser sintered frameworks were cemented with eugenol-free provisional cement. Then, all specimens were thermocycled. The frameworks were removed from the abutments by using the universal test machine and the peak removal force was recorded. Statistical analysis were performed with two-way ANOVA, post hoc Tukey's (HSD) test-adjusted independent samples t-tests.

Results: According to the results, there were significant differences between 15° and 30° groups in terms of retention values ($p < 0.001$). Additional hole and grooves enhanced retention in both groups. The highest mean value of vertical pull-out strength (185.00 ± 23.08 N) was showed in 15° additional grooves group, and the lowest mean value of vertical pull-out strength (27.60 ± 14.84 N) was showed in 30° control group. Means values of additional groove specimens had the highest scores in both groups. In all groups, there were significant differences between all subgroups ($p < 0.05$).

Conclusion: Increased abutment angle decreases retention, while addition of hole and groove increases.

Keywords: Implant-supported dental prosthesis; abutment; cementation; retention

ÖZ

Amaç: Bu çalışmanın amacı, farklı açılarda hazırlanmış implant abutmentlerine uygulanan çevresel oluk ve deliklerin implant destekli restorasyonların tutuculuğuna etkisinin araştırılmasıdır.

Gereç ve Yöntemler: Toplam altmış adet standart implant dayanağı kullanıldı. Abutmentler CNC üzerinde 15° ve 30° açılarda olmak üzere iki gruba ayrıldı. Modifikasyona göre her grup 3 alt gruba ayrıldı; (1) kontrol, (2) çevresel oluklu ve (3) havalandırma delikli. Tüm abutmentler için lazer sinterleme kullanılarak altmış adet metal altyapı hazırlandı. Tüm metal altyapılar, öjenol içermeyen geçici siman ile simante edilmiştir. Daha sonra, tüm örneklere termal döngü işlemi yapıldı. Tüm örneklere universal test cihazında 5mm/dk başlık hızı ile vertikal çekme testi uygulandı. İstatistiksel analiz, iki yönlü ANOVA, post hoc Tukey (HSD) test ve bağımsız student t-testleri ile yapıldı.

Bulgular: Sonuçlara göre 15° ve 30° grupları arasında tutuculuk değerleri açısından anlamlı fark bulundu ($p < 0.001$). Ek delik ve oluklar, her iki grupta tutuculuğu arttırdı. Tutuculuk değerlerinin en yüksek ortalama değeri (185.00 ± 23.08 N) 15° oluklu grubunda, en düşük tutuculuk ortalama değeri (27.60 ± 14.84 N) 30° kontrol grubunda gösterildi. Oluk ilave edilen grupların ortalama değerleri her iki grupta da en yüksek değerlere sahip bulundu. Tüm gruplarda, tüm alt gruplar arasında anlamlı farklılıklar bulundu ($p < 0.05$).

Sonuçlar: Artan abutment açısı tutuculuğu azaltırken, uygulanan delik ve oluk ilavesinin tutuculuğu arttırdığı görülmektedir.

Anahtar Kelimeler: İmplant destekli diş protezi; abutment; simantasyon; retansiyon

Introductıon

The developing technology of dental implants is routinely used in the treatment of missing teeth and to eliminate aesthetic concerns. Implants not only replace missing teeth but also ensure the protection of the alveolar bone.[1,2]

Dental implants are prosthetic alloplastic materials which are placed under the mucosa or periosteum for fixed or removable prostheses and are used to provide support and retention inside or over the bone. Fixed implant abutments are applied with cement or with screws. The use of cemented implants has been optimized with occlusal interdigitation in implant-supported fixed restorations, ensuring passive compatibility, and improving the aesthetic elements.[3] Wall angles can be applied to cemented implant abutments to compensate for incompatibility in the implant body and to achieve a better aesthetic appearance. These angles can be adjusted from 6° up to 30°, based on the position of the implant. There is known to be an inverse relationship between angle and retention.[4,5]

Forms of retention and resistance are the properties that prevent the dislocation of the crown in the crown preparation.[6] Some preparation properties such as groove, hole, and box can be applied to increase the form of resistance of single crowns to which an excessive taper has been applied and in crowns with a short clinical crown length.[7,8] The compatibility and the standard of the metal infrastructure are also important. As a result of the development of the laser sintering method, crowns and abutments can be applied with a suitable high-quality cement range, which is both homogenous and sensitive.[9]

The ideal cement for restorations supported by an implant should have sufficient retention capability to prevent the loosening of the implant for as prognosis, but it should also allow the removal of the restoration without damage to the abutment and the implant.[10] The use of provisional cement in the cementation of restorations supported by an implant is significant in terms of the treatment of complications which may occur in the period following implantation.[11]

In-vitro research has concluded that it is necessary to simulate the oral environment to ensure the reliability of the study. Therefore, the thermal cycling procedure is used to optimize experimental conditions.[12,13]

When applying dental implants, in most cases there is insufficient bone tissue to be able to place the implant in the ideal position especially in the anterior region. In this case, angled abutments are needed to be placed at the correct position and create the correct entry route. Although these angulations help to form the correct entry route, as the

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convergence angle in the abutment increases, this causes a loss in retention.[14] The aim of this study was to investigate how much the size of the angle applied affected retention and the effect on increasing retention of a hole or surrounding groove added to the abutment. In addition, To test the null hypothesis of no difference in retention scores between groups was the purpose of the present study.

Material and Methods

Approval for the study was granted by the Ethics Committee (01 / 2015 - 05). The study was supported by Project no: **2013/263** from the University.

A total of 60 titanium nitrite-coated abutments (3 Inone abutment BioHorizons®, Birmingham, USA; height: 8.0 mm, platform width: 4.5mm) were used with abutment screws and appropriate stainless steel laboratory implant analogs (BioHorizons®, Birmingham, USA). The abutments were separated into 2 groups: angled at 15° and angled at 30°.[14-16] Each of these groups was then separated into 3 sub-groups of 10 abutments; (1) control groups: not applied with any procedure (C15 and C30), (2) hole groups: the addition of two, 0.8 mm radius holes placed 1 mm occlusal of the cervical line of the abutment, 180 ° apart, to represent the mesial and distal proximal surfaces[11,17] (H15 and H30), and (3) groove groups: a groove was added, 0.5 mm wide, 0.4 mm deep with an interwall angle of 60° (G15 and G30)(**Fig.1**) [18]. All the modifications were specially prepared by the CNC (Computer Numerical Control) milling machine on request (First Long Chang Machinery, Taichung, Taiwan). Following the manufacturer's instructions, all the supports were manually placed in analogs using an implant torque wrench applying a standard force of 30 Ncm.

Fig.1. Abutment modifications. (Left to right) C15, C30, G15, G30, H15, H30

Crown patterns were fabricated with Laser-sintered Co-Cr alloy (EOSINT M 270, Munich, Germany) with a ring attached to the occlusal portion and cement film thickness defined as 50 µm.[19,20] Marginal fittings of all copings were checked under a stereo microscope at x10 magnification (Nikon, Tokyo, Japan) and surface properties were confirmed. The copings were numbered 1 to 10 for identification during testing and were assigned to the correspondingly numbered abutments. Finally, all copings were airborne-particle abraded for 15 seconds with 110µm Al_2O_3 particles (RocatecPre; 3M ESPE) at a pressure of 0.2 MPa, washed with water, then dried with compressed air before the cementing procedure was initiated. The analog with its abutment was fixed in the device while the metal coping was cemented. TempBondTM NonEugenol provisional cement (Kerr, Salerno, Italia) was used, mixed according to the manufacturer's instructions. It was then applied in a thin layer 3 mm wide to the cervical margin of the inner surface of the copings. Immediately after the cement application, all the copings were seated on the abutments with finger pressure, followed by 50 N pressure applied for 10 minutes using universal test equipment. (Instron, Model 2710 - 003, Instron Corp. USA).[18,21,22] Any excess cement was then removed with a curette. During the cementing procedure, laboratory conditions were kept constant at a temperature of 21° ± 1°C. After the cementing process, the occlusal-apical distance was measured before and after bonding using digital calipers to determine whether or not the metal infrastructures had completely settled. All the samples were stored in 100% humidity at 37°C for 1 hour. Then, the thermocycle procedure was performed 1000 times between 5°C and 55°C lasting 10 seconds in each tank with 2 seconds rest time. [13] This limited aging protocol has been used in previous studies where provisional cements were tested. [12,23]

A suitable mechanism which could be placed on the metal ring infrastructures was prepared to implement the pulling process. The samples were connected individually to the test equipment. Then, the prepared mechanism was used, and the pull-out test was conducted at the crosshead speed of 0.5 mm / min. (**Fig.2**).[24] The peak force required to remove the castings from the abutments was recorded in N units.

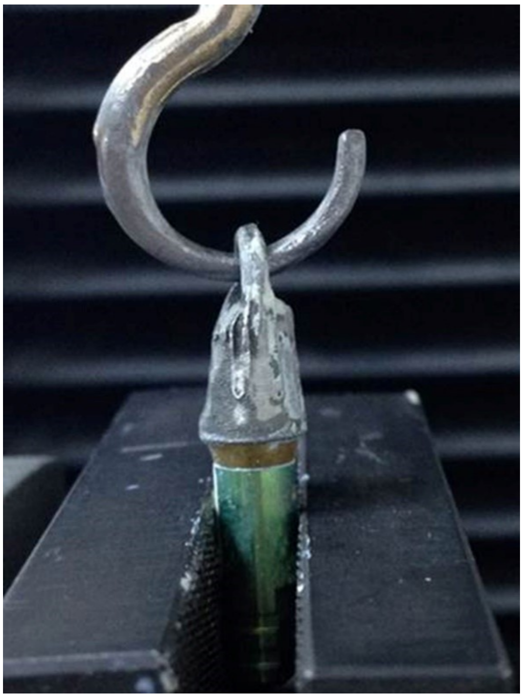

Fig.2. Pull-Out test with universal test machine

Statistical Analysis

Values obtained in the study were evaluated statistically using SPSS vn. 20.0 statistical software. (IBM SPSS versiyon 20.0 (IBM Statistical Package for Social Sciences Corp., Armonk, NY, ABD). Following the calculation of mean and standard deviation values, the groups were compared using the two-way ANOVA test. Multiple comparisons of the groups were made with the *Tukey test* (HSD). *Bonferroni correction* was used to determine statistically significant differences in multiple comparisons. A value of $p<0.05$ was accepted as statistically significant. The present study was reviewed by an independent statistician.

Results

The minimum, maximum, mean, and standard deviation values of each group are shown as N values in (**Table I**).

Table I. Comparisons of the hole and groove subgroups of the 15° and 30° angle groups in respect of the mean (SD) of retention force (N)

Groups	Mean	Standart deviation	Minimum	Maximum
15 ° Control	76.60	45527	38	109
15 ° Angled-Holed	134.20	35.70	90	185
15 ° Angled-Grooved	**185.00**	32.19	125	229
30 ° Control	**27.60**	14.84	12	54
30 ° Angled-Holed	42.00	15.25	25	76
30 ° Angled-Grooved	66.10	21.93	45	98
Total	88.58	60.10	12	229

The highest vertical pulling force was obtained in the angled 15° group. The lowest vertical pulling force score was obtained in the angled 30° group. The lowest pull-out strength was determined to be in the control groups, and the highest pulling force was determined to be in the grooved groups.

The angle degree and sub-groups were determined to be significantly associated with different pull - out strengths ($p < 0.001$) (**Table II**). A statistically significant relationship was determined between the angle value of the main group and pull-out strength ($p < 0.001$).

Table II. Two-way ANOVA results

Groups	Type III Sum of Squares	df	Mean Square	F	p
Angled	112753.35	1	112753.35	179.061	< 0.001
Group	53956.033	2	26978.017	42.843	< 0.001
Angled * Group	12441.9	2	6220.95	9.879	< 0.001
Error	34003.3	54	629.691		

The pull-out strength of the 15° angled groups was determined to be higher than that of the 30° angled groups. ($p < 0.001$)

In the control, holed, and grooved samples, it was seen that the 15° angle samples showed a statistically significantly higher retention capability compared to the 30° angle samples ($p < 0.001$).

The mean pull-out strength of the control group was found to be lower than that of both the hole and groove subgroups of the 15° angled group ($p < 0.016$ *Bonferroni correction*). The mean pull-out strength of the hole subgroup was found to be lower than that of the groove subgroup in the 15° angled group ($p < 0.016$ *Bonferroni correction*) (**Table III**).

Table III. Multiple Comparisons of Force According to Groups

	15 °			30 °			Overall		
Groups	Mean Diff.	Std.Error	p	Mean Diff.	Std.Error	p	Mean Diff.	Std.Error	p
Control vs. Hole	-57.6	11.2	**<0.001**	-14.4	11.2	0.205	-36.0	7.935	**<0.001**
Control vs. Groove	-108.4	11.2	**<0.001**	-38.5	11.2	**0.001**	-73.45	7.935	**<0.001**
Hole vs. Groove	-50.8	11.2	**<0.001**	-24.1	11.2	0.036	-37.45	7.935	**<0.001**

The mean pull-out strength of the control group was found to be lower than that of the groove subgroup of the 30° angled group ($p < 0.016$ Bonferroni correction).

Overall, the mean pull-out strength of the control group was found to be lower than that of both the hole and groove subgroups, and the mean pull-out strength of the hole subgroups was lower than that of the groove subgroups ($p < 0.016$ Bonferroni correction for all).

Discussion

In clinical practice, angled abutments are used to obtain the correct entry route or modifications are made to standardized abutments. However, these applications affect the retention of the crown. Târtea DA et al. reported that custom abutments may help reducing the angulation of the abutment, decreasing the risk of unscrewing or fracturing the dental screw and increasing the retention of the restorations.[25]

In previous studies, different angle values have been used to simulate and compare the effect on retention of the convergence angle used.[15,16,26,27]. In a review by Tiu et al,[28] it was reported that the mesiodistal angles used varied between 7.1° and 37.2°, and the buccolingual angles between 7.4° and 35.7°. To determine the effect of this variable in the current study, 15° was selected as the mean value and 30° as the high value.

An additional interproximal groove and box can be used to increase the forms of resistance of preparations with an excessive taper angled crown.[7] The importance of groove placement has been emphasized to ensure a form of resistance in the tooth preparation.[29-31] In a study by Roudsari et al.[30] it was reported that a group applied with a 22° angle in the cervical region had the highest retention capability, followed by the proximal grooved group, and the 22° angled group had the lowest the lowest score. Lewinstein et al.[18] investigated the effect of different numbers of environmental groove on the retention capability of implant-supported restorations, and the retention capability was reported to be increased both in the NE provisional cement group and the zinc phosphate cement group.

In many studies, the effects of lingual slot,[26] surface treatments,[31] wall modifications,[22] interproximal or buccolingual grooves,[8] and occlusal isthmuses[8] have been investigated on retention capabilities. In addition, Wadhwani et al,[32] examined the effect on retention of screw access channel modification, and showed that the addition of a hole to the abutment increased retention.

The results of the current study were significant in that the environmental grooves and holes added to the abutments were determined to significantly increase the retention capability of both angle groups. Moreover, it was seen that the retention capability was significantly higher in the environmentally grooved groups compared to the holed groups.

The modifications applied to the abutments can be made manually or with CNC milling machines. In this study, all the modifications applied to the implant abutments were made using a CNC milling machine since it achieves better sensitivity and enables working at the same standard on all samples.[33]

The preparation method of metal infrastructures on abutments is important in terms of retention capability. Previous studies have investigated the compatibility with the abutment of crowns made with casting metal and laser sintering methods. Copings made with the laser sintering method have been determined to have better compatibility compared to copings made with the casting method.[21,22,34]

In studies of the abutment retention capability of implant supported restorations, provisional cement has generally been used.[21,22,35]

In the current study, NE provisional cements were used since they are less soluble in intraoral fluids and better maintain their retention capabilities.

To simulate the oral environment in in-vitro studies, ageing procedures such as immersion in water and thermal cycle procedure are used to measure cement resistance. Although there are studies in literature which have not applied the thermocycle procedure, there are also studies which have used different cycles.[13,18,23,36] As thermocycling was not applied as a variable in the current study, it was thought that it would not affect the results and it was determined as a standard protocol.

In the literature, it can be seen that the pull out test has been applied to evaluate the retention capability of single crowns supported with implants.[16,18,21,36,37] In addition, the resistance test can be applied to evaluate clinical situations where force occurs at 45°.8 However, these tests have been applied on molar teeth with a broad occlusal surface and with modifications formed on the occlusal surfaces of copings. As the copings used in this study did not have a sufficient surface area, the pull out test was applied in accordance with other studies.

A limitation of this study was the type of pull out force used. Dynamic intra-oral forces are different from the regular static forces applied by the test machine and cemented restorations are almost never pulled out vertically. Therefore, further studies are required to investigate this matter in more detail. Manual mixing of the cement may affect retention, and it is recommended that automatically mixed types are used if possible. Other cement types should be examined in respect of storage conditions, heat cycle and chewing simulation.

Conclusion

This study showed that when the use of natural teeth is not possible, simple changes to increase retention can be made in implants. Within the limitations of this experimental study, it can be said that minor changes such as a hole and groove, which can be applied to implant abutments to prevent a decrease in retention capability depending on the angle application clinically specified in single crowns, can increase retention capability.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu makale, sempozyum ya da kongrede sunulan bir tebliğin içeriği geliştirilerek ve kısmen değiştirilerek üretilmemiştir.

Bu çalışma, yüksek lisans ya da doktora tezi esas alınarak hazırlanmıştır.

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

This article is not the version of a presentation.

This study was prepared on the basis of a master's or doctoral thesis.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

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Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: HÇA(%60), NY(%40)
Veri Toplanması | Data Acquisition: HÇA(%90), NY(%10)
Veri Analizi | Data Analysis: HÇA (%100)
Makalenin Yazımı | Writing up: HÇA(%70), NY(%30)
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