Impact of mineral oil lubricant from rotary instrument on osseointegration and surface contamination of dental implants: An in vivo rabbit tibia study

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Research Article

Keywords: Dental implant, early failure, lubricant, osseointegration, surface contamination

Posted Date: April 2nd, 2024

DOI: https://doi.org/10.21203/rs.3.rs-4172849/v1

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Additional Declarations: No competing interests reported.
Abstract

Background: The success of osseointegration in dental implants is largely influenced by the surface characteristics, including texture, chemistry, and cleanliness. This study investigates the effect of a rotary instrument mineral oil lubricant on the osseointegration of dental implants in the rabbit tibia, addressing concerns about lubricant-induced surface contamination from dental handpieces.

Methods: We used six New Zealand rabbits and inserted two implants per tibia in each animal for a total of 24 implants. Each group was further divided into two rabbits: the first group was placed with no lubricant used in the fixture and hand-piece (control); the second group was placed in the fixture after the recommended management of the handpiece; and the third group was placed in a lubricant-soaked fixture. Two weeks and four weeks later, the rabbits were euthanized. The removal torque and bone-implant contact were measured by histomorphometric examination.

Results: Although an inverse relationship was observed between the fixture contamination severity and removal torque, the correlation was not statistically significant. In contrast, a clear decrease in bone-implant contact was noted with increased levels of contamination, with this effect being statistically significant at the 4-week.

Conclusion: Even if a handpiece is used for a short duration, difficulties in controlling lubricant expulsion can pose problems for bone osseointegration of the implant. Therefore, a thorough expulsion process is necessary after oiling, and during implant drilling and placement, meticulous cleaning and suction should be employed to minimize the amount of residual oil on the implant.

Background

Implant-supported dental prostheses are common treatment options for fully or partially edentulous patients. Implants form structural and functional bonds with living bone through osseointegration, attributed to the excellent biocompatibility of titanium [1, 2].

A growing body of evidence suggests that implant surface topography and chemistry significantly influence osseointegration by affecting protein signaling and cell migration or differentiation [3, 4]. Research aimed at enhancing osseointegration has focused on implant design and surface texture, indicating that modifications in roughness, morphology, and hydrophilicity, as well as factors such as surface topography, chemical purity, oxide layer thickness and composition, surface cleanliness, and the presence of metallic and non-metallic compounds, are crucial for promoting cell adhesion, faster bone bonding, and the overall success of implant osseointegration [5].

Therefore, the implant surface must function as a biologically inert structure for bone osseointegration [6–9], and its physical and chemical properties are crucial [10]. Consequently, discussions have arisen regarding implant failures due to contamination of the implant surface during insertion [11–13]. The
lubricant used in dental handpieces for implant placement has been suggested to contaminate implants, potentially leading to implant failure.

Cleaning and disinfecting dental handpieces are challenging because of their complex structure, and they are always at risk of cross-infection. Therefore, according to the manufacturer’s instructions, a typical procedure involves the use of a spray-type lubricant. This lubricant was injected into the handpiece, followed by idling for a few minutes to remove excess lubricant. Some studies have indicated that inaccuracies in this process can leave lubricant residues that contaminate the implant surface, alter its wettability, and potentially interfere with cellular adhesion, differentiation, and maturation [14, 15].

However, limited research has been conducted on the impact of lubricants used for cleaning handpieces on the early failure of dental implants. Therefore, this study aimed to investigate the effects of lubricant residues on implant prognosis in rabbits.

Methods

This experiment was approved by the Osstem Implant Animal Experiment Ethics Committee (approval number: OST-IACUC-18-03) and carried out in accordance with the ARRIVE protocol for conducting preclinical in vivo studies. Six male New Zealand White rabbits (3.0-3.2 kg and 4–5 months of age) were used in the present study. Through the experimental period, the rabbits were individually housed in an environment maintained at a temperature of 22–24°C and provided with standardized feed. The light cycle was regulated and consisted of 12 h of light and 12 h of darkness. The implants used in the experiment were TS III SA (Sand blasted with alumina and Acid etched surface) implants (Osstem implant Co., Ltd., Korea), measuring 8.5 mm in length and 3.5 mm in diameter. In this study, we used KaVo Spray (KaVo Dental GmbH., Biberach-Riss, Germany), as the lubricant for handpiece. This widely used lubricant is composed of iso-paraffin oil and propelled by a mixture of propane and butane.

Surgical Procedure

Before surgery, two legs of each rabbit, the area of implant placement were shaved and disinfected with a mixture of betadine and 70% ethanol. The experiment involved implants placed in 12 tibial sites, using a total of 24 implants. They were divided into three groups, and for each tibial site, one group was randomly selected for implantation. (Fig. 1)

The first group served as a control, using handpieces and implants that had not undergone any oiling or oil discharge processes. The second group used handpieces that underwent oiling and oil discharge processes. To achieve as uniform a condition as possible, they followed the manufacturer’s instructions by applying KaVo Spray for 1–2 seconds. This process involved spraying 10 times until no impurities were emitted, followed by a 30-second idle run to remove any residual lubricant. Subsequently, the external surface of the handpiece was thoroughly wiped to eliminate excess oil before applying the drill. The third group used implants immersed in a lubricant, employing a handpiece treated in the same manner as in the second group. The residual amount of lubricant in each group was assessed based on
the results obtained from previous preliminary studies, and special care was taken to prevent additional contamination of the implants throughout the experimental process.

The animals were anesthetized with an intramuscular injection of 0.2 mL/kg tiletamine/zolazepam (Zoletil, Virbac Laboratories, France) and 10 mg/kg xylazine (Rompun, Bayer, Korea). This was followed by local anesthesia with 1.8 mL of 2% lidocaine containing epinephrine (1:100,000) (Huons Co. Ltd., Seoul, Korea) administered into the tibial metaphysis.

Under aseptic conditions, an incision was made on the skin over the rabbit tibia, and flaps in the fascia and periosteum were created to expose the proximal tibia. Subsequently, two implants were placed in the anteromedial aspect of the tibia, according to the manufacturer’s protocol. Using a 123 drill kit (Osstem Implant Co., Ltd., Korea) under profuse saline irrigation, holes were formed at 3 mm intervals in the central portion of each tibia using a 2.2 mm guide drill, followed by bone preparation with a 3.5 mm taper drill. Subsequently, the implants were placed in the tibia up to bone level.

After surgery, the periosteum and fascia were sutured with 4 – 0 Vicryl (Ethicon, Somerville, NJ, USA), and the skin was closed with 4 – 0 blue nylon (Ailee Co., Ltd., Busan, Korea). For infection prevention and pain control, Baytril (enrooxacin, Bayer Korea Ltd, Seoul, Korea) at 0.5 ml/10 kg and Metacam (meloxicam, Boehringer Ingelheim, Barcelona, Spain) at 0.4 ml/10 kg were administered intramuscularly for 3 days. After the procedure, the rabbits were monitored daily to check for complications such as suture site dehiscence, infection, and limping.

At 2 and 4 weeks postoperatively, three rabbits each underwent sedation and anesthesia using the same protocol as during surgery, followed by euthanasia using a CO₂ chamber. The fascia and periosteum were removed, and the tibiae were excised and fixed in 10% buffered formalin for two weeks.

**Histotechnical procedures and histomorphometric analysis**

All the specimens were prepared as non-decalcified samples. Tibiae fixed for two weeks were cut into suitable sizes for tissue sampling (thickness of 2–3 mm) and subjected to tissue preprocessing. The tissue samples were gradually dehydrated from 70% alcohol to 80%, 90%, and finally 100%. They were then infiltrated with a mixture of alcohol and methyl methacrylate (Technovit VLC 7200, KULZER, Germany), increasing the concentration ratio from 1:3 to 3:1, and ultimately infiltrated with pure Methyl methacrylate (Technovit VLC 7200, KULZER, Germany) for a week under vacuum and agitation. The embedded specimens were cured overnight in a UV curing system (KULZER EXAKT 520, Germany) and cut using an EXAKT diamond cutter (KULZER EXAKT 300, Germany). All samples were initially cut to a thickness of 400µm using a low-speed diamond wheel saw (Exakt technologies) and finally polished to 30µm thickness, followed by Hematoxylin & Eosin staining.

The total bone-to-implant contact (BIC) was calculated as a percentage of the implant surface length covered by both existing and newly formed bone. Portions of the implant protruding beyond the cortical layer were excluded from analysis. Histological analysis was conducted using an optical microscope (Olympus, Tokyo, Japan), and images were captured at 12.5 × magnification to observe the entire
implant surface, which was then calculated images at 100x magnification using ImageJ software (version 1.47; National Institutes of Health, Bethesda, MD).

**Removal torque analysis**

All implants were subjected to histological evaluation, followed by the measurement of the removal torque using a digital torque gauge (MGT12, Mark-10 Co. Temecula, USA). The device was mounted on the tibial bone and connected to the implant, and reverse torque rotation was applied to remove the implant; the removal torque values were recorded in Ncm units.

**Statistical analysis**

Given the limited sample size, a separate nonparametric analysis was performed to evaluate parameter variations between the control and test groups. The Kruskal-Wallis test was used to investigate the impact of contamination levels on the three different implant surfaces by testing the differences in removal torque values and BIC ratios between the control and experimental groups. Notably, significant results in BIC ratios from the Kruskal-Wallis test led to additional validation using the Mann-Whitney U test. All P values under .05 were regarded as statistically significant. The analysis of all data was conducted using Minitab® 18.1 software (Minitab Inc., United States).

**Results**

**Bone-to-Implant Contact**

At 2 weeks, the average BIC for the control group was measured to be 55.6 N (SD 7.88); the second group (25 ppm) was 56.35 N (SD 5.66), 101.3% of the control group; and the third group (40,000 ppm) was 49.4 N (SD 9.69), 88.9% of the control group. At week 4, the average BIC for the control group measured 55.6 N (SD 6.46); the second group (25 ppm) measured 48.7 N (SD 2.28), representing 87.6% of the control group, while the third group (40,000 ppm) decreased to 31.3 N (SD 7.21), representing 56.3% of the control group, a statistically significant difference (p < 0.05). (Fig. 2)

Notably, at the 4-week time point, the second group showed multiple inflammatory cells and hemorrhage in some tissues, whereas the third group showed hemorrhage and necrosis of the bone tissue in some tissues (Fig. 3–4).

**Removal torque**

In the control group, the average removal torque was measured at 61.53N (standard deviation, 6.18) at 2 weeks and 78.6N (standard deviation, 8.50) at 4 weeks. In the second group, it was measured at 62.5N (standard deviation, 7.27) at 2 weeks and 76.8N (standard deviation, 6.38) at 4 weeks. In the third group, it was 57.55N (standard deviation 10.78) at 2 weeks and 73.58N (standard deviation 10.03) at 4 weeks, indicating a somewhat lower removal torque trend. However, these differences were not considered statistically significant. The ratios for both groups compared to the control group are shown in Fig. 5.
Discussion

Despite predictable clinical outcomes and high patient satisfaction, dental implant failures still occur, posing challenges for both patients and dental surgeons [16, 17]. Implant failure typically leads to complex retreatment, which adds physiological and psychological burdens to patients[18]. Early failures of dental implants are often attributed to a failure of bony healing around the implant and subsequent failure of osseointegration, potentially due to local or systemic factors[19, 20]. Even with well-documented dental implant systems, adequate clinical experience, measures to avoid cross-infection, and suitable soft tissues, early failure can occur after insertion. Early failure rates have been reported to range from 0.7–3.8%[19, 21–24]. Risk factors for early implant failure vary among studies and include patient-related factors, such as age, sex, smoking, periodontal conditions, site-related factors, bone density, bone augmentation procedures, implant-related factors (system and length), and surgeon-related factors (expertise of the surgeon [25–31].

Moreover, the surface features of the implants influence the healing of the surrounding bone. According to a previous study, the bone-implant interface is positively correlated with the increasing roughness of the implant surface[32]. Wettability and chemical composition, both of which influence the first phases of cell-material interactions[33], are directly affected by surface topography[33–35]. The high hydrophilicity of the implant surface enhances the attachment of fibroblasts and the differentiation of osteogenic cells, which play crucial roles in early osseointegration [34]. This may also influence the stability and success rates of implants in clinical practice. In a practical experiment conducted using rabbit tibias, hydrophilic implants achieved osseointegration (bone-to-implant contact, BIC) 1.5 times higher than hydrophobic implants after 28 days of healing[36]. Therefore, in clinical applications, it is vital to preserve the unaltered titanium surface properties and characteristics at the surgical site. Therefore, various factors that can contaminate the surface, such as bacterial contamination[37], endotoxin adhesion[38–40], and other external contaminants [11, 13, 41] may pose a risk to osseointegration.

This study was guided by the hypothesis that lubricants containing oil-based and hydrophobic components may cause contamination during implant insertion, thereby affecting osseointegration. While the cortical bone resorption pattern remained inconspicuous, and we observed no significant alteration in the removal torque value, our findings in week 4 revealed something more concerning. When examining the tissues from the second and third groups, we detected signs of inflammation and necrotic bone tissue. These findings suggest that residual lubrication induces subacute toxicity, potentially resulting in bone loss.

Reviewing previously published papers, a study by Bloebaum, R D, et al. in 2003 [42] involved dividing 40 New Zealand rabbits into four groups. In total, seven rabbits were administered Type I mineral oil, and three received 1 cc of normal saline. When injected into the paravertebral muscle, the synovial cavity of the knee joint, and cancellous bone of the lateral femoral condyle of the contralateral knee, inflammatory reactions were observed in the synovial cavity and periosteum, although there were no abnormalities in
the bone or bone trabeculae. Furthermore, according to Bonsignore et al. [11] in 2015, it was found that machine oil on the surface of implants suppresses the biomechanical measures of osseointegration and BIC. Conversely, a study by Arturo Sanchez-Perez et al. [43] in 2019 on five New Zealand rabbits implanted with 3.3 mm diameter and 8 mm length implants treated with resorbable blast media (RBM) planned a total of 20 implants. The rabbits were divided into a control group implanted with a handpiece that did not use a lubricant and an experimental group implanted with a handpiece that used a lubricant. The study found no significant differences in the total and cortical BIC between the two groups.

As previously noted, there is limited research on the effects of lubricants used to clean handpieces on implants. One study indicated that evidence on how contamination during implant surgery affects implant survival is insufficient [44], making it a debated issue.

This study had several limitations. First, we used a small number of rabbits, specifically their tibias, as experimental models. The healing rate in rabbits is two to three times faster than that in humans, and there is a significant difference in bone structure. Unlike human jaws, rabbit tibias contain a large amount of fatty marrow. Moreover, the removal torque (RT) in rabbits varies for up to one month after implant placement, with little change thereafter. Additionally, previous research has shown that oil can continue to drain from the hand-piece for at least 240 min [45], implying that the exact amount of lubricant applied to the implant surface remains uncertain, thus necessitating reliance on estimates based on preliminary experiments [46]. Moreover, the use of only one type of lubricant rather than a variety of lubricants is another limitation. Further research is required to address these limitations.

**Conclusions**

Even when the handpiece is used for a brief period, the inability to reduce lubricant emissions can lead to complications in the osseointegration of the implant. Therefore, a comprehensive oil discharge process after oiling is imperative. Moreover, during the drilling and placement of implants, it is crucial to minimize residual oil on the implant by meticulous cleaning and suction. This step is fundamental not only to avert contamination of the implant and prevent damage to its surface properties but also to ensure a favorable long-term prognosis.

**Abbreviations**

BIC - Bone-to-implant contact

SD - Standard deviation

RBM - Resorbable blast media

**Declarations**

Ethics approval and consent to participate
This experiment was approved by the Osstem Implant Animal Experiment Ethics Committee (approval number: OST-IACUC-18-03) and carried out in accordance with the ARRIVE protocol for conducting preclinical in vivo studies.

**Consent for publication**

Not applicable.

**Availability of data and material**

In some cases, authors did not generate or use any data to prepare their paper, or are unable to share their data (e.g. the data is confidential or they do not have necessary permissions). In other cases, research data is available upon request. To request the data, contact the corresponding author of the article.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

This research was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (HI22C1377)

**Authors' contributions**

Heon-Young Kim: Data curation, Formal analysis, Software, Visualization, Writing- Original draft preparation  
Il-Seok Jang, Ju-Dong Song: Investigation  
Sun-Jong Kim: Resources, Validation  
Jin-Woo Kim: Conceptualization, Methodology, Project administration, Writing- Review & Editing, Funding acquisition, Supervision

**Acknowledgements**

None.

**Authors' information (optional)**

**References**


Figures
Figure 1

Schematic diagram of experimental method.
Figure 2

BIC obtained using control and lubricated surfaces. There was a slight decrease in BIC for the lubricated surface group during the fourth week, while the third group exhibited a notable decrease at the same time point. (a) 2-week average total BIC, (b) 4-week average total BIC.
Figure 3

Representative microhistographs (overview at x12.5 and high magnification at x50 & x100) at 4 weeks in the second group. Inflammatory cells surrounding the implant fixture (A) and areas of bleeding (B) are observable.

Figure 4

Representative microhistographs (overview at x12.5 and high magnification at x50 & x100) at 4 weeks in the third group. Bleeding (upper row) and necrotic bone tissue (lower row) can be observed around the
Figure 5

Removal torque measurements. Although there was a slight decrease in torque values for the third group, this difference was not statistically significant. (a) 2-week average removal torque, (b) 4-week average removal torque.