



## EFFECT OF IRRIGATION SOLUTION TEMPERATURE ON THE OSSEOINTEGRATION OF DENTAL IMPLANTS

### ABSTRACT

**Objectives:** Thermal trauma during implant surgery limits the proper healing process. The aim of the study was to investigate the effect of different irrigation temperatures during implant surgery on the osseointegration of dental implants.

**Materials and Methods:** Eight adult male New Zealand white rabbits were used in this study. Total of 32 implants were inserted in each tibia of each rabbit's rear legs. Rabbits were randomly divided according to different irrigation procedures applied (37°C, 24°C, 10°C, and 1°C). Resonance frequency analysis (RFA) was performed following to implant surgery, 1th week, 2nd week, 3rd week, and 1th month. In addition, removal torque values (RTVs) were measured from sacrificed tibias at the end of 30 days.

**Results:** No significant difference in implant stability quotient (ISQ) was detected between groups from the first measurement to 5th measurement. However, there was a statistically significant difference in RTVs between 1°C and 37°C, and 1°C and 10°C (p=0.024 and p=0.013, respectively).

**Conclusions:** Different irrigation temperatures during implant surgery were not effective on the primary and secondary stability values of dental implants in rabbit models.

**Key Words:** Dental implant, osseointegration, trauma, rabbit model.

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## **INTRODUCTION**

Osseointegration is a key factor for dental implant survival and success. To establish an optimal osseointegration, atraumatic surgery is a crucial determinant.<sup>1</sup> Gentle drilling and preservation of healthy tissues are essential prerequisites for atraumatic surgery.<sup>2</sup> During implant bed preparations not only mechanical damage but also thermal trauma occurs.<sup>3,4</sup> Thermal trauma damages the tissue and limits the proper healing process which is essential for implant survival and success.<sup>5</sup>

Temperature ranging from 47°C to 50°C up to 1 minute during implant bed preparation were found to upper threshold to avoid thermal necrosis.<sup>6</sup> Thermal trauma effects both organic and inorganic structures of surrounding surgical area. It leads to inactivation of enzymes and proteins which are required to optimal healing.<sup>7</sup> According to a study, dislocation of hydroxyapatite mineral structure and microscopic bone deformation also induced by thermal trauma<sup>8</sup>, in clinical point of view this may affect primary stability of dental implants and risk of early failure rates increase dramatically.<sup>8,9</sup>

To overcome the unwanted effects of thermal trauma many *in-vitro* and *in-vivo* studies evaluated the potential indicator of thermal trauma.<sup>4,10-24</sup> They concluded multiple factors associated with the condition e.g: drill speed<sup>10,11</sup>, drill material<sup>12</sup>, drilling technique<sup>13</sup>, drill diameter<sup>14</sup>, drill configuration<sup>4</sup>, bone type<sup>15</sup>, irrigation method<sup>16,17-20</sup>, irrigation solution volume<sup>21,22</sup>, and surgical technique.<sup>23</sup> Irrigation solution temperature is also one of the crucial indicator which effect thermal trauma.<sup>24</sup> It has been concluded that cold irrigation solution can minimize temperature elevation at the surface<sup>11</sup> and according to an *in-vitro* study, external irrigation at room temperature can provide sufficient cooling during implant bed preparation<sup>24</sup>, however to the best of author's knowledge data is available regarding impact of irrigation solution temperature on osseointegration. In consideration of these premises, the aim of the study was to investigate the effect of different irrigation solution temperatures, during implant bed preparation, on the osseointegration of dental implants. The hypothesis of lower temperature of irrigation solution would improve the osseointegration was tested.

## **MATERIALS AND METHODS**

### ***Study material and design***

The study protocol was approved by local ethical committee of the Animal Ethics Commission of Cumhuriyet University (protocol number: 65202830-050.04.04-31). Eight, healthy, male, white rabbits (*Oryctolagus cuniculus*, New Zealand) with body weight 3 kg were included the study. Rabbits were housed in standard room conditions (22-24°C, 12/12 light/dark cycle, %55-70 humidity, 1 atm) and each rabbit was housed in separate cages. The conditions of animals were monitored every day. Rabbits were placed in cages two weeks ago to adopt their environmental conditions.

Rabbits were randomly divided according to different irrigation solution temperature applied (37°C, 24°C, 10°C, and 1°C).

### ***Surgical procedure***

Surgical procedures were applied under general anesthesia. The animals were sedated intramuscularly with 10mg/kg xylazine (Rompun 2%, Bayer, İstanbul, Turkey) and 90 mg/kg Ketamin HCl (Ketalar, Eczacıbaşı-Warner Lambert, İstanbul, Turkey). After anesthesia was obtained, proximal tibia area was shaved unilaterally and local anesthetic articaine HCl (Ultraca DS Fort Aventis Pharma, İstanbul, Turkey), intravenous prophylactic antibiotics (50 mg/kg cefazolin) and analgesic (1 mg/kg Tramadol HCl) were injected then, surgical area was covered by sterile drapes and antiseptic solution was applied. (Povidone-iodine, Batticon, Genesis, İstanbul, Turkey). 2 cm skin incision extending distally from the medial of the proximal metaphysis of the tibia was followed by the dissection of soft tissue and detachment of the periosteum was performed in the left and right tibia of every rabbit. At least 6 mm horizontal distance were measured on each osteotomy area. Osteotomies were performed in same room conditions (temperature: 23-24°C, relative humidity: 50±5%, and no direct ventilation.) with different irrigation solution temperatures. (37°C, 24°C, 10°C, and 1°C). The irrigation solution temperatures were measured just before the procedure by liquid thermometer. (HB Durac, SP-Scienceware, NJ, USA). For each different irrigation solution temperature, the same surgical and stability

measurements stages were applied. The osteotomies were performed according to manufacturer recommendations. Each animal was received 3.5×7 mm (Anyone, MegaGen Implant, Daegu, Korea) implants. Briefly TiN coated initial (Ø1.8) and shaping drills (Ø2.8, Ø3.3) were applied, shaping drills were 0.59mm longer than the fixture, so total drill depth was 7.59mm. Drilling time for each implant was approximately 5 minutes and multiple drilling steps were applied at 1500 rpm. Each different temperatures of irrigation solution were applied externally with using a physiodispenser pump (MEG-ENGINE, MegaGen Implant, Daegu, Korea). Each osteotomy was performed by the same experienced surgeon (OV) for operative standardization. Implants were inserted into preparation cavity with ratchet. In order to carry out the stability measurements, the gingival formers were mounted on the implants. Total of 4 implants were applied in each animals (2 left, 2 right) overall 32 osteotomies and implants were applied. Figure 1 illustrates the surgical steps.



**Figure 1:** Surgical steps of the study. (A) Mucoperiosteal flap elevation and implant bed preparation. (B) Insertion of dental implants.

The periosteum, fascia and skin were sutured with Vicryl resorbable sutures (Ethicon, Somerville, NJ, USA). Post-operatively animals were administered 50 mg/kg Cephaxon IM and 4 mg/kg Rimadyl 20 cc flakon for 3 days subcutaneously, besides wound areas were irrigated with Rifamicin SV (Rifeten, Ulagay İlaç Sanayi, Istanbul, Turkey).

### **Stability measurements**

Resonance frequency analysis (RFA) was performed on the implants to detect the degree of primary osseointegration by using the Mega ISQ device (MegaGen Implant, Korea). In brief, a connector so called Smartpeg was screwed into implants, taking care to ensure that no significant torque force was applied to the implants and then implant stability quotient (ISQ) values were

measured. For each implant, the probe of the ISQ machine was held stable at a distance of approximately 2 mm from the Mega ISQ device, Figure 2 illustrates the related step.



**Figure 2:** The measurement of ISQ value with Mega ISQ® device.

Two measurements were conducted on the mesial and distal parts of the device, and mean ISQs were recorded. 5 measurements (following to implant surgery, 1th week, 2nd week, 3rd week, and 1th month) were carried out. In post operative 1st month, animals were sacrificed with an intramuscularly administered 200 mg/kg i.p. sodium pentobarbital.

Prior to removal torque test (RTT), resected tibia fragments were embedded into type IV dental stone (Figure 3) (Moldano, Heraeus Kulzer GmbH, Hanau, Germany).



**Figure 3:** Resected tibia fragments were embedded into type IV dental stone, prior to RTV.

RTT was then performed on the implants. The blocks were stabilized by the second researcher, and a digital torque meter (IMADA, Northbrook, IL, USA) was positioned in the direction of the implant axis which presented in Figure 4.



**Figure 4:** Illustration of RTV measurements which performed by digital torque meter.

The removal torque values (RTVs) were measured until the implant rotated inside the bone tissue, completely rupturing the bone-implant interface. These RTVs were then recorded for statistical analysis.

**Statistical Analysis**

The present methodology was reviewed by an independent statistician. The mean and standard deviations and statistical analyzes of the data were calculated using SPSS 14.0 (SPSS Inc., Chicago, USA) program. Normality of data distribution was confirmed by using Q-Q plot test. The data were analyzed with two-way ANOVA and post hoc Tukey-Kramer multiple comparisons tests ( $\alpha=0.05$ ).

**RESULTS**

The healing was uneventfull and any implant or animal loss was not observed until the sacrifice. The RFA and RTV values, obtained from study groups, presented in Table1.

**Table 1.** Mean RFA (ISQ) and RTV (N/cm) Values Obtained from Study Groups.

	Groups	Mean	SD	N
RFA (ISQ)	37°C	69.37	Ara.59	8
	24°C	70.25	13.27	8
	10°C	64	Kas.78	8
	1°C	69.12	Eyl.78	8
	Total	68.18	Kas.61	32
RTV (N/cm)	37°C <sup>b</sup>	22.25	14.42	8
	24°C	26.91	Haz.76	8
	10°C <sup>a</sup>	21.Şub	Ağu.18	8
	1°C <sup>a,b</sup>	37.98	10.Haz	8
	Total	27.Nis	Kas.89	32

\*Lower case letters represent significant differences in rows.RFA: Resonance Frequency Analyse, ISQ: Implant Stability Quatient, RTV: Reverse Torque Value, SD: Standard Deviation

The samples from irrigation solution temperature 24°C group had the highest mean ISQ values (70.25), while the samples from 10°C irrigation solution temperature group had the lowest mean ISQ scores (64.00). However no statistically significant difference in mean ISQ values were detected between the sample groups from first to 5th measurement. ( $p>0.05$ )

The highest mean RTV values were measured from the samples in 1°C irrigation solution temperature group (37.98 N/cm) while the samples in 10°C irrigation solution temperature group had the lowest mean RTV scores (21.02 N/cm). This difference between the groups was statistically significant ( $p=0.013$ ), also another statistically significant difference presented between the

samples from groups of 1°C and 37°C irrigation solution temperature, in mean RTV values ( $p=0.024$ ).

## DISCUSSION

To best of author's knowledge this is the first study which the effect of irrigation solution temperature on primary and secondary dental implant stability values was tested. The present study indicate that different irrigation solution temperatures during implant surgery did not have a significant effect on RFA values of dental implants however, implants that applied with the lowest irrigation solution temperature had the highest RTV scores. The null hypothesis of the study was not confirmed according to present findings. Osseointegration is a complex process and many determinant have crucial role. In point of thermal trauma heat generation during drilling steps cannot be ignored and may affect the present findings, future studied needed which investigate both determinants.

Rabbit models are convenient for skeletal research studies, and have been extensively used to test the bone reaction to implant biomaterials.<sup>25</sup> Rabbit models provide a cost-effective animal model with maintenance and housing are simple and recovers well postoperatively. The literature reports similarities between rabbit and human bone composition and cortical tibia bone with similarities to the mandible.<sup>26</sup> Disadvantages also exist with rabbit models. One of them is the sample size, larger sample size is not possible due to ethical reasons which is the major limitation of the present study. The term of osseointegration always has been the first place in successful implant rehabilitation. The osseointegration may be evaluated in several ways. In the present study RFA and RTV were utilized. RFA is a non-invasive method for measuring implant stability.<sup>27</sup> RTV is an invasive, objective method with easy to administer. It has been said to be beneficial to identify of secondary stability, quality of bone-implant contact especially in the second stage of implant surgery.<sup>28</sup> In the present study, RTV was applied after 1 month of dental implant surgery, that mimics the term of second surgery of humans.<sup>29</sup>

Thermal trauma may cause osseonecrosis and directly effects the osseointegration process.<sup>30</sup>

More heat is generated in the superficial part of implant bed preparation area, owing to compact and spongy components of bone.<sup>31</sup> Therefore cooling the area and keep the temperature below critical threshold is essential to avoid thermal necrosis.<sup>6</sup> Cooling the implant bed preparation area with an irrigation solution is the most common technique to overcome detrimental effects of thermal trauma and the saline is the first choice as an irrigation solution.<sup>32</sup> It has been widely accepted that external cooling systems effectively prevent excessive heat generation which had been used in present study. Different determinants may be contribute in the effect of irrigation solution on thermal trauma.<sup>16-22,24</sup> However there is limited information in literature, regarding the impact of irrigation solution temperature on current issue.<sup>24,33</sup> An interesting study pointed out the effect of irrigation solution temperature on heat control.<sup>24</sup> In that *in-vitro* study, the authors measured the bone temperature without irrigation, and with irrigation using saline at 25° and 10°C and concluded that lower temperature saline was more effective in cooling the bone.<sup>24</sup> The findings of the present study were in concurrence with Sener *et al.*<sup>24</sup>, irrigation solutions with different temperatures that included the study were able to cool the bone adequately so the proper osseointegration was achieved. Regardless of the proper osseointegration and ISQ values, implants performed by 1°C irrigation solution temperature had statistically higher RTV scores, which demonstrate secondary stability values, compared with the implants applied with 10°C and 37°C irrigation solution temperature. Even though the cooling was enough to establish osseointegration, there may be an optimum temperature range to achieve better RTV scores. Biological variables of osseointegration may be the potential explanation on this issue. Osteoblast, alkaline phosphatase (ALP) activity, osteogenic and angiogenic markers have an undeniable effects to establish an osseointegration.<sup>34</sup> To avoid the excessive thermal increase which is warranted for proper dental implant healing 47°C reported as a threshold for osseonecrosis<sup>6</sup>, however some reports noted that limited hyperthermia during implant surgeries which below the threshold of 47°C enabled an optimal field which promotes the

osseogenesis by increasing human mesenchymal stem cell (hMSC) mineralization, ALP activity and led to induction of angiogenesis.<sup>35</sup> The results of the present study support these findings.

In present study, dental implants which were applied had surfacetreated based on SLA technique with nano layer of Ca incorporated. Implant surface also is an important key factor for proper osseointegration<sup>36</sup>, and it is still unclear how surface characteristic would response thermal trauma, future studies which biochemical and mechanical properties of osseointegration subjected together with larger sample size included to identify optimal thermal range during implant surgery and to achieve better primary and secondary stability scores in healing and maintenance phases for the long term success of dental implant treatment are warranted.

## CONCLUSIONS

Within the limitation of the study, in rabbit models, different irrigation solution temperatures during implant surgery did not have a direct effect on the primary and secondary stability values of dental implants.

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## CONFLICT OF INTEREST STATEMENT

No potential conflict of interest relevant to this article was reported.

### *İrrigasyon Solüsyon Sıcaklıklarının Dental*

### *İmplantların Osseointegrasyonu Üzerine Olan Etkisi* **ÖZ**

**Amaç:** İmplant cerrahisi sırasındaki termal travma, iyileşme sürecini sınırlar. Bu çalışmanın amacı, implant cerrahisi sırasında kullanılan farklı sıcaklıktaki irrigasyon solüsyonlarının, dental implantların osseointegrasyonu üzerine olan etkisini araştırmaktır.

**Gereç ve Yöntemler:** Bu çalışmada sekiz yetişkin erkek Yeni Zelanda beyaz tavşanı kullanıldı. Tavşanların tibialarına toplam 32 implant yerleştirildi. Tavşanlar,

uygulanan farklı sıcaklıktaki irrigasyon solüsyonlarına göre (37 °C, 24 °C, 10 °C ve 1 °C) rastgele gruplara ayrıldı. Rezonans frekans analizi (RFA) implant cerrahi uygulamasından hemen sonra ve cerrahiye takip eden; 1. hafta, 2. hafta, 3. hafta ve 1. ayın sonunda yapıldı. İmplant cerrahisinden 30 gün sonra, sakrifiye edilen tavşanların tibialarına yerleştirilen implantların, çıkarma torqu değerleri (RTV'ler) ölçüldü ve uygun istatistiksel yöntemlerle değerlendirme yapıldı.

**Bulgular:** Çalışmada uygulanan implantların, implant stabilite katsayısında (ISQ) İlk ölçümden 5. ölçüme kadar gruplar arasında anlamlı bir fark bulunmadı. Bununla birlikte, RTV'lerde 1 °C ile 37 °C ve 1 °C ile 10 °C arasında istatistiksel olarak anlamlı bir fark tespit edildi. ( $p=0,024$  ve  $p=0,013$ , sırasıyla). **Sonuçlar:** Tavşan modellerinde, implant cerrahisi sırasında kullanılan farklı sıcaklıktaki irrigasyon solüsyonları, dental implantların primer ve sekonder stabilite değerlerini etkilememiştir. **Anahtar Kelimeler:** Dental implant, osseointegrasyon, travma, tavşan modeli.

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