Comparison of Delayed Implant Placement vs Immediate Implant Placement Using Resonance Frequency Analysis: A Pilot Study on Rabbits

Ashish T. Kunnekel, MDS[1]*
Mohit T. Dudani, MDS[2]
Chandrasekharan K. Nair[3]
E. M. Naidu[4]
G. Sivagami[5]

Ten identical implants were equally divided into 2 groups. In the immediate placement (control) group, implants were placed immediately following osteotomy preparation, and in the delayed placement (test) group, implants were placed 2 weeks following osteotomy preparation, in rabbit femurs. Implant stability quotient values for both groups were measured using resonance frequency analysis immediately following placement and at day 40. Results were statistically analyzed and indicate that delayed placement of implants leads to faster rates of osseointegration.

Key Words: delayed implant placement, resonance frequency analysis, bone activation

Introduction

Architecture and microenvironment around the implant are crucial determining factors in the healing process. Placement of implants elicits a sequence of healing events, including necrosis and subsequent resorption of traumatized bone around the implant body, concomitant with new bone formation.[1–8] Excessive trauma during surgery is considered an important cause of implant failure because thermal, vascular, and mechanical factors contribute to the formation of necrotic tissue, thereby affecting maturation at the bone-implant interface.[9–13] In an attempt to allow the bone to recover from surgical injury, thereby allowing implant placement into an environment more conducive to healing and development of osseointegration, delayed placement of implants was proposed.[14–16] The present study on rabbits compares the effects of delayed implant placement vs immediate implant placement following osteotomy preparation using resonance frequency analysis (RFA).

[1] Maulana Azad Institute of Dental Sciences, New Delhi, India.
[2] Singhad Dental College, Pune, Maharashtra, India.
[3] Department of Prosthodontics, AECS Maaruti College of Dental Sciences and Research Centre, Bangalore, India.
[4] Private Practice, Chennai, Tamil Nadu, India.
[5] Saveetha Dental College & Hospital, Chennai, Tamil Nadu, India.
**Corresponding author*, e-mail: drkunnekel@gmail.com.
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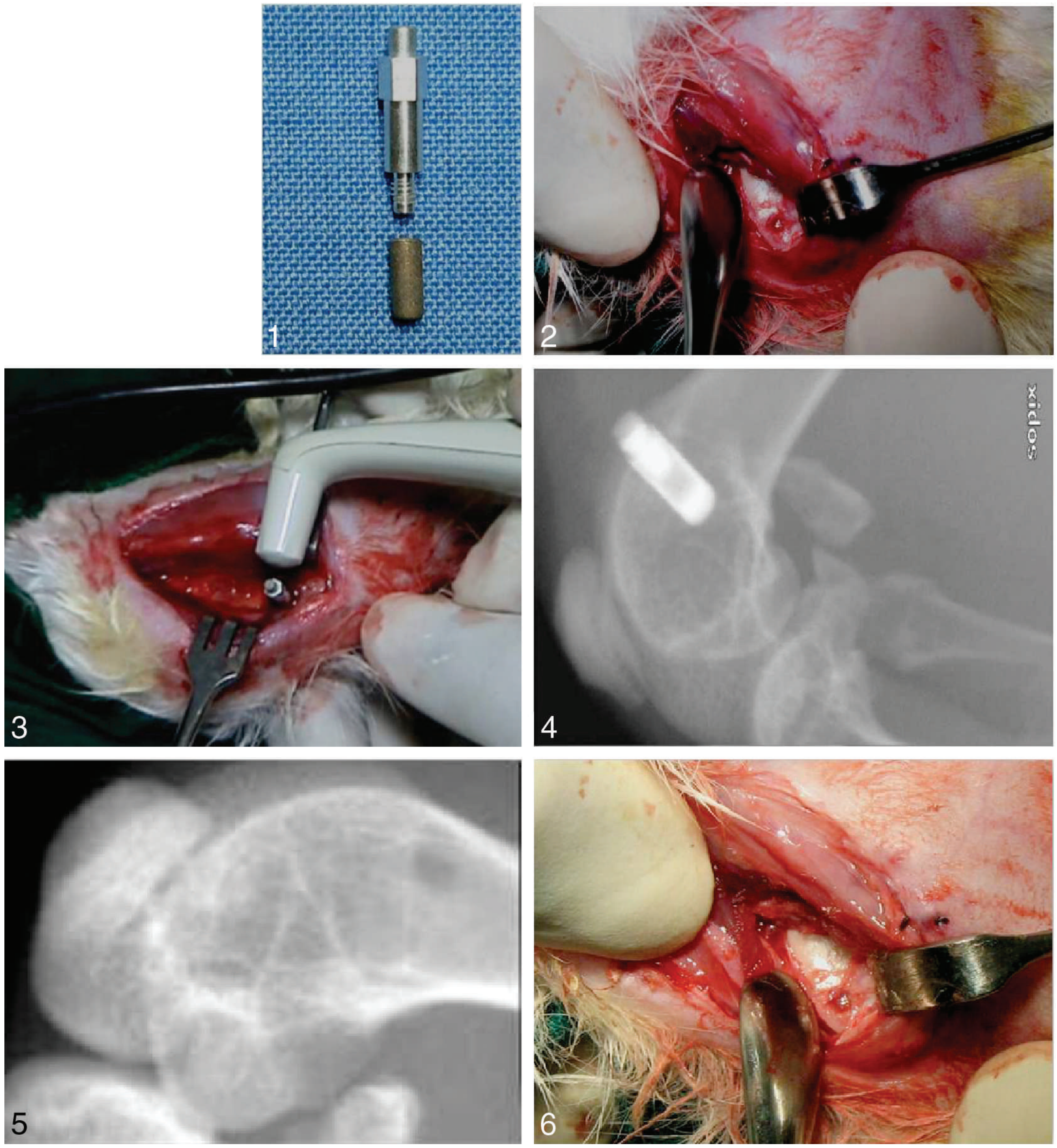
Materials and Methods

Ten indigenously fabricated, cylindrical, sandblasted implants with dimensions of 2.3 mm



Figures 1–6. Figure 1. Implant with Smartpeg. **Figure 2.** Preparation of control implant osteotomy. **Figure 3.** Placement of implant and measurement of implant stability quotient values. **Figure 4.** Radiovisiography of implant with cover screw. **Figure 5.** Radiovisiography of test implant osteotomy following preparation. **Figure 6.** Exposure of test implant osteotomy after 14 days.

diameter and length of 5.5 mm were used. An access channel was milled within the body of the implant to receive the Smartpeg (Osstell Mentor, Osstell Inc USA, Linthicum, Md) (Figure 1). The implants were equally divided into 2 groups, namely, the immediate placement (control) group and the delayed placement (test) group. Control implants were placed immediately following osteotomy preparation, whereas test implants were placed 2 weeks later.

Control implants were placed in the left and test implants were placed in the right distal femoral condyles, respectively, of 5 female New Zealand White rabbits. The rabbits had an average age of 10.5 months and weighed between 2.5 and 3.0 kg.

Each rabbit underwent a total of 4 surgeries designated as stages 1, 2, 3, and 4. Stage 1 surgery was performed at day 0 and consisted of placement of a control implant followed by measurement of implant stability quotient (ISQ) values for the same and osteotomy preparation for the test implant. Stage 2 surgeries were performed at day 14 and involved placement of the test implant followed by measurement of ISQ values for the same. Stage 3 surgeries were performed at day 40 and involved uncovering and measuring ISQ values for the control implants. Stage 4 surgeries were performed at day 54 (day 40 for the test implants) and involved uncovering and measuring ISQ values for the test implants.

Preoperatively, the sites were shaved and swabbed with povidone-iodine. Antibiotic cover was provided with amikacin 5 mg/kg (Alfakim, Ranbaxy Laboratories Limited, Haryana, India) administered subcutaneously. The rabbits were administered general anesthesia using a combination of diazepam 5 mg/kg and ketamine 50 mg/kg given intramuscularly, and local anesthesia with infiltration of 1 mL 2% lignocaine hydrochloride/adrenaline. Depth of anesthesia was monitored by the "ear pinch" reflex. A skin incision with a periosteal flap was used to expose the distal femoral condyles. All osteotomies were performed at a speed of 2500 rpm, under copious irrigation with normal saline using a No. 6 round bur followed by a final drill of diameter 2.3 mm (Figure 2). Control implants were placed into the prepared osteotomy and their positions verified with radiovisiography. The Smartpeg was attached to control implants via the access channel, and RFA readings were measured using the Osstell Mentor instrument (Figure 3). Two readings each were recorded in 2 different directions—1 with the probe tip along the length of the bone, and the other perpendicular to the first, as per the manufacturer's instructions. If readings showed wide variation in values, they were repeated. Data were automatically stored in the device and later were transferred to a personal computer. The Smartpeg was removed and was replaced with cover screws, and a radiovisiograph was taken (Figure 4). The osteotomies were identically prepared for the test implants and were left as is. A radiovisiograph of the test osteotomy was taken (Figure 5). The periosteum and the fascia were sutured with catgut and the skin with silk.

Postoperative care included antibiotic administration of amikacin 5 mg/kg (Alfakim) and cefazolin sodium 10 mg/kg (Reflin; Ranbaxy), delivered subcutaneously for 5 days, and tramadol hydrochloride 4 mg/kg administered intramuscularly for 3 days to control pain and inflammation.

Stage 2 surgeries included placement of test implants and recording of exposure of the previously prepared osteotomy (Figure 6). Stage 3 and 4 surgeries were performed according to the previously mentioned protocol.

Statistical analysis

Student's independent *t* test was used to calculate the *P* value. Statistically significant differences were set at $P < .5$. The mean of ISQ values at days 0 and 40 for the 2 groups and the difference in mean ISQ values between days 0 and 40 between test and control implants were statistically analyzed.

Results

Mean ISQ values at day 0 for both groups did not exhibit statistically significant differences (Table 1). At day 40, mean ISQ values for the test group were significantly higher, with a *P* value of .005 (Table 1). The difference in mean ISQ values between days 0 and 40 for the test group was significantly higher, with a *P* value of .002 (Table 1).

Discussion

In drilling for an implant, success depends on atraumatic preparation of the implant site so that vital bone is adjacent to the implant at placement.[12] The threshold temperature

TABLE 1

Comparison of mean implant stability quotient (ISQ) values at days 0 and 40, and differences in mean ISQ values between days 0 and 40

Variable	Test	Control	*P* Value*
Day 0	32.4 ± 2.3	35.20 ± 3.7	.19 (not significant)
Day 40	44.3 ± 2.6	37.0 ± 3.5	.005 (significant)
Difference (Day 40 − Day 0)	12.6 ± 3.4	1.8 ± 0.4	.002 (significant)

level for bone survival is 47°C for 1 minute.[10] This temperature is frequently exceeded, which results in osteocytic destruction due to frictional heat, mechanical vibration, and ischemia following capillary destruction; this may contribute to a delay in osseointegration.[1,12,13]

A "pumping" motion, copious external irrigation, drilling with progressively larger drill sizes, high drill speeds with high drilling pressure, and intermittent drilling are proposed to prevent heat.[9,11–13,17–19] Several surgical techniques, including use of lasers and osteotomes, have similarly been proposed.[20,21] Despite use of these surgical modifications, bone injury does occur. In an attempt to allow bone to recover from surgical injury, thereby allowing implant placement into an environment more conducive to healing and development of osseointegration, delayed placement of implants was proposed.[14–16] Implants were placed after 14 days following osteotomy preparation, as peak formation of newly formed trabeculae corresponds to this time interval.[6]

Subsequent evaluations were done on day 40, because the bone remodeling cycle in rabbits is 6 weeks. To extrapolate these results to the clinical situation, the time frame must be multiplied by a factor of 3, as the remodeling cycle in rabbits is 3 times faster than that in humans.[6]

In this study, test implants were placed in accordance with techniques of delayed placement.[14–16] Resonance frequency analysis was performed to quantify implant stability in ISQ values to indicate progression of healing. The accuracy of RFA in assessing implant stability is well documented. ISQ values reflect bone-implant contact.[22–26] Thus it can be inferred that monitoring of the former allows an estimation of the osseointegration process. Based on these facts, ISQ values were measured at specific intervals for test and control group implants, to determine which group showed greater rates of healing.

Lack of statistically significant differences in primary stability values between the 2 groups could be attributed to the structure of the rabbit femur, because the implants engaged only the outer cortex. Significantly higher ISQ values at day 40 for the test group indicate increased bone formation around the implant compared with the control group. Statistically significant greater increases in ISQ values between days 0 and 40 for implants of the delayed placement (test) group compared with the immediate placement (control) group could indicate more rapid healing, characterized by faster deposition of woven and lamellar bone in cases of the former, which could be the manifestation of the stimulatory effect of this technique. The drilling procedure results in release of several growth factors such as platelet-derived growth factors and tumor growth factor-β, which has a stimulatory effect on the healing process. This is in accordance with the regional acceleratory phenomenon described by Frost, which has been shown to intensify remodeling up to 50 times.[27] These findings indicate faster healing and progression of events leading to osseointegration with the use of delayed placement as compared with the conventional method of implant placement and are in accordance with the findings of other studies.[15,16]

However, more definite conclusions may be drawn only with a larger sample size. Delayed placement of implants assumes greater significance in bone of low density because of decreased initial stability. Application of this method in bone of high density would be beneficial because of the greater heat generation and surgical trauma associated with such bone. Also, with changing trends in implant loading, from delayed to early or immediate, faster rates of healing and osseointegration can be achieved with the use of this technique, which would allow faster restoration of dental function.

Conclusions

Findings of this study show faster rates of osseointegration for implants placed by the delayed placement method, as compared with immediately placed implants.

Abbreviations

ISQ: implant stability quotient
RFA: resonance frequency analysis

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