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위 원 장 이원섭
편집간사 이두형, 이소현

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발 행 처 **대한인공치아골유착학회**
(07985) 서울시 양천구 안양천로 1071
이대목동병원 치과
전화. (02)545-4600
E-mail: kaoimp@gmail.com
홈페이지: http://kaoimplant.org

편집제작 (주)메드랑
(05116) 서울시 광진구 광나루로56길 85,
프라임센터 31층
전화. (02)325-2093, 팩스. (02)325-2095

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Extraction with immediate full mouth implant surgery at Mx. edentulous patient without surgical stent: case report

Min-Seok Oh[1], Chul-Min Park[1], Ka-Young Seol[1], Woo-Jin Jeon[1], Kil-Hwa Yoo[1], Na-Ra Kang[1], Hye-Sung Bae[1], Dong-Soo Shin[2], Seong-Gu Han[2], Chan-Ik Park[3], Se-Ha Kang[3], Ji-Eun Moon[3], So-Young Kim[4], Lee-Rang Lim[4], Hoon Kim[5]

[1]Departments of Oral and Maxillofacial Surgery, [2]Periodontology, and [3]Prosthodontics, Sun Dental Hospital, Daejeon, [4]Department of Oral and Maxillofacial Surgery, Veterans Health Service Medical Center, Seoul, [5]Department of Oral and Maxillofacial Surgery, Konyang University Medical center, Daejeon, Korea

Treatment of a patient with few remaining teeth in a compromised condition, seeking full mouth reconstruction with extraction and immediate implant placement at his initial visit is often challenging for a clinician. Because, the ideal placement of dental implants in a non-guided surgery while considering anatomic landmarks (e.g. anterior nasal spine, canine fossa, maxillary tuberosity, etc.) and optimal prosthetic requirements is difficult and unpredictable. Without the use of a surgical stent, therefore, the clinician needs to place implants on both sides in a single visit to achieve predictable and symmetrical results. Here, we want to present a successful case of a patient who had all compromised teeth removed and received immediate implant placement in full-arch without the surgical guide during his first visit. (THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2021;13(1):1-9)

Key words: Extraction with immediate full mouth implant surgery, Implant operation without surgical stent, Free hand full mouth surgery, Implant, Immediate implant, Bone graft

INTRODUCTION

Many surgeons may have difficulty establishing implant placement in an ideal prosthetic position if a patient with a multiple loss of teeth is in a first visit and wants to have an implant surgery immediately. If the patient is on the first visit and wants to immediately install the full-arch implant, the surgeon has to establish the position of the implant based on anatomical structures without any surgical stents. Anterior nasal spine, canine fossa, maxillary tuberosity, etc. can be anatomical criteria and must be performed bilaterally to obtain symmetrical results. We would like to present a successful case which is the one-day extraction and immediate reconstruction of full-arch implantation based on anatomical structures without the surgical stent.

CASE REPORT

The maxilla of the patient was edentulous with only #11, 13, 22 retained roots and both maxillary sinuses were in a pneumatization state with the bone level of 3~4 mm based on alveolar crest (Figure 1, 2). The immediate extraction and implant installation were conducted on the first visit with the reference to anatomical structures without a surgical stent.

Even in the case of an operation with a surgical stent, full-mouth operation is conducted by only checking the location of #13, 23, which are the most important landmarks of implant installation. Therefore, full-mouth implant installation could be easily conducted by identifying anatomical structures.

Under local anesthesia, we opened one flap from #17 to #27 and extracted the retained roots (Figure 3). By using an EO gas-sterilized pencil, we checked anatomical landmarks on alveolar bone surface with reference to anterior nasal spine (ANS), intermaxillary suture, canine fossa, and maxillary tuberosity.

We marked the midline from ANS along intermaxillary suture and marked the distal border on both canine fossa. 2 mm mesial from the point, we set the installation location (Figure 4). After setting both intermaxillary suture and canine fossa lines parallel, we formed holes on #13 and #23 with point drill and 2.0-diameter drill. Afterwards, with guide pins, panoramic photo was taken to check the proper location. Then, with a ster-

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Corresponding Author: Min-Seok Oh, Department of Oral and Maxillofacial Surgery, Sun Dental Hospital, 29 Mokjung-ro, Jung-gu, Daejeon 34811, Korea, Tel: +82-42-251-5000, Fax: +82-42-257-2280, E-mail: omin333@naver.com

ilized pencil, we marked the location of #14~16, #24~26, and lateral walls of maxillary sinuses (Figure 5).

After marking all important anatomical landmarks, we opened lateral walls of both maxillary sinuses with sinus bur and a handpiece. Sinus mucosal elevation without any perforation was also conducted with sinus elevator and sinus curette.

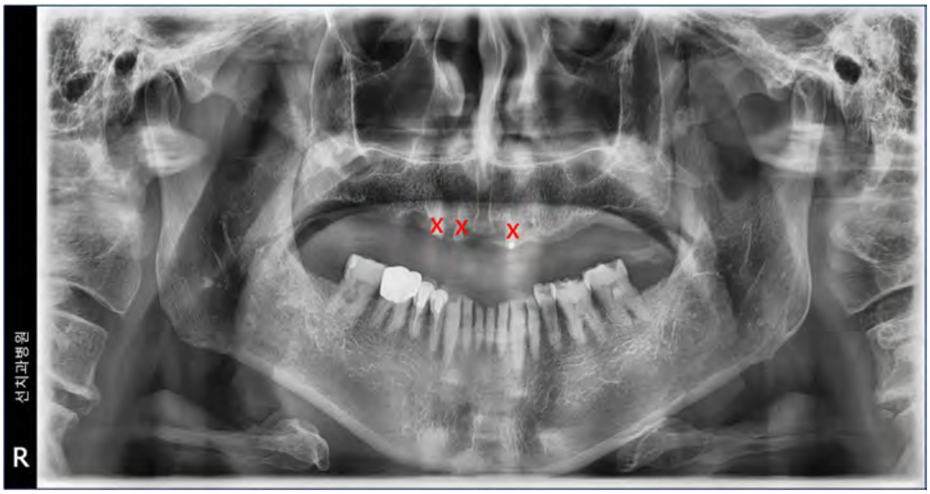

Figure 1. 1st visit panorama.

Figure 2. 1st visit intra-oral view.

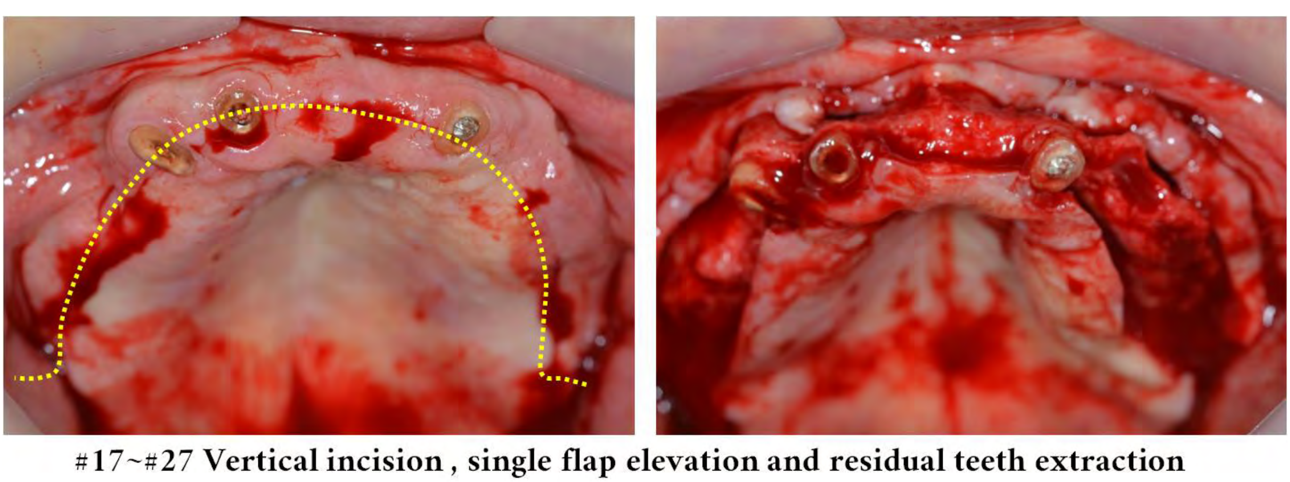

Figure 3. Flap design and elevation after extraction of root rest.

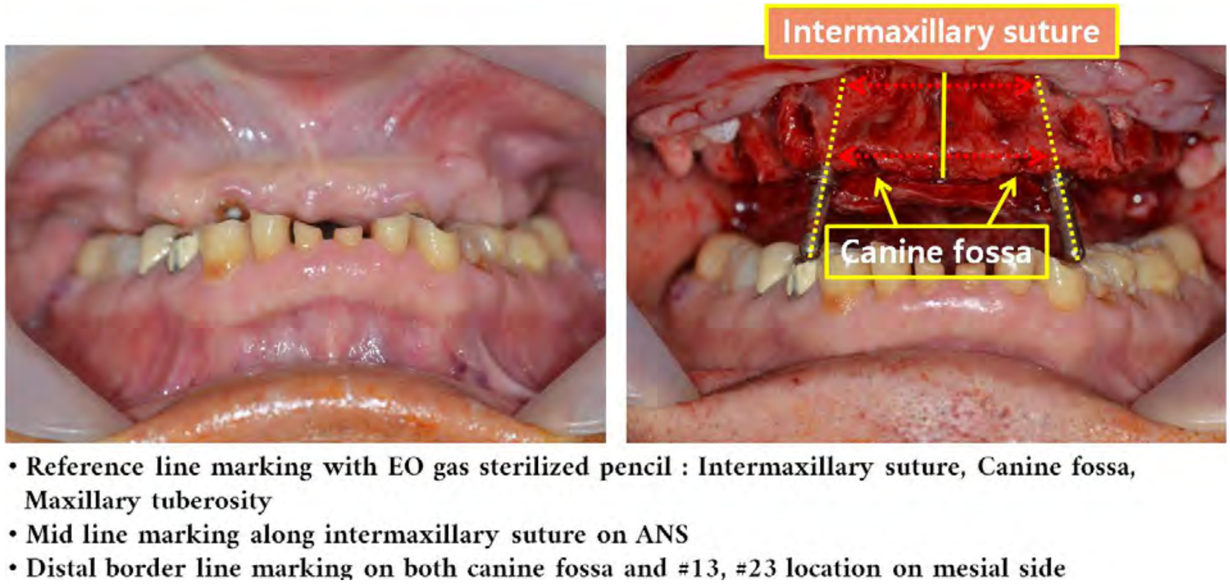

Figure 4. Anatomical landmark (anterior maxilla).

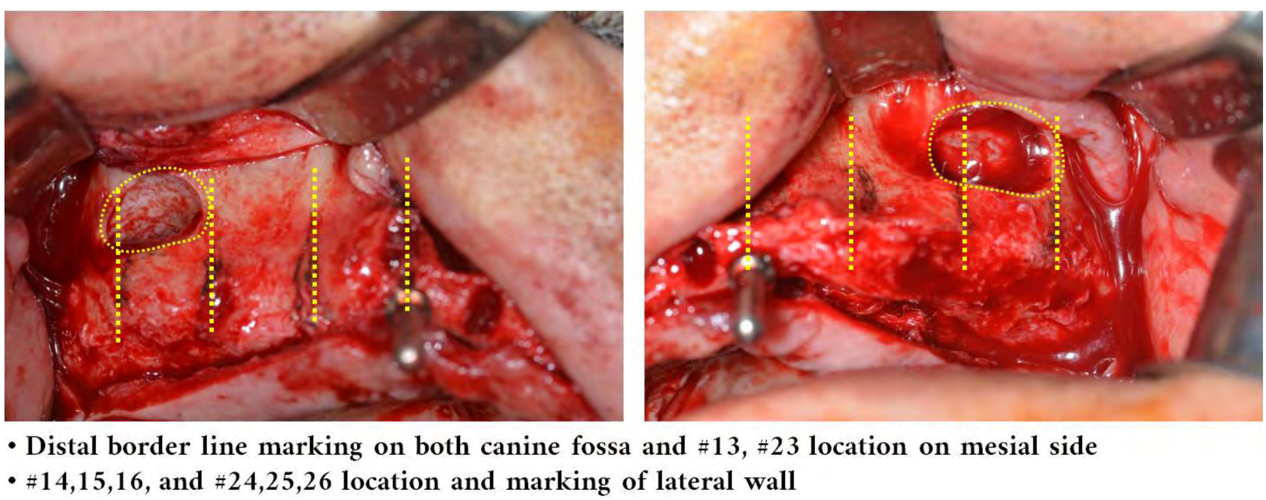

Figure 5. Anatomical landmark (posterior maxilla).

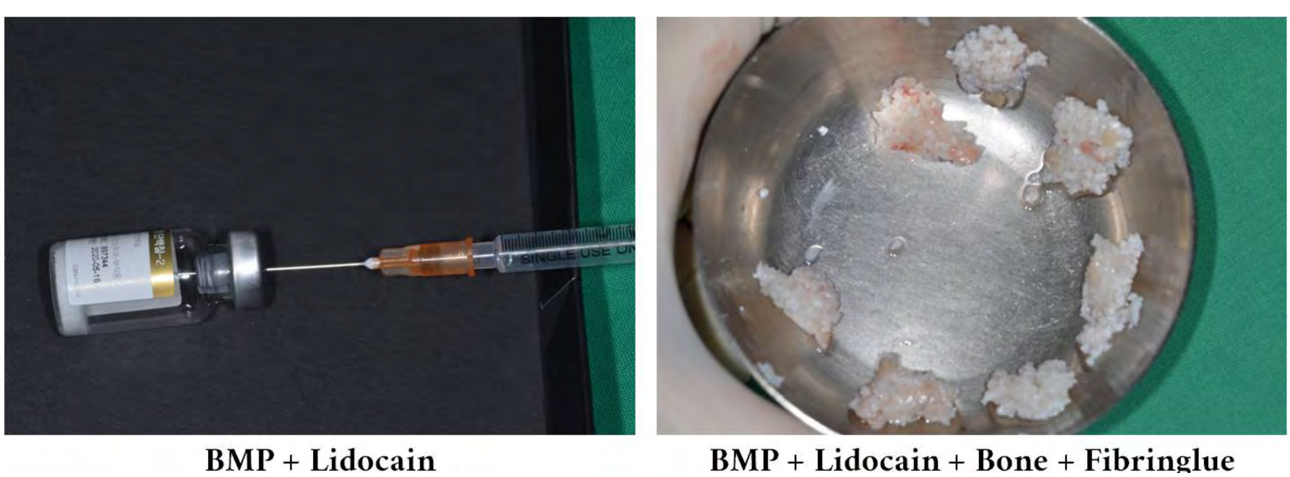

Figure 6. Bone graft material preparation.

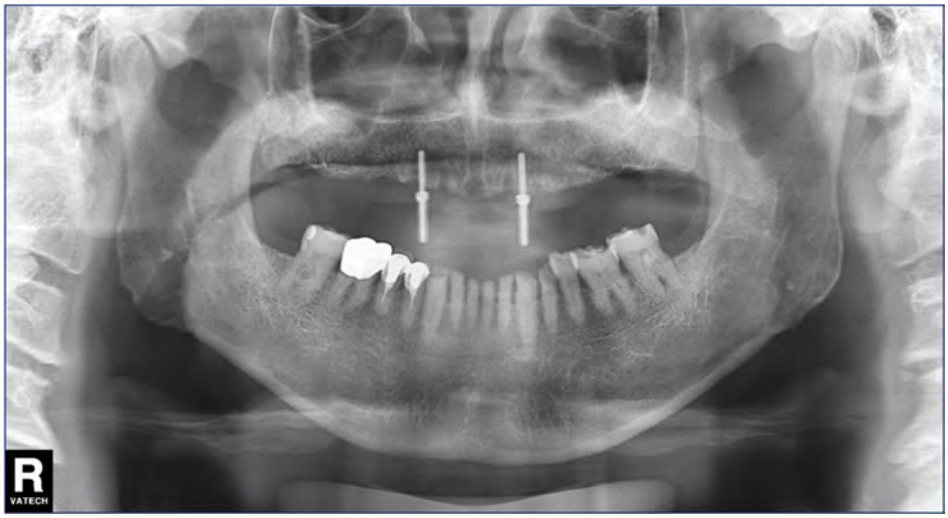

Figure 7. Guide pin panorama.

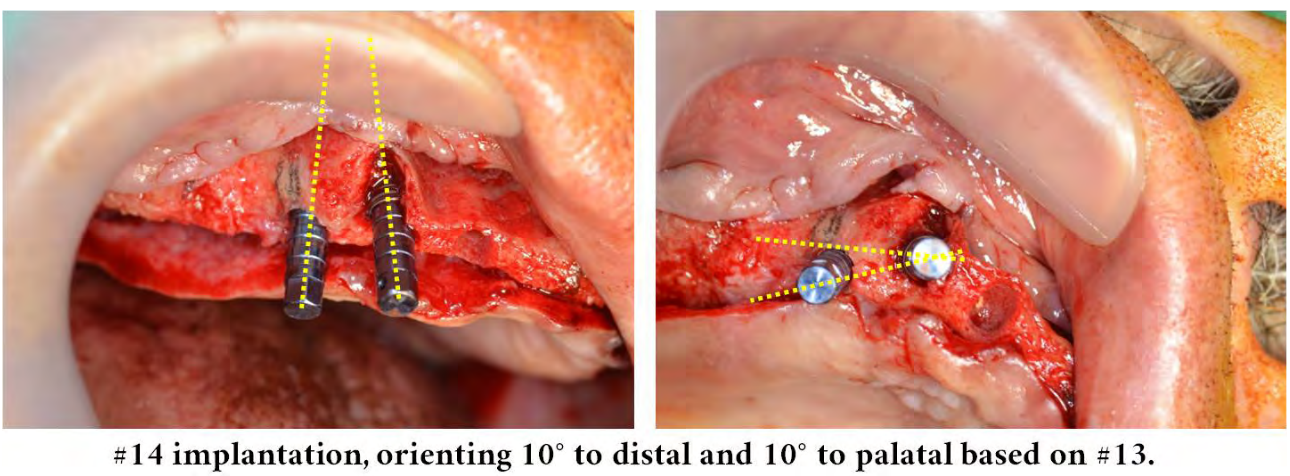

Figure 8. Direction and angulation formation of implant (#13,#14, Dio UV, Dio implant, Seoul, Korea).

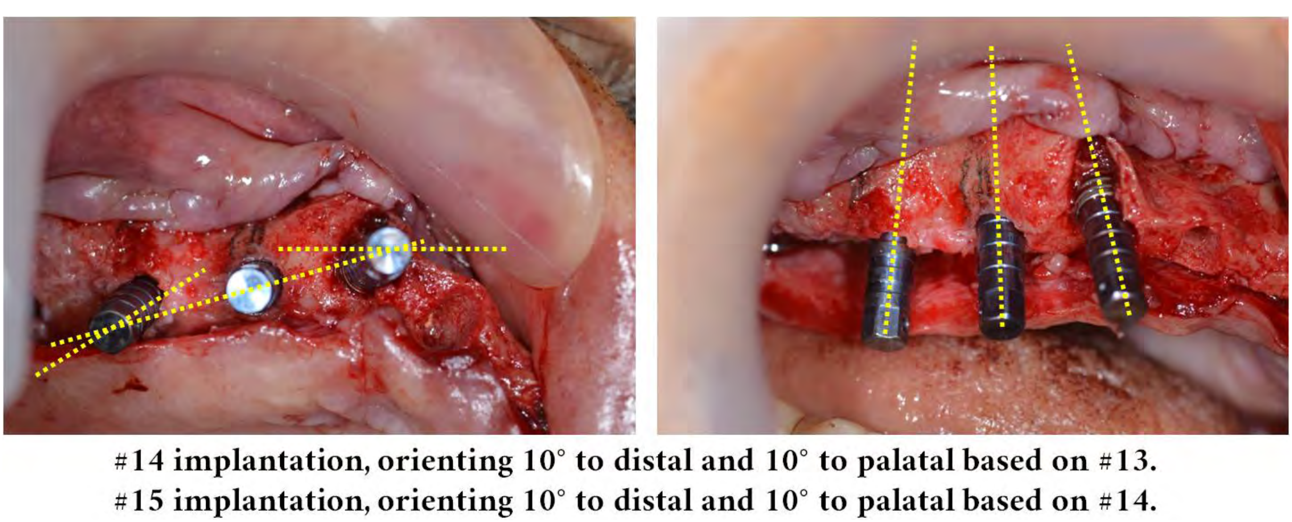

Figure 9. Direction and angulation formation of implant (#14,#15, Dio UV, Dio implant, Seoul, Korea).

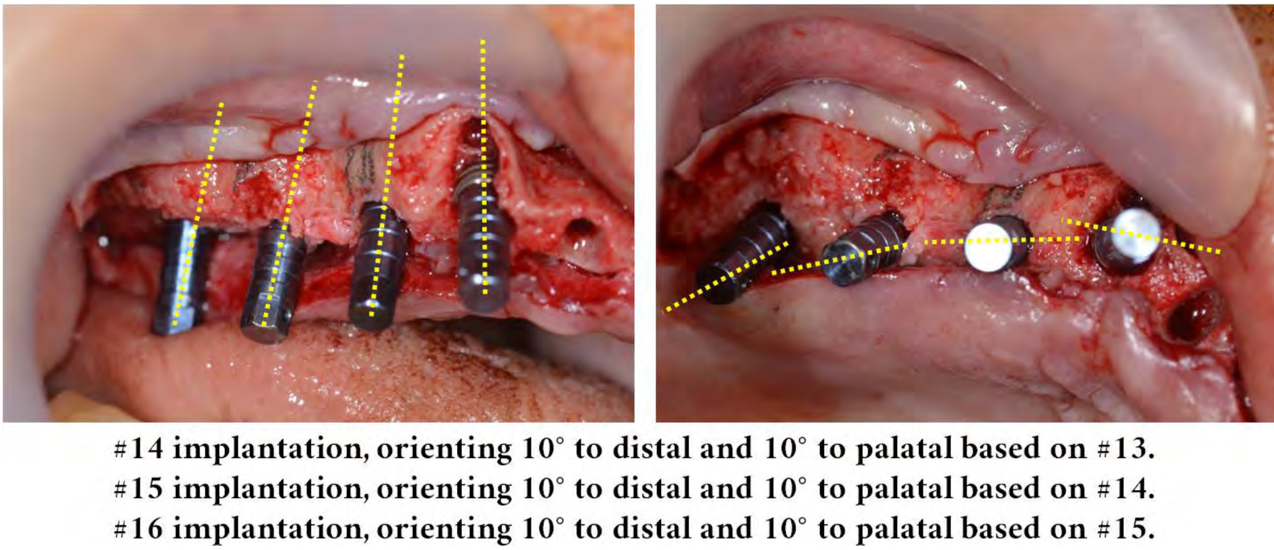

Figure 10. Direction and angulation formation of implant (#15,#16, Dio UV, Dio implant, Seoul, Korea).

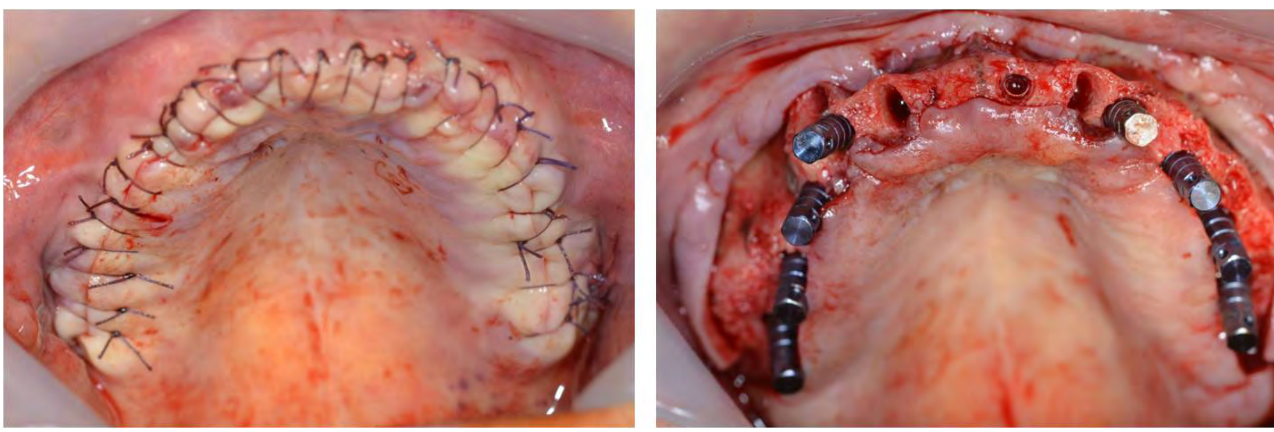

Figure 11. After 1st operation intra–oral view.

Heterogeneous bone graft material (EQUIMATRIX, NIBEC, Seoul, Korea), Fibrin Glue (TISSEEL, Baxter, Wien, Austria), Lidocaine (1:100,000, Huons, Seoul, Korea), and Bone Morphogenic Protein (NOVOSIS, Daewoong Pharmaceutical, Seoul, Korea) were mixed and sinus bone graft was completed (Figure 6, 7).

Implant (Dio-UV, Dio, Seoul, Korea) was installed at #13 and another implant at #14 was placed orienting 10° to distal and 10° to palatal according to #13 (Figure 8). With the same method, #15 and #16 were installed based on the location of #14 and #15 respectively (Figure 9, 10).

By setting #23 as a standard, we placed #24, 25, and 26 with the same pattern. To determine the direction of each implant, occlusion pattern and the Curve of spee of maxilla and mandible were considered.

Lastly, we installed an implant at #21 which had better alveolar bone condition than #11 (Figure 11).

Finally, additional ridge augmentation was conducted at the site with inadequate bone level and the operation was finished after suturing each site (Figure 12).

Second surgery was conducted 5 months after the first surgery and the ISQ value was measured with Ostell mentor. The values of each implant on maxilla were over 80 (Figure 13, 14).

Intra-oral scan was taken with TRIOS III scanner (3shape TRIOS, Copenhagen, Denmark) and an intra-oral model was printed by 3D printer (Cara printer, Kulzer korea, Seoul, Korea). We tried in abutment on the model and completed the temporary crown (Figure 15).

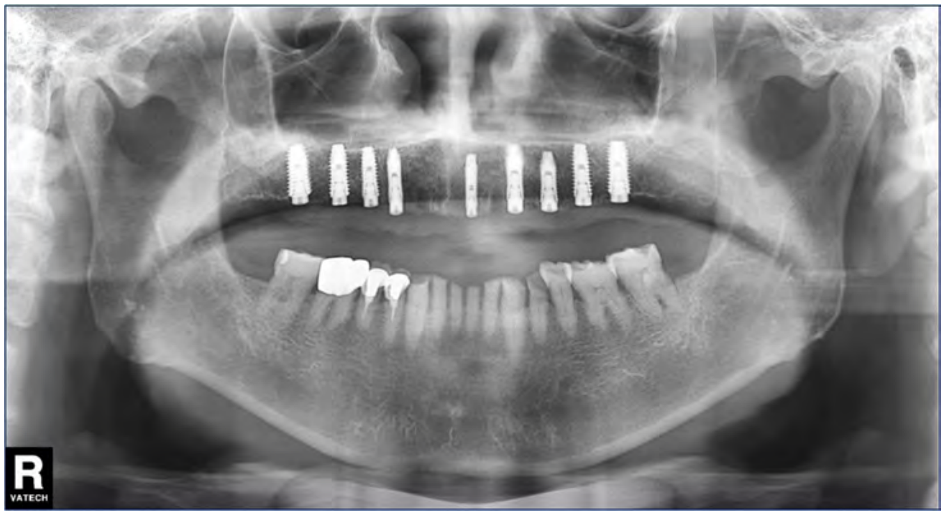

Figure 12. 1st operation panorama.

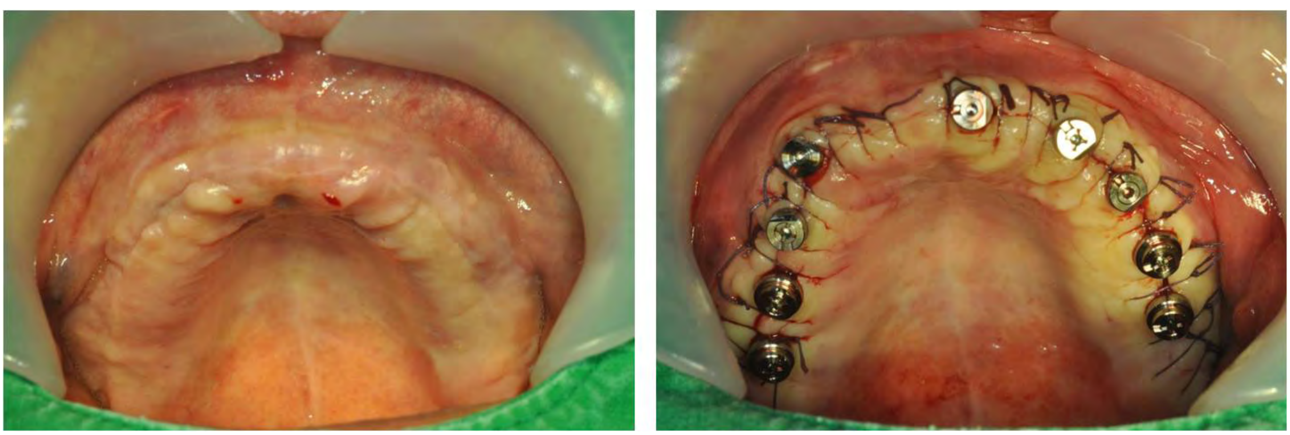

Figure 13. After 2nd operation intra-oral view.

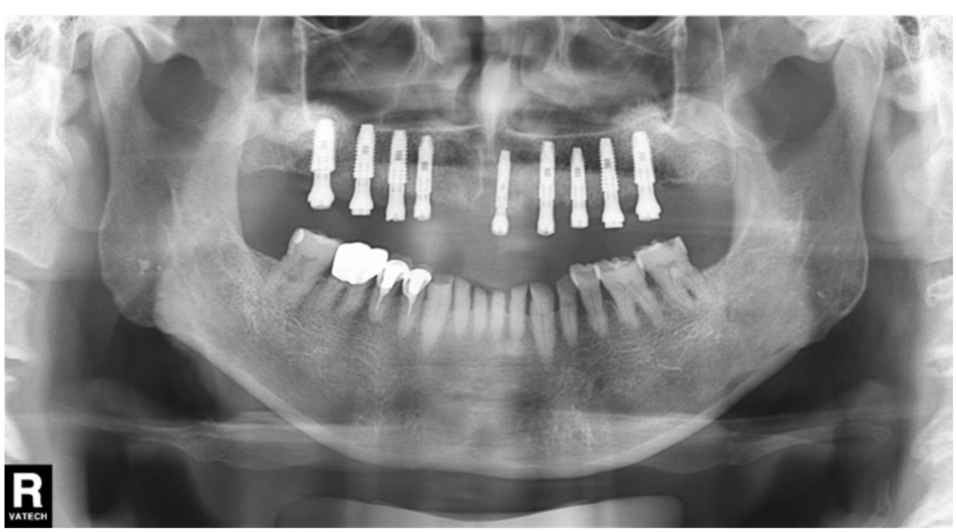

Figure 14. 2nd operation panorama.

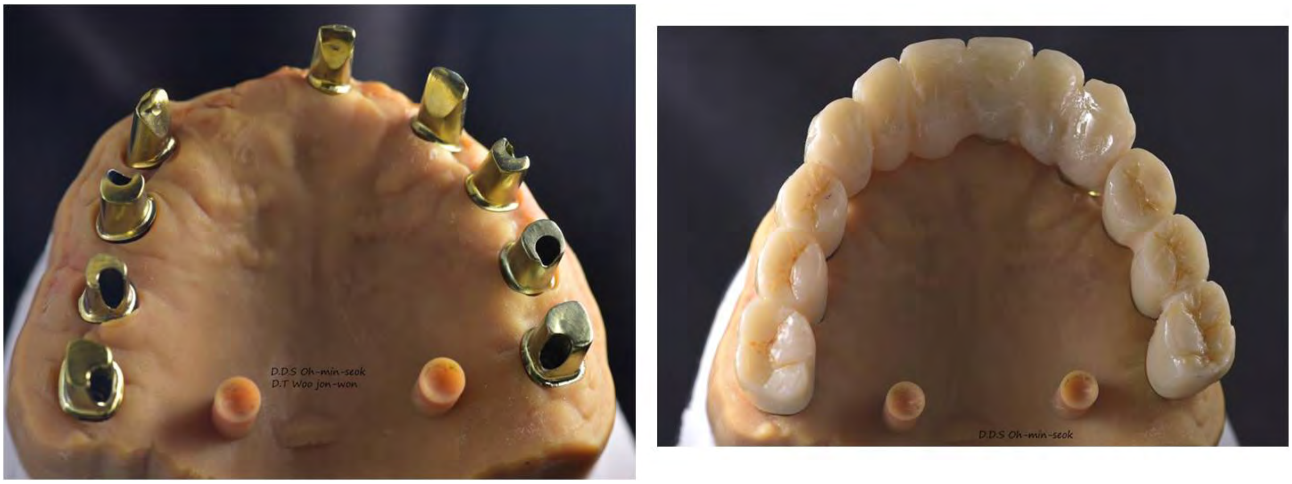

Figure 15. Print out intra–oral model & temporary crown.

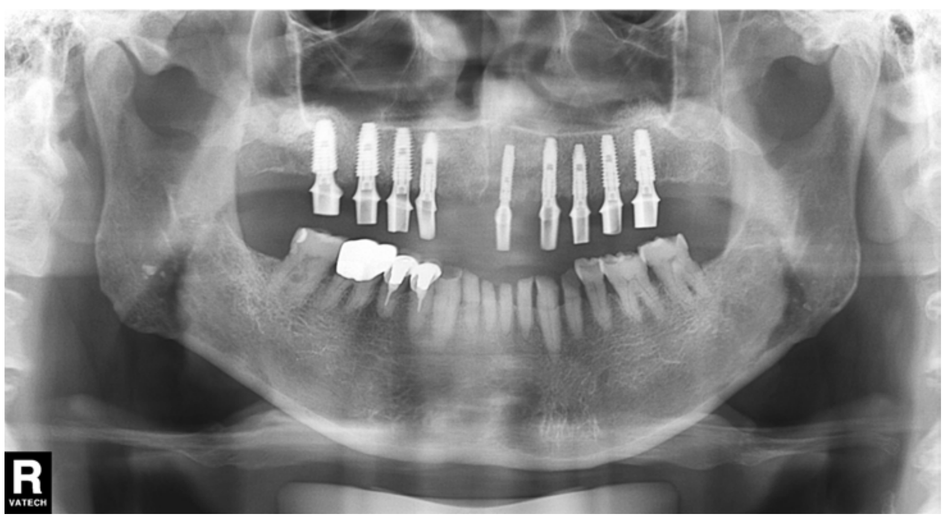

Figure 16. Temporary crown connection panorama.

Figure 17. Final zirconia crown connection intra–oral view (coronal).

Figure 18. Final zirconia crown connection intra-oral view (axial).

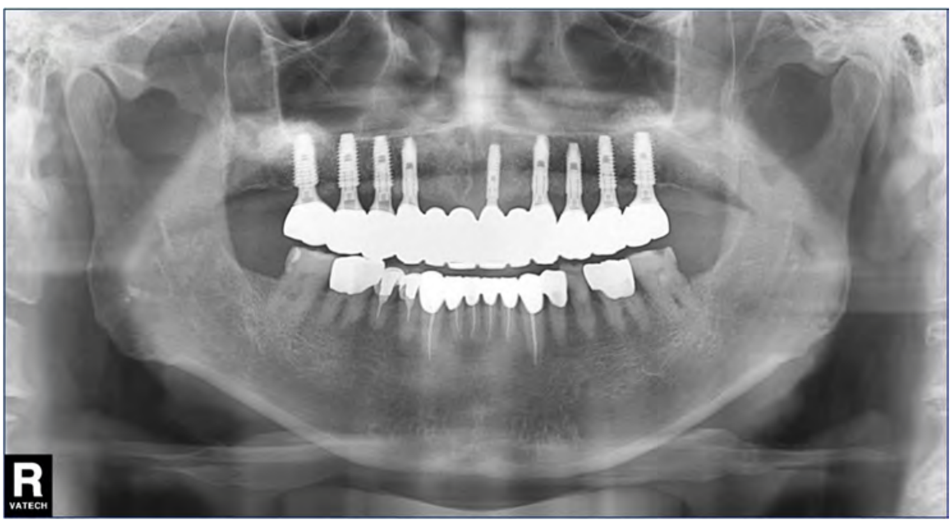

Figure 19. Final zirconia crown connection panorama.

Occlusion force was applied for 8 weeks with temporary crowns and the temporary crowns were replaced by final zirconia crowns after fine occlusal adjustment (Figure 16).

6 mandibular incisors were restored with zirconia crowns after the endodontic treatment in order to obtain stable occlusion (Figure 17~19).

DISCUSSION

The advantages of guide implant surgery using surgical stent have been discussed through several studies[1,2]. Implant surgery with Surgical stent shows higher accuracy than implant surgery without surgical stent, and this exact implant positioning reduces the risk of complications in implant surgery[3]. It also has the advantage of reducing the exchange rate of complications through minimally invasive surgery.

However, implant surgery using surgical stent requires digital implant planning and CBCT image analysis through digital waxing before surgery[4]. Due to these factors, surgery using surgical stent takes a lot of time and additional cost[5-7]. Therefore, it is impossible for a surgeon to use a surgical stent when performing full-arch implantation of a patient on the same day. In this case, the patient who visited the hospital on the same day was reconstructed by immediately installing the implant. Therefore, the position of the implants was established based on the anatomical structure without the surgical stent. Anterior nasal spine (ANS), intermaxillary suture, canine fossa, and maxillary tuberosity were established on an anatomical basis, and implantation was carried out bilaterally to obtain symmetrical results.

CONCLUSION

A surgical stent based on CT images is essential to obtain stable surgical results and occlusion. However, even if implantation is carried out in the absence of a surgical stent due to various requirements such as cost and time limitation, successful surgery results can be obtained if the implant is operated based on the surrounding anatomical structure.

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Removal of fractured implant abutment screw in a single posterior tooth with or without microscope: a case report

Jin-Ho Chung[1], Jeong-Woong Kim[1], Yu-Seon Park[1], Bo-Ah Lee[1], Jung-Seok Lee[2], Young-Taek Kim[1]

[1]*Department of Periodontology, National Health Insurance Service Ilsan Hospital, Goyang,* [2]*Department of Periodontology, Research Institute of Periodontal Regeneration, College of Dentistry, Yonsei University, Seoul, Korea*

Although fracture of abutment screw appears in small proportion of mechanical complications, removing fractured screw is harassing situation to clinicians, often leads to fixture removal. Several studies have been presented the screw removal techniques, but usually withdrawing the remnant with a sharp edge instrument should be the first choice of treatment. In this report, we described successful screw removal cases with simple anti-rotation movement of endodontic explorer, with or without microscope. **(THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2021;13(1):10-15)**

Key words: Dental abutment, Periprosthetic fractures, Prosthesis loosening, Prosthesis failures, Single-tooth implants

INTRODUCTION

With an explosive increase in the cases of dental implantation in the last decade, clinicians are faced with several postoperative complications. Complications in the field of implantology can be divided into biological complications (unsuccessful osseointegration and peri-implantitis) and mechanical complications (veneer material fracture, screw loosening, screw fracture, and fixture fracture)[1].

Mechanical failure accounts for a larger proportion of implant failure than biological failure[2]. The most frequent mechanical failures are acrylic resin fracture (22%), followed by screw loosening of the abutment (7%~10%), porcelain fracture (7%), implant component fracture (2%~4%), and fixture fracture (1%~2%)[3,4].

Mechanical fractures can occur in the fixture or any of the other components. Goodacre et al.[3] reported that the occurrence of abutment screw fracture had a fourtimes higher ratio than fixture fracture during the early to mid-loading period. Abutment screw fracture often results in the prosthesis falling out, leaving the component inside the fixture screw. Some clinicians suggest that screw fractures could be a safety component of the fixture[5], as it seems to replace the fixture fracture at times. However, the remnant frequently precludes the reuse of the fixture, sometimes leading to the removal of the fixture.

The primary reason behind screw fracture is undetected screw loosening, possibly due to bruxism, an ill-fitting suprastructure, overloading, or malfunction[1] implants with excessively long height leading to screw loosening, even culminating in abutment fracture[6]. Screw loosening occurs more frequently in single-tooth implants (8%) than multiple-unit fixed prostheses (5%)[7].

Bickford suggested that the screw loosening process occurs in two stages: initially, external forces applied to the screw joint cause slippage, releasing the preload. In the next stage, the loosened body involves a continual decline of preload below the critical level, resulting in thread turn and loss of function[8]. Furthermore, the loosened body will convert the occlusal force to lateral force, thereby increasing the inappropriate force on the implant system resulting in alveolar bone resorption or fracture of the connecting part in the long run[9].

Several studies have described methods for screw retrieval; however, no consensus has yet been reached on abutment screw removal[10,11]. In this clinical case report, we present three cases of abutment fracture in a single-tooth implant by a conservative method with or without visual aids.

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Corresponding Author: Young-Taek Kim, Department of Periodontology, National Health Insurance Service Ilsan Hospital, 100 Ilsan-ro, Ilsandong-gu, Goyang 10444, Korea, Tel: +82-31-900-0625, Fax: +82-0303-3448-7138, E-mail: youngtaek@nhimc.or.kr

CASE REPORT

1. Case 1

A 60-year-old female patient visited our clinic with an i27 implant abutment screw that had fractured the previous night. A periodontal flap was elevated to expose the fixture hole (Figure 1b). A microscope (OPMI pico S100, ZEISS, Germany) was used to improve the visibility. By viewing through the microscope, a fractured screw thread tip was detected (Figure 1c). Although technically demanding, the remaining part was removed using an endodontic explorer by rotating it counter-clockwise (Figure 1d). A new adequate healing abutment (5.0 mm × 7 mm) was placed, and the seating was confirmed through radiography (Figure 1e).

2. Case 2

A 62-year-old male patient visited the clinic with an i16 implant fixture with a fractured screw covered by gingival tissue.

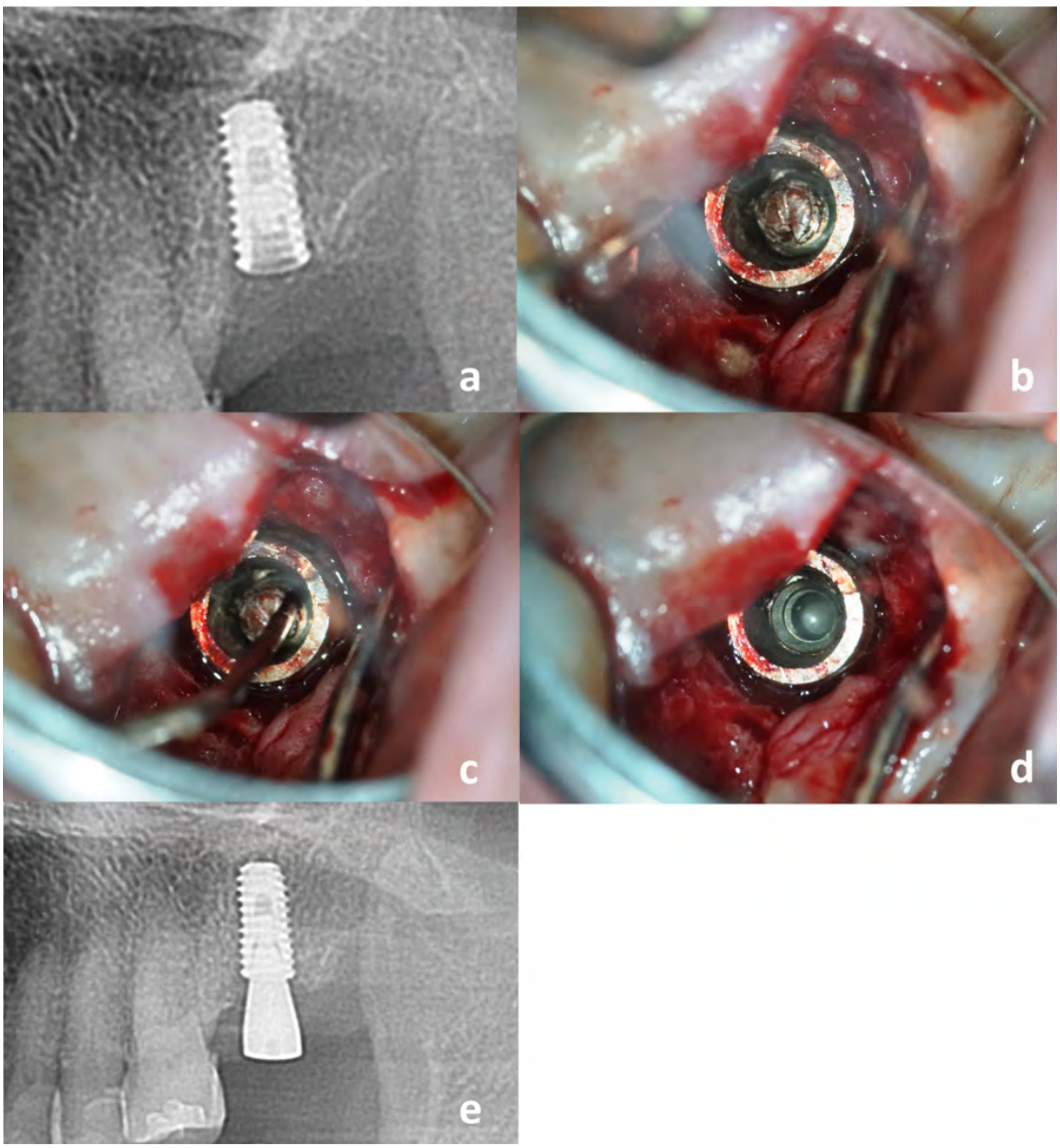

Figure 1. (a) Panoramic view of the fractured screw. (b) The fractured screw thread tip. (c) The endodontic explorer is moved counter-clockwise to move the fragment outward. (d) After verifying there is no internal thread worn out, healing abutment is placed. (e) New healing engagement is confirmed.

An internal tapered joint type implant fixture (Implantium, 4.8 mm × 10 mm, Dentium, Seoul) had been placed 2 years before the fracture, followed by the screw & cement-retained prosthesis (SCRP) type implant crown installation. There was no sign of screw loosening during the 2-year follow-up period before the prosthesis detachment due to screw fracture.

After the administration of local anesthesia, the i16 fixture hole was exposed by elevating a periodontal flap. Using an endodontic explorer tip, the clinician traced the fragment's cutting plane tactilely and rotated it counter-clockwise. The remaining

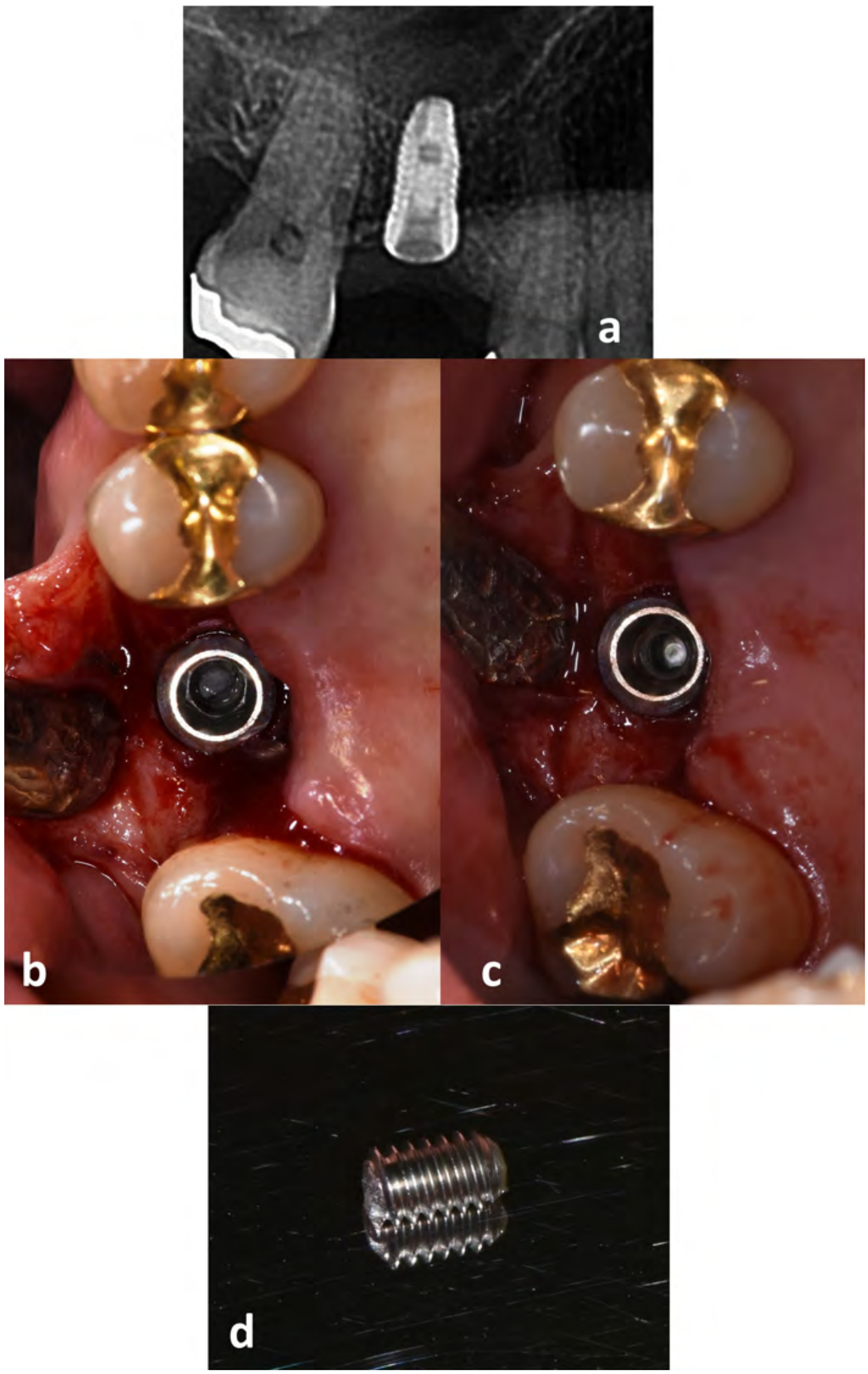

Figure 2. (a) Panoramic view of the fractured screw. (b) The flap is elevated for visibility. Abutment screw fractured horizontally, with partial step height. (c) The fractured piece is removed with endodontic explorer. (d) Photo of fractured component taken after removal.

screw component was successfully removed through the internal thread with adequate force, and an adequate healing abutment (6.5 mm × 3 mm) was engaged (Figure 2a~d).

3. Case 3

A 68-year-old female patient visited the clinic with the chief complaint of an i16 implant that fractured while having dinner the previous night. The patient reported that the implant crown was placed at least five years earlier.

From the radiograph of the implant, we could clearly see a broken screw inside the tapered internal-type fixture. After the administration of local anesthesia and elevation of a periodontal flap, the tip of the endodontic explorer with a counter-clockwise movementwas used to successfully remove the fractured segment from the fixture. A radiographic examination was performed after a suitable healing abutment hookup (Figure 3a~c).

DISCUSSION

All the patients mentioned above had single-tooth implants with an internal-tapered joint in the posterior area. Implant components are known to fracture more frequently in the posterior region[12,13]. Dental implants in the posterior region are easily exposed to excessive occlusal forces (200 lbs) compared to the anterior region (25~100 lbs)[12] and screw loosening is the most common restorative failure in replacing a single posterior tooth

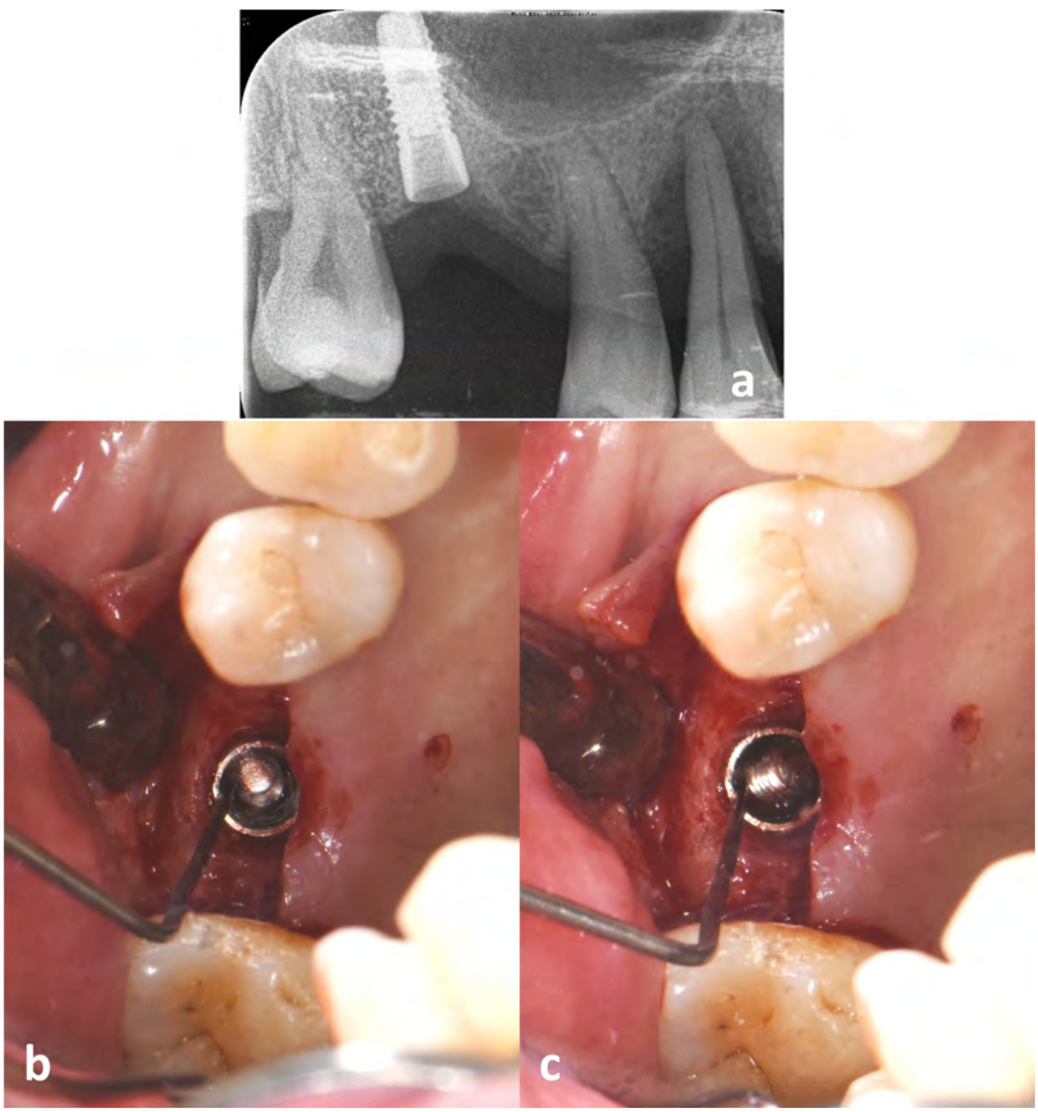

Figure 3. (a) Fractured screw observed on periapical radiograph. (b) The fragment's end point is found using an endodontic explorer. (c) The fragment is removed through counter-clockwise rotation.

with implant therapy, (~26%) in an earlier year[13]. According to Balshi et al.[14], the proportion of screw loosening of splinted implants declined (8%) compared with single tooth replacement (48%) during the same 3-year analysis. All the patients mentioned above had a single-tooth implant, which is vulnerable to fracture.

Implant abutment design plays a key role in implant therapy by affecting the force transmission mechanism at the interfaces between the fixture and the abutment. Merz et al. reported that the butt joint and external hex connection type were more prone to screw loosening than the internal-taper/cone joint due to the force concentration on the abutment screw. Conversely, the internal type has the advantage of off-axis loading by resting on a tapered interface[15]. Although most screw fractures are reported on external type, internal-type screw fractures can be observed easily due to clinician preference[16]. All the cases reported here were of the internal-tapered type, with the fracture fragment remaining below the tapered surface.

Fundamentally, dentists should be concerned about preventing screw loosening before its occurrence. Torquing an abutment screw has a clamping effect, called preload, resulting in friction resistance between the screw and the internal thread[17]. Therefore, in clinical situations, using an adequate preload is essential, and it is recommended that the abutment screw be retightened 10 minutes after the first tightening. In addition, selecting a fixture that is as wide as feasible will diminish the static and fatigue stress of the abutment screw[18,19]. Cho et al.[20] reported that a wide diameter fixture showed less screw loosening (5.8%) than the standard diameter (14.5%), particularly in the single-tooth posterior area.

Nevertheless, screw fractures can occur spontaneously at any moment. Several case studies have shown how to remove the fractured screw fragment with an explorer, endodontic file, straight probe, or hemostats[10,11]. If the fractured segment remains stuck inside the fixture, a notch should be carved on the periphery to make a lever arm[1]. Furthermore, if affordable, clinicians can choose the manufacturer's implant retrieving kit if. Utilizing an additional visual aid, such as a microscope, will enable the clinician to make a precise decision on the fractured section and shorten the chair time in every case.

As seen in our cases, withdrawing the remnant with a sharp edge instrument should be the first choice of treatment. As abutment screw fracture occurs mostly due to screw loosening, the remaining screw has a fair chance of loosening out of the internal screw. The clinician must rotate the instrument counterclockwise immediately after adjusting the tip on the fractured section. At times, the fragment remains unperturbed and seems to be stuck in the fixture, with the expectation of internal thread wear out. Before attempting aggressive treatment such as fixture removal, the clinician should double-check if the sharp-edge tip is properly located. In the first case, we could not remove the fragment successfully because of finite visibility. Subsequently, by applying the endoscope, we noticed that the cut-off edge we expected was not the right edge, and the segment could be removed conservatively.

CONCLUSION

Despite its low incidence rate (2%~4%), abutment screw fracture in dental implants usually presents a challenging situation, sometimes leading to implant removal. Meanwhile, due to the limitations in visibility and approachability, retrieving screw-fractured implants still depends mostly on the clinician's technical sensitivity. As seen in Case 1, using microscopes will help remove fractured screws by improving visibility. By extension, clinicians should make constant efforts to prevent screw loosening and fracture, such as selecting proper implant design considering overall occlusal force control and applying proper preload, especially on posterior single-tooth implants.

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Alveolar ridge augmentation using simultaneous sinus bone graft and ramal block bone graft on a severely atrophied posterior maxilla: a case report

Yongwook Jung, Jeong Joon Han, Hoon Myoung

Department of Oral and Maxillofacial Surgery, Dental Research Institute, School of Dentistry, Seoul National University, Seoul, Korea

Insufficient vertical and horizontal alveolar bone is found frequently in the posterior maxilla, resulting from bone resorption and pneumatization of the maxillary sinus after the loss of teeth. Although maxillary sinus bone grafting alone can provide adequate bone height and width for implant placement, it can lead to an unfavorable dental prosthesis biomechanically and esthetically due to the greater crown-implant ratio. In the present case, a 59-year-old female patient received alveolar ridge augmentation using guided bone regeneration with ramal block bone graft and sinus bone graft to overcome a severely atrophied alveolar ridge. During the postoperative period, grafted bone was exposed partially with signs and symptoms of infection. However, it could be treated conservatively with curettage of infected bone only. Three implants were placed approximately 10 months after bone grafting without any significant complications. This case report suggests that simultaneous sinus bone graft and ramal block bone graft can be a feasible treatment option to overcome severely insufficient height and width of the alveolar bone. **(THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2021;13(1):16-22)**

Key words: Alveolar ridge augmentation, Block bone graft, Sinus bone graft, Dental implant

INTRODUCTION

Insufficient vertical and horizontal residual alveolar bone is one of the contributing factors that makes it difficult to place dental implants in the maxillary posterior region. After the loss of posterior maxillary teeth, alveolar bone resorption usually occurs in bucco-palatal and vertical apical directions, resulting in an atrophied alveolar ridge with narrow width and reduced height[1]. In addition, pneumatization of the maxillary sinus results in downward displacement of the maxillary sinus floor[2]. In the study by Kim et al.[3], implants placed in the posterior maxilla exhibited the lowest success rate due to the large amount of cancellous bone and maxillary pneumatization resulting in the lack of proper alveolar bone height. Since an implant located within the alveolar bone has to resist occlusal forces, a sufficient quantity and quality of supporting bone around the implant are required for long-term success[4,5].

After the first attempt to place a dental implant with sinus floor elevation in the mid-1970s, several surgical methods have been developed to reconstruct the alveolar bone in the posterior maxilla to be favorable for implant placement, including maxillary sinus bone grafting with sinus floor elevation, autogenous block bone grafting, distraction osteogenesis, guided bone regeneration (GBR), the ridge splitting technique, and the subperiosteal tunnel technique[6-8]. In determining the surgical method for reconstruction of maxillary posterior alveolar bone, the residual height and width of alveolar bone and the degree of pneumatization of the maxillary sinus usually are considered. However, when the residual alveolar bone is severely insufficient, two or more methods should be performed simultaneously or in stages to obtain sufficient bone volume.

Vertical ridge augmentation is one of the most difficult and complicated bone augmentation procedures, with a relatively high complication rate, even though it is often required to reconstruct severely atrophied alveolar ridges[9-11]. When vertical ridge augmentation is combined with other additional bone augmentation techniques, the surgical difficulty and complication rate can increase. The aim of this case report is to describe a patient with a severe atrophied alveolar ridge in the posterior maxilla who received implant treatment after simultaneous maxillary sinus bone grafting with sinus floor elevation and autogenous onlay block bone graft for vertical ridge augmentation.

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Corresponding Author: Jeong Joon Han, Department of Oral and Maxillofacial Surgery, Dental Research Institute, School of Dentistry, Seoul National University, 101 Daehak-ro, Jongno-gu, Seoul 03080, Korea, Tel: +82-2-2072-4088, Fax: +82-2-762-4735, E-mail: ooops01@snu.ac.kr

CASE REPORT

A 59-year-old female patient with a chief complaint of mobility of the fixed dental prosthesis in the posterior maxilla visited the Department of Oral and Maxillofacial Surgery at Seoul National University Dental Hospital. The prosthesis was supported by the left upper first premolar, implant at the left upper second premolar, and left upper second molar (Figure 1). In the clinical and radiographic examinations, the prosthesis exhibited mobility greater than 2 degrees, and severe alveolar bone loss around the supporting teeth and implant of the prosthesis was observed. Except for drug allergies to aceclofenac and amoxicilline, there were no specific underlying diseases. In the treatment planning stage, the patient preferred to establish a plan for dental rehabilitation after extractions of the diseased teeth and implant. Therefore, surgical extractions of the supporting teeth and removal of the implant were performed under local anesthesia. Treatment planning for dental rehabilitation was established 3 months after extractions of the teeth and removal of the implant. In the radiographic examination with a panoramic view and cone-beam computed tomography, a severe alveolar bone defect was observed, with the remaining alveolar bone height ranging from 1.5 mm to 2.5 mm in the edentulous area (Figure 2). Placement of three dental implants after simultaneous maxillary sinus floor elevation, sinus bone grafting, and ramal block bone grafting was planned.

Figure 1. Panoramic radiograph at initial examination.

Surgery for alveolar ridge augmentation and sinus bone grafting with maxillary sinus floor elevation was performed under general anesthesia (Figure 3). A vertical incision was created at the area distal to the left maxillary canine. Through the vertical incision, subperiosteal pocket formation was performed before the crestal incision to increase the space for the volume of the grafted bone. After elevation of a full mucoperiosteal flap, maxillary sinus floor elevation and sinus bone grafting using 1.7 cc of allogenic bone (Sure-oss, Hansbiomed, Daejun, Korea) were conducted through the lateral approach. Conventional harvesting of mandibular ramal block bone was performed at the size of 20 mm (length) × 10 mm (width) × 4 mm (height). Harvested ramal block bone was then grafted on the alveolar bone vertically and stabilized using three micro-screws 1.2 mm in diameter and 8 mm in length (Leforte, Jeil-medical, Seoul, Korea). To fill the space between the block bone and the underlying alveolar bone and achieve ridge augmentation with greater volume, further GBR was performed using 1.7 cc of allogenic bone (Sure-Oss, Hansbiomed, Daejun, Korea) and bio-gide (Geistrich Pharma AG, Wolhusen, Switzerland). Primary closure of the grafted area was carried out through releasing incisions.

At the follow-up visit 4 weeks after surgery, wound dehiscence with partial exposure of the grafted bone at the distal region of the recipient site was observed (Figure 4). Patients were recommended to rinse with chlorhexidine digluconate 0.12% and maintain appropriate oral hygiene. Eight weeks after bone grafting, the patient exhibited signs and symptoms of infection

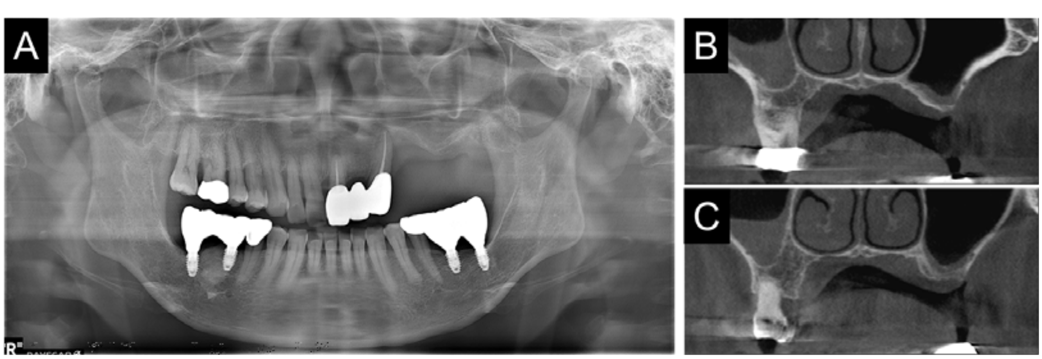

Figure 2. Radiographic examination before bone grafting for implant placement. (A) Panoramic radiograph after extraction of teeth (#24 and #27) and removal of implant (#25); (B, C) Reconstructed coronal view of cone-beam computed tomography at the posterior maxilla (#25~26 area).

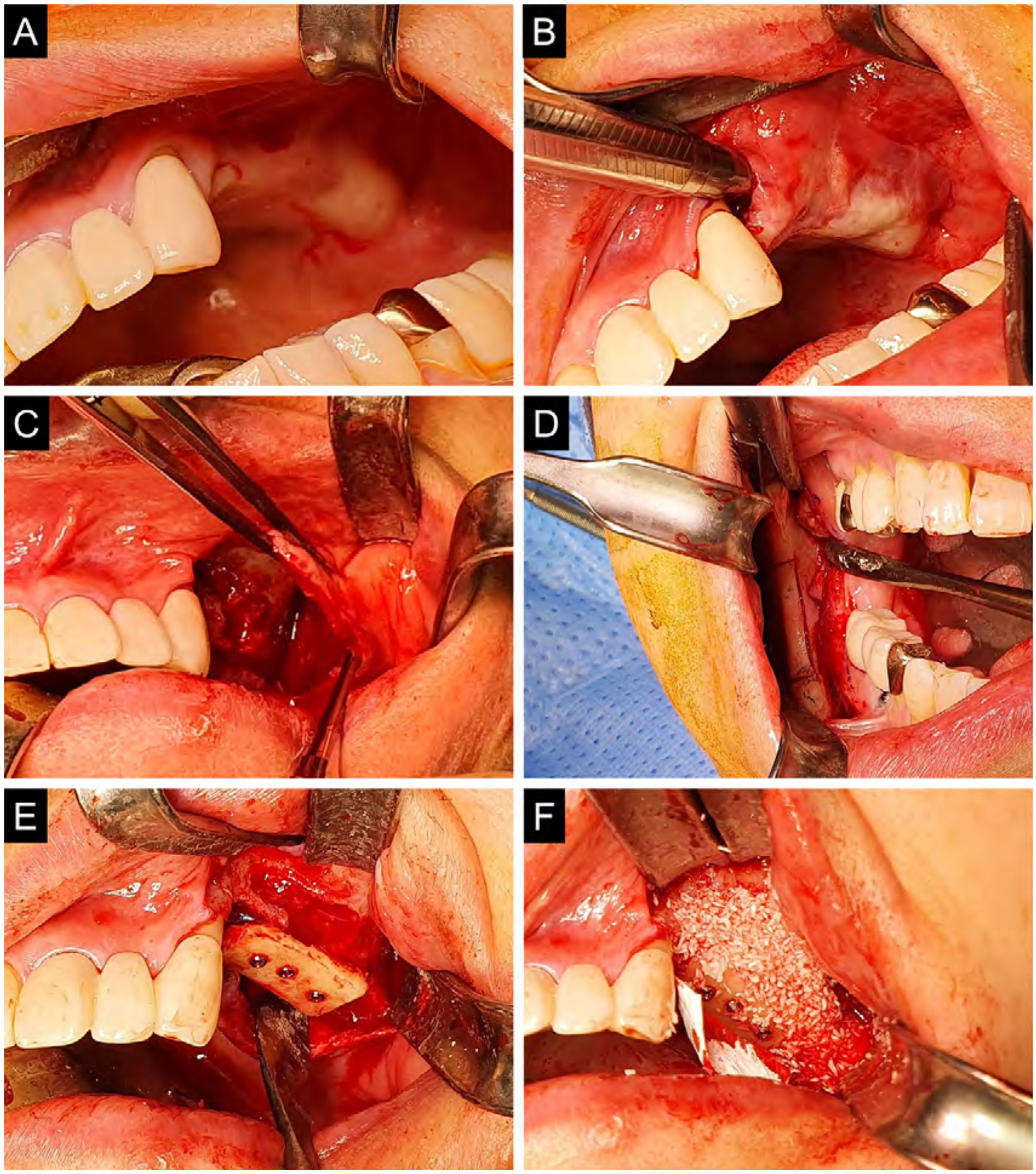

Figure 3. Intraoperative clinical photographs. (A) Initial intraoral photograph; (B) Subperiosteal tissue expansion; (C) Sinus floor elevation using the lateral approach and bone grafting; (D) Harvesting of the block bone from the mandibular ramus; (E) Stabilization of the ramal block bone; (F) Guided bone regeneration.

at the exposed bone and underwent the removal of screws for stabilization of the block bone and curettage of the infected particulated bone and inflamed soft tissue under local anesthesia. Postoperative medication was prescribed as follows: cefaclor 250 mg three times per day for 7 days and ibuprofen/arginine 200/185 mg three times per day for 7 days. Even though there were no signs of infection with decreased bony exposure 5 months after grafting, trimming of non-vitalized cortical bone was performed due to a sustained wound dehiscence, allowing for the exposed site to be completely re-epithelized. After 10 months of bone grafting, complete mucosal healing was observed without any significant complications, and the placement of three dental implants (Luna, Shinhung, Seoul, Korea) on #24 (4.5 × 11.5 mm), #25 (4.5 × 10.0 mm), and #26 (4.5 × 10.0 mm) (Diameter × Length) was performed under local anesthesia (Figure 5). There were no specific unusual complications until 3 months after implant placement.

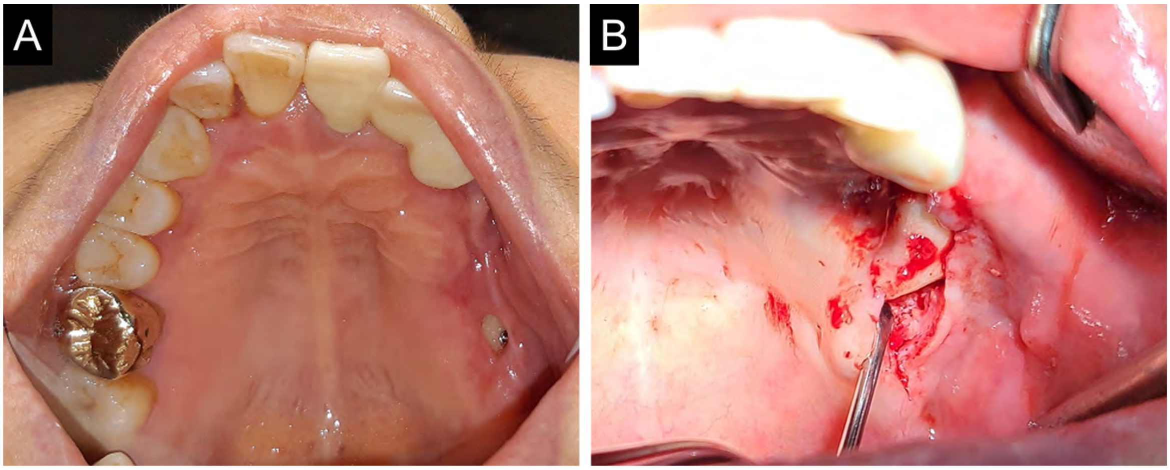

Figure 4. Management of the exposed graft bone. (A) Exposure of the grafted bone 4 weeks after bone grafting; (B) Curettage of the infected particulated bone and inflamed soft tissue 8 weeks after bone grafting.

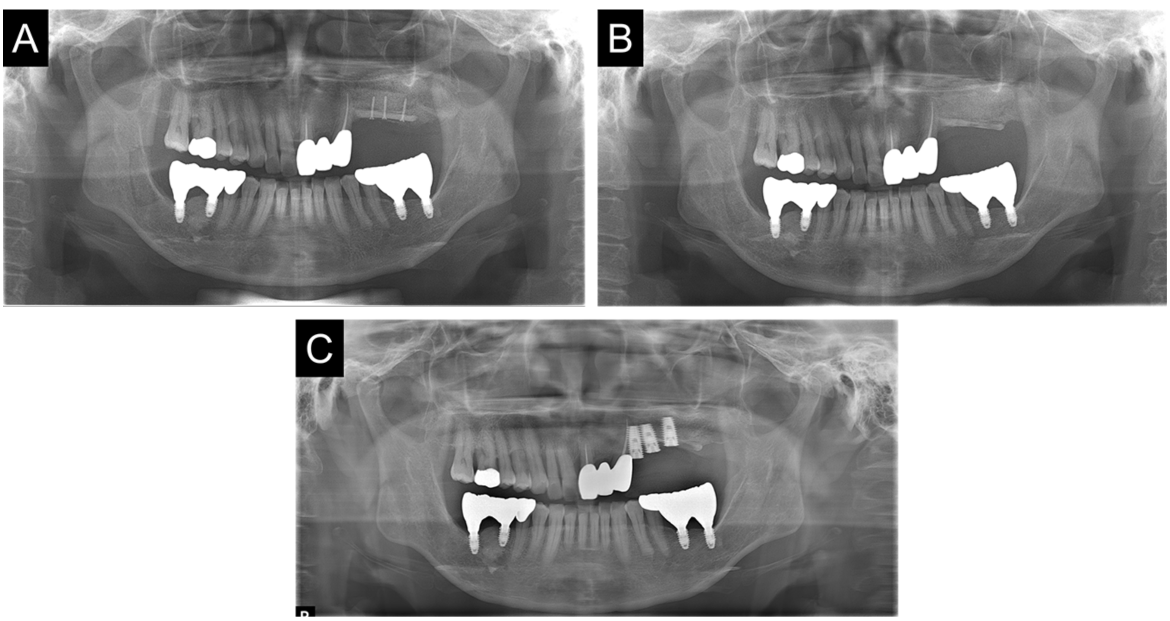

Figure 5. Panoramic radiographs after bone grafting. (A) Immediately after bone grafting; (B) After removal of the stabilization screws and curettage of the infected bone; (C) After implant installation.

DISCUSSION

Sufficient height and width of the residual alveolar ridge are essential to achieve optimal placement and stability of dental implants[11]. To increase the available alveolar bone in atrophic posterior maxilla, sinus bone grafting techniques and alveolar ridge augmentations are used frequently. Sinus bone grafting after maxillary sinus floor elevation through a lateral or crestal approach is a well-established and predictable surgical procedure with clinically successful outcomes. However, for patients with insufficient vertical height of the maxillary alveolar ridge, increase of available bone height using only sinus bone grafting can lead to unfavorable prosthetic results biomechanically and esthetically with improper crown-implant ratios[9]. In contrast, vertical ridge augmentation can provide a favorable crown-implant ratio with increased height of the alveolar ridge and enables the esthetic placement of prostheses. However, when insufficient residual alveolar bone height is mainly due to a severely pneumatized maxillary sinus, it is difficult to achieve sufficient residual alveolar bone required for optimal implant placement only with vertical ridge augmentation, and maxillary sinus bone grafting is necessary.

For alveolar ridge augmentation, the GBR technique using particulate bone substitutes and barrier membranes has been successfully performed for several decades, especially for widening the width of the alveolar bone[12]. Though the GBR technique using particulate bone substitutes is considered suitable when the defect is small, it can be challenging when the defect is large or for vertical bone augmentation because the particulate bone substitutes do not provide three-dimensional stability[13,14]. In addition, the use of a reinforced non-resorbable membrane or titanium mesh can increase the potential success of GBR for large defects or vertical augmentations, however, the use of these barriers has been reported to increase the required bone healing time and risk of dehiscence[8,15].

Block bone grafting has been used as another bone grafting method for large alveolar bone defects. Although various block bones, such as autogenous block bones, allogenic block bones, or xenogenous bone blocks, have been used, several investigators have proposed autogenous bone blocks as the gold standard for bone grafting due to its osteogenetic, osteoinductive, and osteoconductive properties[16-18]. Autogenous block bones can be harvested from iliac bone, ribs, the skull, clavicles, or the mandible. Among them, mandibular ramal bone is one of the most commonly used donor sites in alveolar ridge augmentations for implant placement due to its decreased morbidity and invasiveness[19]. Though several possible complications, such as inferior alveolar nerve injury and dental root injury, can occur, the surgical procedure for harvesting ramal bone is relatively easy compared to that for other donor sites with lower complications rates. In addition, this harvesting does not affect the facial morphology. With respect to postoperative bone resorption, it has been reported that membranous bone such as the mandible exhibits lower resorption compared to endochondral bone such as the iliac bone[20,21].

In this case report, the patient with a severely atrophied posterior maxilla successfully received the placement of multiple dental implants after simultaneous sinus bone grafting through the lateral approach and vertical alveolar ridge augmentation using a mandibular ramal block bone graft. Several investigators reported that simultaneous sinus bone grafting and vertical alveolar ridge augmentation exhibits several difficulties in the surgical procedures, which could be one of the factors that causes failure of the implant and graft[9,10]. Block bone in large volumes can make primary closure difficult, and the failure of tension-free primary closure through releasing incisions creates postoperative wound dehiscence, which can lead to graft failure. In addition, since the bone graft material is placed on either side of thin alveolar bone, delayed healing or partial necrosis of the grafted bone can occur due to poor blood supply. In this case report, wound dehiscence was observed at the distal region of the recipient site 4 weeks postoperatively, and the patient exhibited signs of infection 8 weeks after grafting.

Exposure of the grafted bone is one of the most common complications after bone grafting, and it can result in complete loss of the graft. In a recent systematic review by Sanchez-Labrador et al.[22], the calculated overall dehiscence rate was 12.8% for the xenogenic block bone graft group and 9.8% for the autogenous block bone graft group. However, exposure of the bone can be successfully treated by several conservative methods, including the application of chlorhexidine solution or removal of the necrotic part of the grafted bone[23]. Removal of the exposed region in the grafted bone can be repeated multiple times based on the extent of the exposed bone[24]. Penarrocha-Diago et al. reported that, although eight grafts exhibited dehiscence postoperatively, five showed re-epithelialization after application of chlorhexidine mouth rinse. In the study by Sanchez-Labrador et al.[22], the failure rate of block bone grafts was 6.1% for autogenous bone and 6.8% for xenogenic bone which was lower than the overall dehiscence rate.

For determination of successful management of exposed bone, the amount of time of bone exposure has been regarded as the most important factor for treatment[24]. Barone and Covani[7] reported 4 exposures of 129 grafted bone sites for maxillary ridge augmentation, which consisted of 3 early exposures and 1 late exposure. In their study, all the early exposed block bone was removed completely, whereas the grafted bone with late exposure was successfully treated with fixation screw removal. In the study by Proussaefs et al.[25], 2 patients with bone exposure at 3 months after grafting did not exhibit any clinical or histological necrotic changes, while 1 patient with bone exposure at 2 weeks after grafting showed necrosis of the grafted bone. In the present report, wound dehiscence was found 4 weeks after grafting, and the patient exhibited signs and symptoms of infection 8 weeks after grafting. Although exposure of the grafted bone occurred at a relatively early stage, it could be treated with minimal surgical intervention and conservative treatment including oral hygiene management and antibacterial mouth rinses. This might be because the infection was limited to particulate bone grafting posterior to the block bone. In addition, given that revascularization begins in the first week after bone grafting and lasts until 6-8 weeks[26], the grafted block bone might have already revascularized or was in the process of revascularization.

CONCLUSION

This case report suggests that simultaneous sinus bone grafting and ramal block bone grafting can be a feasible treatment option to overcome severely insufficient height and width of alveolar bone. Although exposure of the grafted bone can occur postoperatively, it can be treated conservatively with curettage of infected bone only when the exposed site is limited and the infection is well-controlled.

CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

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Clinical survey and working time evaluation in guided drilling for preparing a screw hole in implant-supported fixed prosthesis

Hai Yen Mai[1], Hang-Nga Mai[2], Du-Hyeong Lee[1,2]

[1]Department of Prosthodontics, School of Dentistry, Kyungpook National University, [2]Institute for Translational Research in Dentistry, Kyungpook National University, Daegu, Korea

Purpose: This study aimed to examine the prosthetic likelihood on the manufacturing and removal methods of implant-supported fixed prostheses and to compare the time taken to form a screw hole in implant-supported cement-retained prostheses according to whether or not a digital drilling guide template is used in the oral cavity.

Materials & Methods: Twenty-five dentists participated in this study. A survey was conducted to assess participants' prosthetic likelihood on the fabrication and removal of implant-supported fixed prostheses. To make the study model, implants were placed in the mandibular molar at 0 and 30 degrees of angulation. Drilling guides for forming a screw hole were fabricated using digital technologies. The conditions were classified into four groups according to implant angulation and use of the guide. Participants prepared a screw hole through the crowns in the dental phantom models, and the working time was recorded. Statistical significance was assessed using the two-way analysis of variance (ANOVA) ($\alpha = 0.05$).

Results: The survey showed that clinicians tend to prefer easy removal and reuse of implant prostheses. The guided drilling required a significantly shorter time in hole formation than the freehand drilling at the 30-degree setting ($P < 0.05$), whereas there were no differences at the 0-degree setting.

Conclusions: The ease of removal and reuse of prostheses are elements of interest in clinic. The use of a drilling guide for locating the abutment screw highly reduces the working time for severely angulated implants. **(THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2021;13(1):23-28)**

Key words: Implant, Fixed prosthesis, Guide template, Survey, Screw hole, Preparation time

INTRODUCTION

The cement-retained implant fixed prostheses use cement to hold the prosthesis to the implant abutment. The cement layer between the prosthesis and the abutment reduces the possibility of mechanical complications due to the misfit between the components and stress concentration[1]. Main advantage of cement retention type is high esthetics and easy formation of the occlusal surface because a screw hole is not present. Meanwhile, when the prosthesis needs to be removed due to biological, mechanical, and esthetic complications in cement-retained implant prostheses, it may be difficult to separate from the abutment. Mechanical sectioning method using cutting burs causes destructive damage to the prosthesis, preventing reuse and damaging the abutment and underlying implant[2].

Forming a screw hole in the oral cavity for the removal of cement-retained implant prostheses is a conservative procedure and can increase the reusability of the prosthesis. However, because it is difficult to accurately estimate the position of the abutment, the hole may be formed in the wrong position. In order to improve the accuracy of the formation of screw access holes in the oral cavity, various visual and physical guidance methods have been introduced. The methods used in the early days were marking the area corresponding to the position of the abutment on the occlusal surface with colored dots[3,4], image taking of the position of the abutment in manufacturing the prosthesis as a digital photograph during the prosthetic treatment process[5], and radiography taking as using apical radiographs or cone-beam computed tomography images[6,7]. A physical method of using a guide template with a simple structure using a vacuum-pressed

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Corresponding Author: Du-Hyeong Lee, Department of Prosthodontics, School of Dentistry, Institute for Translational Research in Dentistry, KyungPook National University, 2175 Dalgubeoldae-ro, Jung-Gu, Daegu 41940, Korea. Tel: +82-53-600-7676, Fax: +82-53-427-0778, E-mail: deweylee@knu.ac.kr

resin plate was also introduced[8].

With the introduction of computer-aided design and computer-aided manufacturing (CAD/CAM) methods into dentistry, digital fabrication of guide templates became possible[9,10]. It has been reported that the use of the guide template significantly improves the accuracy of hole formation[11,12]. Although there have been studies on the accuracy of the hole drilling guide template, the effect of the use of the guide template on the working time required for screw hole formation has not been investigated. The first purpose of this study was to examine the current status of the manufacturing and removal methods of implant-supported fixed prostheses used by dentists in clinical practice. The second purpose of this study was to compare the time taken to form a hole in an implant-supported cement-retained prostheses accord-

설문지 번호 (   )

임플란트보철물 제거 가이드 설문지

KNUDH 경북대학교치과병원

•각 질문에 대해 볼펜을 이용하여 해당 난에 표시해주십시오. (예: ☑)

I. 사용하고 있는 고정성 임플란트 보철물의 제작방식은 무엇인가요? (빈도에 따라 □ 뒤에 1,2,3 기재)
- 나사-시멘트 유지형(screw-cement retained prosthesis)…………………□
- 나사 유지형(screw retained prosthesis)……………………………………□
- 시멘트 유지형(cement retained prosthesis)……………………………… □

II. 사용하고 있는 고정성 임플란트 보철물의 교합면 재료는 무엇인가요? (빈도에 따라 □ 뒤에 1,2,3 기재)
- 지르코니아(Zr)…………………………………………………………………□
- 장석계 도재(Porcelain)………………………………………………………□
- 비귀금속합금(Non-precious metal: Ni-Cr, Co-Cr, Ti)…………………□
- 귀금속합금(Precious metal)…………………………………………………□

III. 시멘트 유지형 보철물을 제거 시 가장 선호하는 방법은?
- 버로 절단하여 보철물 제거(bur sectioning of prosthesis)…………………□
- 나사접근구멍을 형성하여 보철물과 지대주를 함께 제거………………………□
  (formation of screw hole, and remove prosthesis-abutment complex
- 기타 (   )………□

IV. 기존 보철물을 제거 후 활용하는 방식은 무엇인가요?
- 재사용한다
  - 영구(permanent) 보철물로 활용…………………□
  - 임시(interim) 보철물로 활용……………………□
- 재사용하지 않는다…………………□3

V. 기존 보철물 제거 시 중요하게 생각하는 부분은 무엇인가요? (우선순위에 따라 □ 뒤에 1,2,3,4 기재)
- 제거 시간……………………………………………………………… □
- 제거 용이성…………………………………………………………… □
- 보철물 재사용 유무……………………………………………………□
- 제거용 절삭버의 손실…………………………………………………□
- 기타 (   )………□

Figure 1. Questionnaire for assessing participants' prosthetic likelihood.

ing to whether or not a digital guide template is used when forming a screw hole in the oral cavity.

MATERIALS AND METHODS

1. Participant recruitment and questionnaire survey

Twenty-five dentists were recruited who had a similar educational background and practical training. To assess participants' prosthetic likelihood on implant-supported fixed prostheses, a survey was conducted. The survey comprised five questions assessing types of implant prosthesis used, prosthesis removal methods, and preference for reuse of removed prosthesis (Figure 1). Dentists were asked to respond to the questions according to frequency and their priority. Ethical approval for the study was granted by the institutional review board of Kyungpook National University Dental Hospital (KNUDH-2019-12-01-01).

2. Study model preparation and working time measurement for screw hole formation

Two partial edentulous mandibular stone models with the second molar missing were prepared. An implant with 4.5 mm in diameter and 10.0 mm in height (AnyOne, MegaGen, Daegu, Korea) was placed at angles of 0 or 30 degrees (Figure 2A). Then, a prefabricated prosthetic abutment (Anyone abutment, MegaGen) was connected to the implant, and digitized by using an intraoral scanner (CS3600, Carestream, Rochester, NY, USA). Definitive zirconia crowns (N = 50) were fabricated by using a CAD/CAM method (IDC D1, Amann Girrbach, Koblach, Austria; NextDent 3100, Prettau, Zirkonzhan, Bruneck, Italy) (Figure 2B).

The experimental groups were divided into four conditions based on the implant placement angles and the use of the drilling guide: 0-degree implant, freehand drilling (0F); 0-degree implant, guided drilling (0G); 30 degrees tilted implant angle, freehand drilling (30F), 30 degrees tilted implant, guided drilling (30G). The screw-hole drilling guides were made by using digital fabrication technologies (Figure 3)[9,10]. The fabricated study casts were positioned in the phantom heads (PH-1-DK, Shinhung, Seoul, Korea), and the dentists were directed to form a screw hole on the implant-supported cement-retained restoration in the mandibular molar region. The hole preparation was performed first using end-cutting burs (FG #330, Komet Dental, Lemgo, Germany; Diamond point FG #265R, Shofu, Kyoto, Japan), and widened using a torpedo bur (CR-26F, Mani, Tochigi, Japan). When the drilling was completed, the abutment screw was loosened and the prosthesis-abutment complex was collected.

3. Statistical analysis

The means and standard deviations of the working time were calculated. Statistical comparisons among groups were performed by using the analysis of variance (ANOVA). All statistical analyses were carried out using statistical software SPSS (IBM SPSS Statistics v25.0, IBM, Armonk, NY, USA) at a 0.05 significance level.

RESULTS

The results of the survey are shown in Figure 4. In prosthesis fabrication, the screw-cement retention type is used the most in

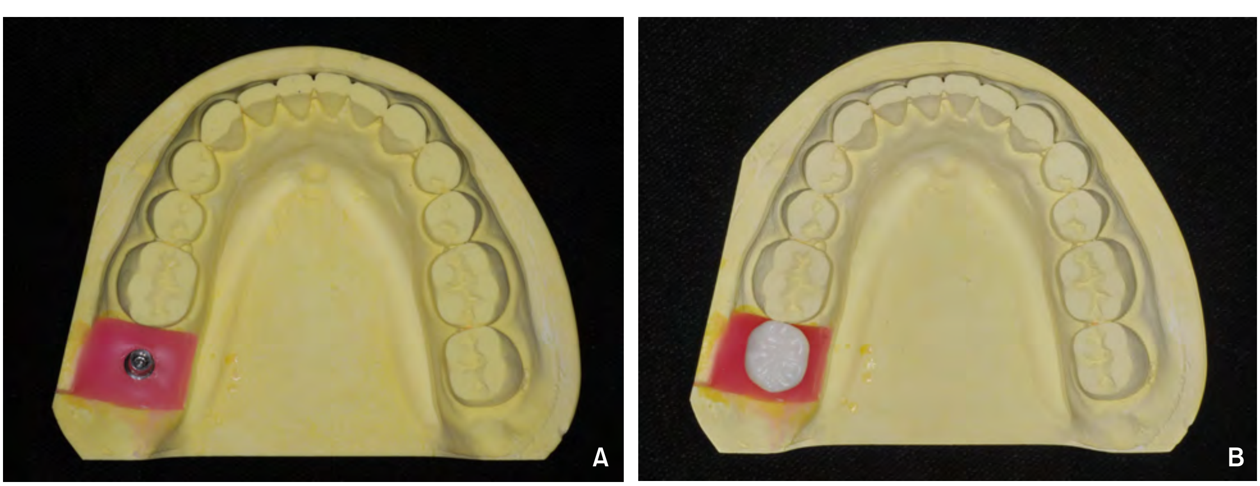

Figure 2. Study model fabrication. (A) Implant placement, (B) Zirconia crown delivery.

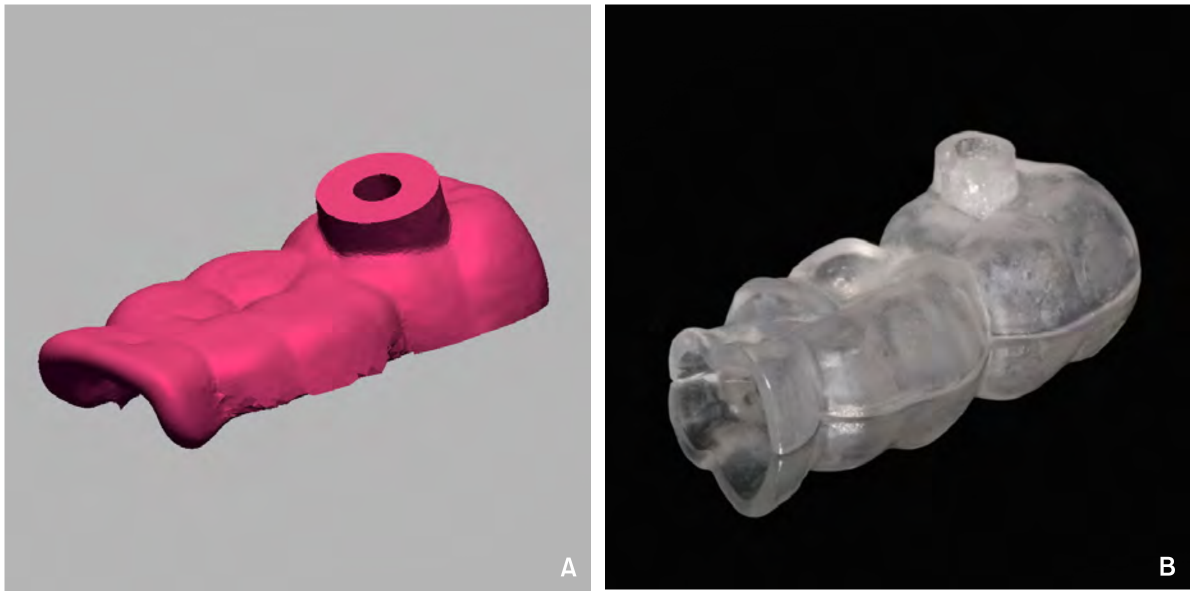

Figure 3. Screw–hole drilling guide. (A) Computer–aided design. (B) 3D–printed guide template.

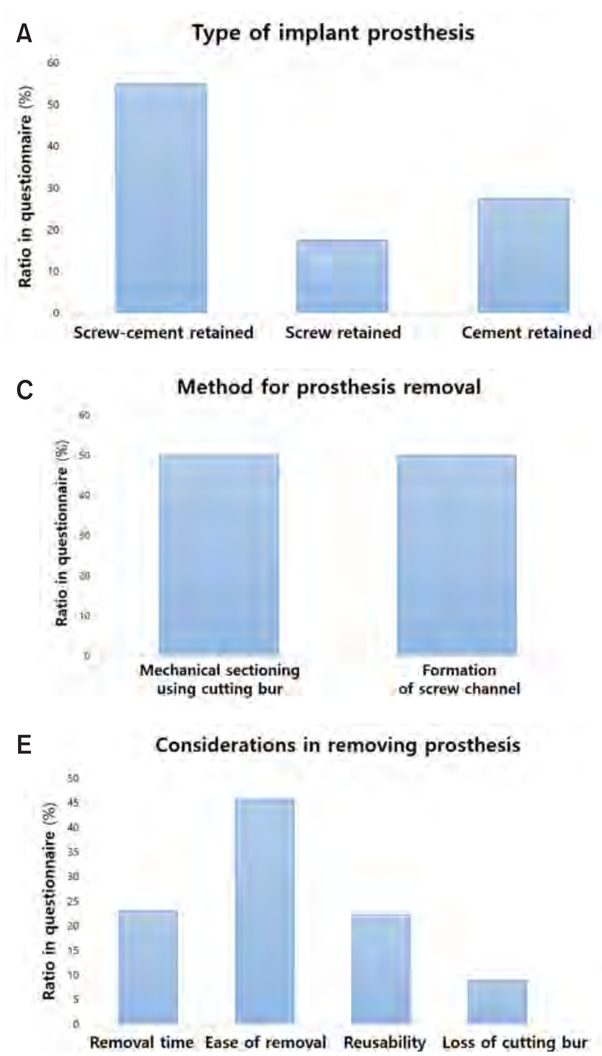

Figure 4. Survey results on the participants' prosthetic likelihood. (A) Type of implant prosthesis, (B) Material in occlusal surface, (C) Method for prosthesis removal, (D) Reuse of removed prosthesis, (E) Considerations in removing prosthesis.

Table 1. Means (SDs) of time used for screw-hole formation

	0F	0G	30F	30G	*P*
Time used (min)	5.18 (2.10)[a]	4.68 (1.76)[a]	10.91 (6.82)[b]	6.16 (3.46)[c]	<0.001

0F: 0-degree implant, freehand drilling; 0G: 0-degree implant, guided drilling; 30F: 30-degree tilted implant, freehand drilling; 30G: 30-degree tilted implant, guided drilling.
The same superscript letter indicates no statistical difference in the raw.

clinic, followed by the cement retention type and screw retention type. As to the material for occlusal surface, monolithic zirconia and non-precious alloys are commonly used. Participants had a similar preference to mechanical sectioning and screw-hole formation in retrieving prostheses. Most of the participants agreed that temporary reuse of the removed prosthesis is needed. As considerations during prosthesis removal, most participants responded that ease of removal is important, and the working time for removal and the re-usability of removed prosthesis should be taken into account.

The working time used for screw-hole formation is shown in Table 1. Generally, the working time was smaller in the guided drilling than in the freehand drilling. One-way analysis of variance presented that the time reduction in the guided drilling was significant in the 30-degree tilted implant condition ($P < 0.05$).

DISCUSSION

This study was designed to investigate the clinician's likelihood on the implant-supported fixed dental prosthetic treatment, and determine the time efficacy of the use of drilling guide in the formation of the screw hole in the prosthesis. In the questionnaire survey, most of the participants preferred the screw-cement retention type. When a screw hole does not exist, both the mechanical sectioning and hole formation can be used, and the participants responded easy removal of the prosthesis and the reuse of prosthesis might be important. Meanwhile, in the working time for preparing screw holes, the use of a drilling guide significantly decreased working time when the guides were applied to the tilted implants.

Anatomical limitations, such as pneumatization of the maxillary sinus, the proximity of the nerves, and lack of available bone, could cause implants to be placed in tilted position[13]. Sometimes, the angulated placement of implants is intentionally planned to avoid excessive bone grafting and to achieve esthetic goals[14]. In the tilted implants, it is difficult to estimate the position of the abutment screw because the screw is usually located out of the center of the crown. Based on our findings, the efficacy of the guide use was markedly greater as the implant was placed with a 30-degree angulation setting. These results correspond well with those presented in the earlier studies[11,12]. The previous studies examined the accuracy of hole formation in various implant inclination and bucco-lingual positions, and demonstrated that the guided drilling improves hole preparation. In particular, the use of guided drilling was meaningful in the implants highly angulated or malposed. Collectively, the present study proved the intimate relationship between the drilling guide and hole formation time, which could affect the convenience and satisfaction of clinicians and patients in clinic.

Implant therapy has become a daily routine procedure, and the number of implantations is further increasing. Thus, valid methods to retrieve implant prostheses become more essential. Although the survey in this study showed clear tendency and likelihood, bigger data might be required to analyze the results between different experiences and ethnic groups. The findings in the in vitro study should also be validated by comprehensive clinical studies. Thus, to confirm the results of the present study, further human factor-related studies are needed on the convenience and satisfaction in guided drilling for hole formation.

CONCLUSION

Within the limitations of this study, the following conclusions can be drawn. Clinicians showed high interest in the easy removal of implant prostheses and the reuse of prostheses in the accompanying survey. The effect of the drilling guide on the working time reduction of the screw-hole formation within the crown was evident when an implant was tilted by an angle of 30 degrees.

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A retrospective clinical study on the evaluation of the survival rate and marginal bone resorption of implant placement immediately after tooth extraction

Sangrae Park, Miri Moon, Seulki Lee, Hyehyun Jo, Hyein Park, Yongbin Lee

Department of Oral and Maxillofacial Surgery, Hankook General Hospital, Cheongju, Korea

Purpose: The purpose of this study was to analyze the clinical results of screw retained type and locking taper type implants immediately placed in the extraction site to determine the implant survival rate and to analyze the marginal bone resorption of both types of implants during the healing process.

Materials & Methods: From January 1, 2012 to December 31, 2016, 211 implants placed immediately after tooth extraction in 158 patients at Cheongju Hankook Hospital were followed up for up to 6 years for survival rate and mesiodistal marginal bone resorption. The implants used were 96 screw retained type (AF) implants and 115 locking taper type (SF) implants from SNUCONE®.

Results: 1) Two out of 211 implants in a total of 158 patients failed, resulting in a survival rate of 99.05%. The cause of the failed implant was the lack of initial fixation power due to lack of bone quality and bone mass. 2) The marginal bone resorption was 0.44 ± 0.59 mm in the mesial marginal bone and 0.39 ± 0.71 mm in the distal marginal bone for about 4 years after the prosthesis was installed, and very good results were obtained. In detail, in AF implants, mesial bone resorption was 0.41 ± 0.58 mm, distal marginal bone resorption was 0.38 ± 0.83 mm, and in SF implants, mesial marginal bone resorption was 0.46 ± 0.59 mm, and distal marginal bone resorption was 0.39 ± 0.58 mm, there was no statistically significant difference between the two groups ($P > 0.05$).

Conclusions: Previously, there were not many papers comparing the screw retained type implant and the locking taper type implant in implants placed immediately after tooth extraction, so this study was conducted. If the initial fixation with the alveolar bone is secured when the implant is placed immediately after tooth extraction, it is thought that a high predictive treatment result can be obtained not only for screw retained type implants but also for locking taper type implants. (THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2021;13 (1):29-35)

Key words: Immediate implant placement, Marginal bone resorption, Survival rate

INTRODUCTION

Since implants were first introduced by Branemark, implants have become a predictive and universal treatment method for tooth loss[1]. With remarkable advances in surface treatment, implantation equipment, and implantation methods, the time for implant placement after tooth extraction is also moving forward.

Depending on the timing of implant placement after extraction, immediate implantation is performed immediately after extraction, recent implantation is placed after 6~8 weeks to allow soft tissue to heal, delayed implantation is performed 6 months after bone grafting if the bone in the receptor is not suitable for placement, and mature implantation, which is placed after 9 months or more so that the socket is completely healed by bone[2]. Immediate implant placement after extraction is a treatment compared to the traditional method of waiting for more than several months for bone healing of the extraction socket. Not only can the period be reduced, but it also has the advantage of reducing the number of surgeries, and has abundant healing and regeneration ability of the tooth extraction site. It is easy to select the implant position according to the position of the tooth before extraction, and in the case of the anterior region, it can be esthetically advantageous because natural interdental papilla can be secured by performing restoration immediately after extraction. Due to these many advantages, despite the burden of immediate procedure after tooth extraction, implants placed immediately after tooth ex-

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Corresponding Author: Yongbin Lee, Department of Oral and Maxillofacial Surgery, Hankook General Hospital, 106 Danjae-ro, Sangdang-gu, Cheongju 28713, Korea, Tel: +82-43-222-6175, Fax: +82-43-255-7007, E-mail: ybpurpleroo@gmail.com

traction are considered a good treatment option for clinicians[3].

In this study, the immediate implantation technique was used, which was placed immediately after tooth extraction, and the clinical results were analyzed using AF and SF implants, the implant survival rate was investigated, and the amount of marginal bone resorption during the healing process was analyzed.

MATERIALS AND METHODS

1. Subjects

From January 1, 2012 to December 31, 2016, at Cheongju Hankook Hospital, 211 implants placed immediately after tooth extraction in 158 patients were investigated for up to 6 years of survival and mesiodistal marginal bone resorption. The implants used were AF and SF implants from SNUCONE®.

1) Age and gender distribution of patients

The patient group consisted of 78 males and 80 females, and a total of 211 implants were placed. The age distribution was 26~86 years old, 4 people in their 20s, 6 people in their 30s, 6 people in their 40s, 36 people in their 50s, 68 people in their 60s, 36 people in their 70s, and 2 people in their 80s (Table 1, 2).

2) implant location and distribution

Of the total 211 implants, 126 were placed in the maxilla and 85 in the mandible, 65 in the anterior region, 72 in the premolar region, and 74 in the molar region (Table 3).

3) Types of implants

The implants targeted in this study are SNUCONE®'s AF implants and SF implants. AF implant is a screw type, and it has a shape that is internally connected to the abutment and has a tapered tip, so it has excellent initial fixation power, and can provide adequate strength to the dense bone in the marginal area and increase bone density. The SF implant is in the form of a locking taper and has a sloping shoulder on the top of the fixture to have resistance to marginal bone loss. Each implant and abutment design is as follows (Figure 1, 2). Of the 211 implants placed in 158 patients in this study, 96 were AF implants and 115 were

Table 1. Patient distribution according to gender

Gender	Number of patient (% of patients)	Number of implant (% of implant placed)
Male	78 (49.37%)	103 (AF40, SF63) (48.81%)
Female	80 (50.63%)	108 (AF56, SF52) (51.18%)
Total	158	211

Table 2. Patient distribution according to age

Age	Number of patient (% of patients)	Number of implant (% of implant placed)
21~30	4 (2.53%)	5 (2.37%)
31~40	6 (3.80%)	8 (3.79%)
41~50	6 (3.80%)	6 (2.84%)
51~60	36 (22.78%)	47 (22.27%)
61~70	68 (43.04%)	92 (43.60%)
71~80	36 (22.78%)	51 (24.17%)
81~90	2 (1.27%)	2 (0.95%)
Total	158	211

Table 3. Numbers of implants placed according to location in arch

	Maxilla	Mandible	Total
Anterior	48	17	65
Premolar	42	30	72
Molar	36	38	74
Total	126	85	211

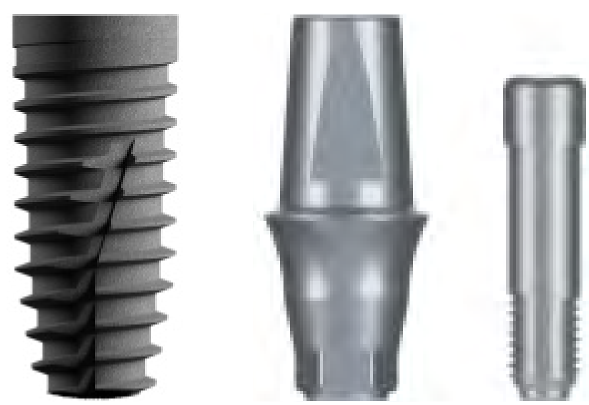

Figure 1. AF fixture and abutment (SNUCONE® Co., Korea).

Figure 2. SF fixture and abutment (SNUCONE® Co., Korea).

SF implants.

4) Implant length and diameter

Three types of implant lengths were used: 8 mm (79 pieces), 10 mm (97 pieces), and 12 mm (35 pieces). The implant diameters were 3.5 mm (6 pieces), 3.8 mm (18 pieces), 4.3 mm (100 pieces), 4.8 mm (58 pieces), 5.3 mm (19 pieces), and 5.8 mm (10 pieces) were used.

2. Methods

Implant surgery was usually performed in one or two approaches under local anesthesia. Whether or not the second operation was performed was decided by the operator according to the initial stability of the implant during surgery. All implants were AF and SF implant systems from SNUCONE®, and were placed according to the protocol using the manufacturer's dedicated drill.

After the healing period after surgery, prosthetic work was performed, and SNUCONE® products were used for all abutments used for upper prosthetic restoration. When the final prosthesis was installed, patients were asked to visit the clinic every 6 months or 1 year after installation to undergo plaque control, clinical examination, and radiographic examination.

The implant survival rate was evaluated according to the criteria for success presented by Rosen et al., and the evaluation according to the implant failure period was based on a suggestion by Rosenberg et al. in 2004. Classification according to the implanted position was divided into 6 parts: maxillary anterior, premolar, molar, mandibular anterior, premolar, and molar, and the survival rate and marginal bone resorption were compared for each part. Also, the amount of marginal bone resorption according to the type of implant was investigated. For the amount of marginal bone resorption, mesial and distal bone changes were measured based on the platform of the implant on the panorama by comparing radiographs before and after the functional load of the implant prosthesis was applied. For statistical analysis on the amount of bone resorption, IBM SPSS Statistics program was used and Mann-Whitney test method was used.

RESULTS

1. Overall survival rate

In this study, 211 implants placed immediately after tooth extraction were followed up for up to 6 years in 158 patients. During the total follow-up period, two implants were removed, all of which failed before loading the implant prosthesis, and the survival rate was 99.05%.

2. Survival rate according to patient gender and age

In this study, the implant survival rate according to the patient's gender was 99.10% in men and 100% in women. The survival rate according to the age of the patients was 98.88% because one implant failed in the 51-60 year old patient group, and 98.18% because one implant failed in the 61 to 70 year old patient group.

3. Survival rate according to implant placement location, diameter and length

The survival rate according to the implantation location was 94.44% in the maxillary molars, and 100% in other areas (Table 4).

The survival rate according to the diameter and length of the implant is as follows. 58 implants with a diameter of 4.8 mm were placed, and one of them failed, showing a survival rate of 98.28%, and one out of 10 implants with a diameter of 5.8 mm failed, showing a 90% survival rate. As for the survival rate for the implant length, 2 out of 79 implants with a length of 8 mm failed, showing a survival rate of 97.47%.

4. Marginal bone resorption

The marginal bone resorption was 0.44 ± 0.59 mm in the mesial marginal bone and 0.39 ± 0.71 mm in the distal marginal bone

Table 4. Survival rate of implant according to implant location

Site		State		Survival rate (%)
		Placed	Failed	
Maxilla	Anterior	48 (AF27, SF21)	0	100
	Premolar	42 (AF, 14SF28)	0	100
	Molar	36 (AF, 19, SF17)	2 (SF2)	94.44
Mandible	Anterior	17 (AF8, SF9)	0	100
	Premolar	30 (AF10, SF20)	0	100
	Molar	38 (AF18, SF20)	0	100

for about 4 years after the prosthesis was installed, and very good results were obtained. In detail, the amount of marginal bone resorption in AF implants and SF implants is as follows (Table 5). The amount of marginal bone resorption between the two types of implants according to the placement location is as follows (Table 6~8).

5. Failed implant analysis

Two implants did not satisfy the survival criteria. One was a locking taper fixture with a diameter of 4.8 mm and a length of 8 mm, implanted in #27, a male in his 50s. The other was a locking taper fixture with a diameter of 5.8 mm and a length of 8 mm that was placed on #26, a male in his 60s. All implants were placed in the position of the maxillary molars, and they were floating teeth at the time of the first visit, and due to severe bone loss, the thickness of the remaining alveolar bone below the maxillary sinus floor was less than 2 mm, so it is presumed that osseointegration failed because it was difficult to obtain initial fixation.

Table 5. Marginal bone resorption of implant according to implant type

	Bone resorption		
	Mesial (mm)	Distal (mm)	Mean (mm)
AF	0.41 ± 0.58	0.38 ± 0.83	0.40 ± 0.72
SF	0.46 ± 0.59	0.39 ± 0.58	0.43 ± 0.59
P value	0.643	0.737	0.546

Table 6. Marginal bone resorption of implant according to implant location (AF + SF)

Site		Bone resorption		
		Mesial (mm)	Distal (mm)	Mean (mm)
Maxilla	Anterior	0.44 ± 0.63	0.45 ± 0.54	0.44 ± 0.59
	Premolar	0.52 ± 0.63	0.60 ± 0.91	0.56 ± 0.78
	Molar	0.43 ± 0.49	0.30 ± 0.67	0.36 ± 0.59
Mandible	Anterior	0.43 ± 0.42	0.40 ± 0.78	0.42 ± 0.63
	Premolar	0.37 ± 0.53	0.19 ± 0.67	0.23 ± 0.61
	Molar	0.41 ± 0.65	0.30 ± 0.59	0.35 ± 0.62

Table 7. Marginal bone resorption of implant according to implant location (AF)

Site		Bone resorption		
		Mesial (mm)	Distal (mm)	Mean (mm)
Maxilla	Anterior	0.46 ± 0.63	0.43 ± 0.58	0.44 ± 0.60
	Premolar	0.46 ± 0.67	0.76 ± 1.18	0.61 ± 0.97
	Molar	0.44 ± 0.51	0.30 ± 0.83	0.37 ± 0.69
Mandible	Anterior	0.61 ± 0.46	0.46 ± 1.03	0.54 ± 0.80
	Premolar	0.37 ± 0.47	0.21 ± 0.82	0.29 ± 0.67
	Molar	0.22 ± 0.53	0.16 ± 0.58	0.19 ± 0.55

Table 8. Marginal bone resorption of implant according to implant location (SF)

Site		Bone resorption		
		Mesial (mm)	Distal (mm)	Mean (mm)
Maxilla	Anterior	0.43 ± 0.63	0.47 ± 0.48	0.45 ± 0.56
	Premolar	0.56 ± 0.61	0.51 ± 0.72	0.54 ± 0.67
	Molar	0.41 ± 0.46	0.30 ± 0.42	0.35 ± 0.45
Mandible	Anterior	0.27 ± 0.29	0.36 ± 0.46	0.31 ± 0.39
	Premolar	0.37 ± 0.56	0.19 ± 0.57	0.28 ± 0.57
	Molar	0.59 ± 0.71	0.43 ± 0.57	0.51 ± 0.64

DISCUSSIONS AND CONCLUSIONS

The advantage of implant placement immediately after tooth extraction is that it can achieve the esthetic purpose well in the anterior region while shortening the treatment period, reducing the number of surgeries, and minimizing the loss of soft and hard tissue. Since the height and width of the alveolar bone decreases rapidly after extraction, the resorption of the alveolar bone can be prevented if the implant is placed immediately after extraction. In addition, since it is placed based on the original tooth, there is an additional advantage that it can be placed in an ideal three-dimensional position. In particular, since esthetic recovery is more important than functional recovery in the maxillary anterior region, if the alveolar bone and gingival tissue before extraction are healthy, implant placement can be considered immediately after extraction to maintain them. On the other hand, disadvantages include invasion of major anatomical structures, failure to obtain initial fixation, higher risk of failure, and possible postoperative infection by activating inactive infected tissue[4].

Since Schulte et al. first reported an immediate implant in an extraction orthodontic area in 1978, steady research has been actively conducted, and a study comparing it with delayed implantation also reports a similar survival rate. In addition, Novae et al. reported a 2-year cumulative survival rate of 100% immediately after implant placement in infected dentition, and Chen and Covani et al. In another study, the immediate implant showed a relatively low survival rate compared to the delayed implant, but there was no significant difference in marginal bone loss and implant stability. In another study, immediate implant showed a relatively low survival rate 18203compared to delayed implant, but there was no significant difference in marginal bone loss or implant stability[5]. Chen et al. reported that there was no significant difference in the short-term survival rate between immediate and delayed implant placement, and Tan et al. reported that the 2-year survival rate reached 98% with immediate implant placement. As such, a high survival rate of immediate implants has been reported through several studies. However, immediate implant placement is not possible in all cases, and several studies including the papers published by Schwartz-Arad et al. Also, Penarrocha et al. stated that immediate implantation in the area with acute apical inflammation is an absolute contraindication[6].

In addition, since this procedure is difficult to obtain initial fixation and the amount of soft tissue is small, it is difficult to achieve primary fusion when a complex procedure such as bone-guided regeneration is accompanied, and it is a procedure sensitive to the skill of the operator. Therefore, for immediate implant success, thorough preoperative diagnosis and treatment plan are important factors, and systemic disease, periapical disease, cause of extraction, and implant system should be evaluated before surgery, and bone resorption patterns after extraction should be predicted.

As the use of implants has become more common, many studies have been conducted on the success rate and survival rate over a long period of time[7-14]. It is very difficult to determine which of the success rate and the survival rate is an excellent retrospective study method for implants, but the success rate is a realistic problem that it is difficult to investigate all the success criteria.

One of the objective indicators to judge the long-term success of implants is the level of marginal bone around the implant. The measurement of marginal bone height has an important meaning as a method to evaluate the success of implants[15]. Looking at the results of other authors who conducted studies on marginal bone resorption, Astrand et al.[16] used Branemark implants and Astra Tech implants. In a 5-year study using the abutment connection, when the amount of bone loss was measured by dividing the maxilla and the mandible 14 months after the abutment was connected, in the case of the Branemark implant, bone resorption of 1.97 ± 0.18 mm in the maxilla and 1.73 ± 0.20 mm in the mandible occurred compared to the time of implantation. In the case of Astra Tech implants, it was reported that bone resorption occurred at 1.74 ± 0.36 mm in the maxilla and 1.26 ± 0.20 mm in the mandible. Another study compared an implant placed immediately after tooth extraction with an implant placed on mature bone in 48 patients. There was no difference in direct implant-bone contact (DBC) and no bone resorption was observed, indicating clinical and radiological differences. When the screw-type implant is placed immediately after extraction, even if a barrier membrane or other regenerative material is not used, if the distance between the bone and the implant is less than 2 mm, the clinical results and osteointegration of implants in mature bone are significantly different. showed no significant difference[17].

The average absorption of marginal bone analyzed through radiographic examination in this study was 0.44 ± 0.59 mm in the mesial marginal bone and 0.39 ± 0.71 mm in the distal marginal bone for about 4 years after the prosthesis was installed, resulting in very good results. In detail, the mesial marginal bone resorption of the AF implant was 0.41 ± 0.58 mm, the distal marginal bone resorption was 0.38 ± 0.83 mm, the mesial marginal bone resorption of the SF implant was 0.46 ± 0.59 mm, and the distal marginal bone resorption was 0.39 ± 0.58 mm. There was no statistically significant difference between the two groups ($P > 0.05$). In the amount of marginal bone resorption according to the placement location, the distal maxillary premolars showed more bone resorption than the mandibular premolars ($P < 0.05$), and other Marginal bone resorption occurred more in the maxilla than in the mandible, but there was no statistically significant difference ($P > 0.05$). It is presumed that this is because the cortical bone is relatively thin compared to the mandible and the bone quality is poor. When comparing the two implants according to the placement location, the mesial marginal bone resorption in the mandibular anterior region was lower in SF, and the average marginal bone resorption in the mandibular molars was less in AF ($P < 0.05$). Although there was a difference in the amount of resorption, it is thought that it is meaningful to show good results with bone resorption within an average of 1 mm in all cases.

In addition, as a result of follow-up of a total of 211 implants, two failed, resulting in an overall survival rate of 99.75%. Two implants failed only in the maxillary posterior region with a survival rate of 98.41% in the maxilla and 100% in the mandible. All were molars accompanied by bone graft, and they occurred before loading the prosthesis. It is presumed that the maxillary molars have thinner cortical bone than the mandible or maxillary anterior teeth, and mostly consist of reticulated bone, which has disadvantageous bone quality for implant placement. Therefore, in case selection, if the thickness of the remaining alveolar bone below the maxillary sinus in the maxillary posterior region is less than 2 mm, it is difficult to obtain initial fixation power, which increases the possibility of implant failure. Immediately upon implantation, a method of securing initial fixation should be determined and a treatment plan established. Through CT, anatomical structures such as the maxillary sinus and inferior alveolar nerve are taken into consideration to confirm whether the alveolar bone mass is secured in the apical region for initial fixation. For good results of implants placed immediately after tooth extraction, accurate diagnosis and case selection before surgery are important. If sufficient bone mass cannot be secured, it is wise to change the treatment plan to a method other than implantation immediately.

During the investigation period, implants were placed immediately after tooth extraction at a rate of about 4%, and showed a high survival rate and low marginal bone resorption for an average of 4 years after placement. In particular, the locking taper type implant placed immediately after tooth extraction showed satisfactory results. Previously, there were not many papers comparing screw retained type implants and locking taper type implants in implants placed immediately after tooth extraction, so this study was conducted. If the initial fixation force of the conjunctiva is secured, it is thought that a high predictive treatment result can be obtained not only for screw retained type implants but also for locking taper type implants.

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Surgical management of medication-related osteonecrosis of the jaw: a retrospective study of Mronj patients

Won-Tack Shin[1], Won-Soek Yang[1], Heon-Young Kim[1], Jung-Hyun Park[2], Jin-Woo Kim[2], Sun-Jong Kim[1]

[1]*Department of Oral and Maxillofacial Surgery, Ewha Womans University Medical Center, Seoul Hospital,*
[2]*Department of Oral and Maxillofacial Surgery, Ewha Womans University Medical Center, Mok-dong Hospital, Seoul, Korea*

Treatment for patients with Mronj vary according to stage. Purpose of this study is to inform the effectiveness of surgical treatment on Mronj stage 2 and 3 patients. We investigated the success rates and treatment outcomes of two stages of Mronj patients who received surgical treatment from March 2019 to May 2021 at Oral and Maxillofacial Surgery Department, Ewha Womans University Seoul Hospital. Total of 55 patients who underwent surgical treatment were studied. Data was collected by analyzing clinical and radiological findings. Of the 54 patients observed, 36 stage 2 patients ended treatment within six months of surgery and 4 out of 18 stage 3 patients went through another surgery. From the study, we could conclude that treating Mronj patients with aggressive surgical intervention properly enables reconstruction of settled oral environment. **(THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2021;13(1):36-41)**

Key words: Mronj, Surgical treatment, Bone morphogenic protein

INTRODUCTION

American Association of Oral and Maxillofacial Surgery (AAOMS) defines Medication - related osteonecrosis of the jaw (Mronj) as ischemic necrosis of the jaw caused by current or previous treatment with antiresorptive or antiangiogenic agents.

Mronj can be diagnosed from exposed bone or bone probed through an intraoral or extraoral fistula in the maxillofacial region that has persisted for more than 8 weeks, and no history of radiation therapy to the jaws or obvious metastatic disease to the jaws.

Treatment for patients with Mronj vary according to stage. When treating patients in stage 1 and 2, conservative treatment—taking antibiotics and gargling with 0.12% chlorohexidine is recommended (Figure 1). However, many authors have recently supported the positive effect of resecting the affected area, expecting symptoms to relieve quickly.

Choi et al.[1] confirmed the success rate of surgical treatment of Medication - related osteonecrosis of the jaw (Mronj) by analyzing the outcomes of treatment. Of the 116 study subjects, 96 (83.0%) terminated treatment within 6 months of surgery, and 20 (17.0%) terminated treatment after 6 months or more. Treatment failure was observed in seven patients (6.0%). Purpose of this study was to inform the effectiveness of surgical treatment on Mronj stage 2 and 3 patients.

MATERIALS AND METHODS

We investigated the success rates and treatment outcomes of two stages of Mronj patients who received surgical treatment from March 2019 to May 2021 at Oral and Maxillofacial Surgery Department, Ewha Womans University Seoul Hospital.

Total of 55 patients who underwent surgical treatment were studied, 34 patients diagnosed as stage 2 and 21 patients as stage 3.

Data was collected by analyzing clinical and radiological findings. Items included in the analysis were as follows: (1) sex / age, (2) cause of necrosis (medication), (3) dental risk factor, (4) region of necrosis (5) stage of disease (6) number of surgery.

1. Surgical procedure

Surgical treatment of patients included removing the sequestrum and saucerization of adjacent cortical bones to achieve blood

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Corresponding Author: Sun-Jong Kim, Department of Oral and Maxillofacial Surgery, Ewha Womans University Medical Center, Seoul Hospital, 260 Gonghang-daero, Gangseo-gu, Seoul 07804, Korea, Tel: +82-2-6986-3401, E-mail: tinoshin@naver.com

Figure 1. Clinical pictures of Stage 2 Mronj showing exposed, necrotic bone.

circulation. Then curettage of granulation tissues were done in conjunction with recombinant human bone morphogenic protein (rhBMP-2) using collagen sponges as carriers. Finally, Leukocyte-rich and platelet-rich fibrin (L-PRF) insertion was held before flap closure of the operation site (Figure 2).

2. Case I

The first patient, an 83-year-old woman, was a patient with systemic diseases such as high blood pressure, arteriosclerosis, and osteoporosis. She was diagnosed with Mronj in October 2019 and was admitted to Department of Oral and Maxillofacial Surgery, Ewha Womans Seoul Hospital. Sequestrectomy of necrotic bone was performed under sedation and bone morphogenic protein was transplanted. After antibiotic adjuvant therapy during the hospitalization period, symptoms improved and she was discharged from the hospital in November 2019. Afterwards, the patient started Forsteo injection from December 2019, and was injected until March 2020. No further bone necrosis was observed, and it remained without complaints of pain (Figure 3).

3. Case II

The second patient, a 70-year-old woman with osteoporosis, was admitted to Department of Oral and Maxillofacial Surgery,

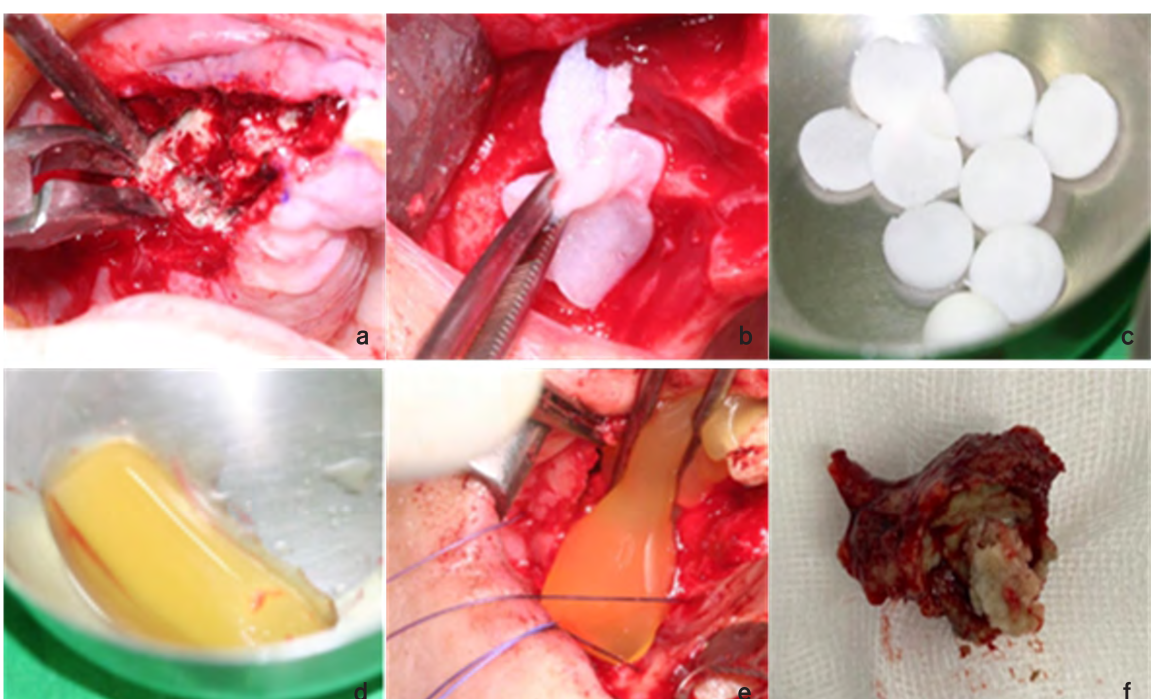

Figure 2. Surgical procedure of mronj stage 2 patients. (a) Removal of sequestrum. (b) Insertion of BMP. (c) BMP preparation. (d) PRF preparation. (e) Insertion of PRF before flap closure. (f) Removed sequestrum.

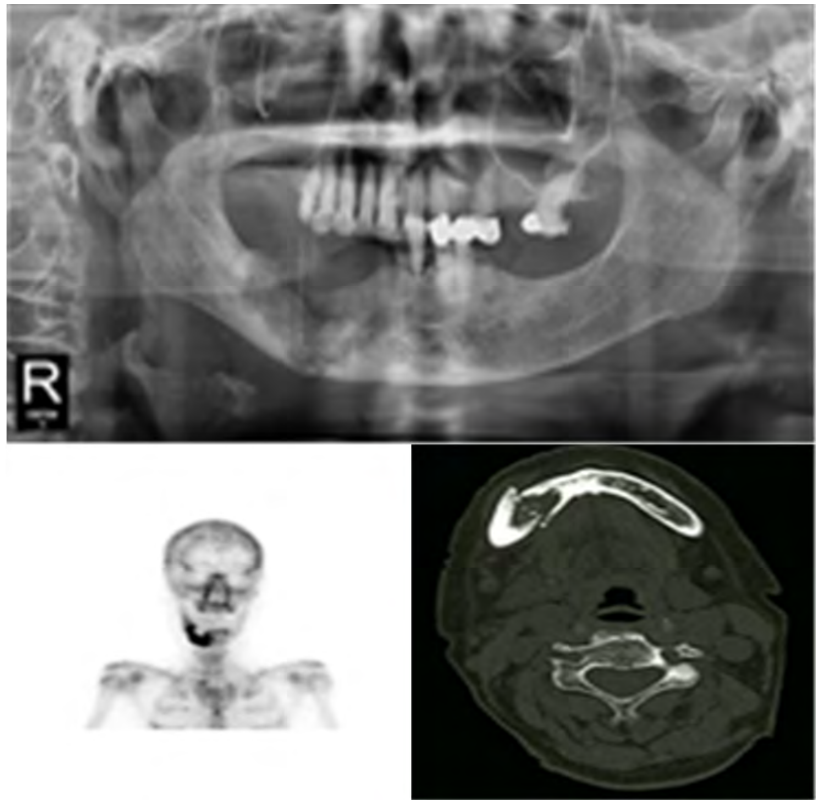

Figure 3. Panorama, CBCT, and bone scan of patient before operation (case 1).

Figure 4. Panorama, CBCT, and bone scan of patient before operation (case 2).

Ewha Womans Seoul Hospital for persistent pain after extraction of #34i and 35i implants. She was diagnosed with Mronj and hospitalized in August 2020. Sequestrectomy of necrotic bone was performed under general anesthesia and bone formation-inducing protein with platelet-rich fibrin were transplanted into the affected bone. Antibiotic adjuvant therapy was performed, symptoms improved, and the patient was discharged. Continuous follow-up was conducted and normal healing state was maintained (Figure 4).

RESULTS

In this retrospective study, 54 Mronj patients were enrolled to a surgical procedure. Patients' data were acquired analyzing clinical and radiological findings, including sex, age and medical records, any underlying primary diseases such as cancer and osteoporosis (Table 1). Overall, the mean age was 75.59 years old.

A total of 37 patients received Mronj related medication for the treatment of osteoporosis, and 17 patients administered medication including zoledronic acid from cancer and cardiovascular diseases. 33 out of 54 patients showed Mronj symptoms at their mandible region, which was 1.5 times the amount of maxilla symptoms. Characterization of the Medication - related osteonecrosis of the jaw (Mronj) is reported in Table 2.

Patients followed up at 7 to 10 days after surgery, and three to six months after then. Healing state of the bone were evaluated based on panoramic radiograph clinical examination (Figure 5). When symptoms worsened without healing during follow-up, another surgery was considered. Of the 54 patients observed, 36 stage 2 patients ended treatment within six months of surgery, and 4 out of 18 stage 3 patients went through another surgery.

DISCUSSION

Medication-related osteonecrosis of the jaw (Mronj) is primarily an adverse side effect of denosumab or bisphosphonates, or possibly anti - angiogenic cancer treatment. In general, the incidence of Mronj increases as the duration of drug administration increases[8], and is increased by antiresorptive agents like denosumab, which confer greater risk of Mronj than bisphosphonates. However, our data analysis shows that developed stages of Mronj does not correlate with the medical intake between osteoporosis and cancer patients.

In Min and Kang's study[4], use of rhBMP on bone defect sites after sequestrectomy increases the rate of new bone formation. Therefore, use of rhBMP on bone defect sites after sequestrec-

Table 1. Symptoms before surgery by patients with Mronj

Pus	Sinusitis	Bleeding	Bone exposure	Swelling	Pain	Bone fracture
20	5	2	3	17	17	1

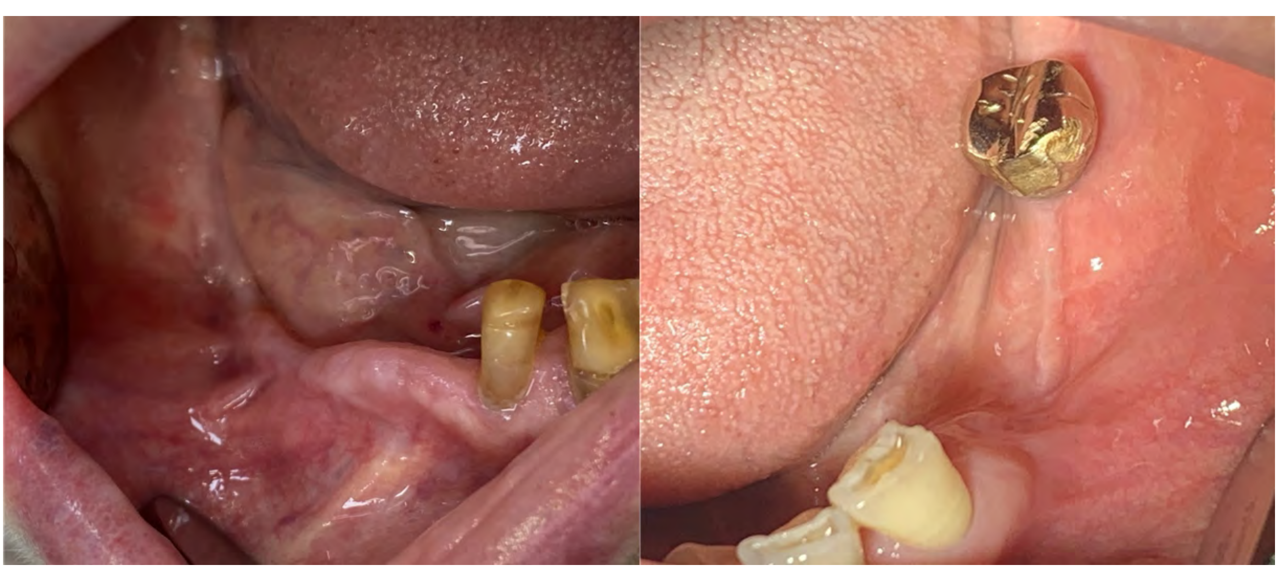

Figure 5. 6 months post–operative state (case 1, 2).

Table 2. Clinical characteristics of patients with Mronj

	Patients (n = 54)	Percentage (%)
Sex		
F	43	79.63
M	11	20.37
Age	75.59 (average)	
Osteoporosis	37	68.51
Non-osteoporosis	17	32.49
Cancer	9	17.68
Breast	2	
Prostate	1	
Multiple myeloma	1	
Stomach	4	
Cardiovascular disease	8	14.81
DM	14	25.95
Nervous system disease	4	7.4
Hypertension	31	57.4
Stage		
II	36	66.66
III	18	33.33
Region of necrosis		
Maxilla	21	38.89
Mandible	33	61.11
Dental risk factor		
Denture	13	24.07
Implant	21	38.89
Extraction	14	25.92
No dental factors	6	11.11
Inflammation findings including actinomycosis	12	22.22
Number of surgery		
Once	50	92.59
Twice	3	5.55
Third time	1	1.85

tomy could be a successful strategy in treatment of Mronj patients. Cicciù et al.[5] investigated the clinical effects of rhBMP in Mronj patients undergoing sequestrectomy and reported successful healing of the necrotic region. In their study, the experimental group identified an increase in radiographic index 6 months after surgery (Wilcoxon signed rank test, $P < 0.05$). In addition, there was a statistically significant difference in the radiographic index increase between experimental and control groups (Mann-Whitney U-test, $P < 0.05$), which may be the result rhBMP facilitating bone healing. This result suggests that rhBMP contributes to new bone formation.

PRF, containing white blood cells in combination with neutrophils and platelets, is able to enhance tissue wound healing, improve angiogenesis, and enhance tissue formation. In particular, the peculiarity of PRF consists in acting as a scaffolding material in which leukocytes, macrophages, neutrophils, and platelets present in supraphysiological doses release chemotactic factors and growth factors for wound healing[3]. So the use of PRF can improve the outcome of wound healing preventing osteonecrosis and leading to an early epithelization[6].

Marcianò et al.[2] also emphasized that surgical treatment of Mronj is a reliable approach to the disease, and they confirm that appropriate soft tissue management procedures represent an additional guarantee against wound dehiscence, favoring the release of endogenous growth factors and leading to the successful healing of Mronj disease.

CONCLUSION

This study was conveyed to determine the effectiveness of surgical treatment on stage II and III Mronj patients. 50 out of 54 Mronj patients (92.5%) in all stages achieved effective healing state after surgical treatments and failed in only 4 (7.4%) patients. Four patients in the failure group were initially diagnosed as

Mronj stage III before treatment and went through additional surgeries. From the study, we could conclude that treating Mronj patients with aggressive surgical intervention properly enables reconstruction of settled oral environment.

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Effects of teriparatide on the osseointegration of dental implants: a literature review of animal studies

Kyeong-Soo Ko, Byung-Kyu So, Eui-Seok Lee, Ho-Kyung Lim

Department of Oral & Maxillofacial Surgery, Korea University Guro Hospital, Seoul, Korea

Dental implant is one of the most effective methods for restoring missing teeth. Osseointegration, which is influenced by various factors including bone quality around the implant fixture, is important to achieve successful implantation. We investigated the relationship between osseointegration and teriparatide, which has been recently used as an alternative to bisphosphonate, in animal studies. A total of 10 studies were selected upon conducting a thorough search using the keywords '(parathyroid OR teriparatide) AND dental implants AND osseointegration' in PubMed/Medline databases. In these studies, various indicators, such as stability and fixation torque of implants, density of peri-implant bone, and formation of new peri-implant bone according to the administration of teriparatide were investigated. Since it was found that the administration of teriparatide had a positive effect on osseointegration in most animal studies, we would like to report the findings obtained through a literature review. **(THE JOURNAL OF KOREAN ACADEMY OF OSSEOINTEGRATION 2021;13(1):42-48)**

Key words: Teriparatide, Osseointegration, Dental implant, Animal study

INTRODUCTION

Dental implant is one of the most effective method for restoring missing teeth[1]. Although the success and survival rates of these implants are increasing with the development of materials and technologies, implant failure is a major burden for clinicians[1]. For a successful implant, sufficient primary stability must be obtained, which may be achieved by ensuring that the implant is firmly fixed to the bone[1]. Osseointegration is affected by various factors, such as surface and design of the implant fixture, density and quality of bone, and systemic diseases such as diabetes and other clinically relevant factors such as smoking[2-6].

Osteoporosis is a metabolic disease wherein the mass of bone per unit volume decreases as bone density decreases[7]. Patients with osteoporosis are at risk of bone fractures in various parts of the body, such as the spine and pelvis, and bisphosphonates are used as the primary treatment drugs to prevent these complications[8,9]. Bisphosphonates reduce bone resorption by limiting the function of osteoclasts, thereby effectively preventing fractures in osteoporotic patients[8,9]. However, medication-related osteonecrosis of the jaw (MRONJ) may occur when invasive treatment of the oral and maxillofacial region is performed in patients taking bisphosphonates[8]. Therefore, the need for a drug that can replace bisphosphonates has emerged, and teriparatide has recently been gaining attention[9]. Teriparatide is a recombinant human parathyroid hormone (rhPTH)[9], which, unlike bisphosphonates, induces the differentiation of osteoblasts, stimulates existing osteoblasts to form a new bone, and reduces apoptosis of osteoblasts[9]. Moreover, its fracture-preventing effect is as effective as that of bisphosphonates and is known to increase bone mineral density (BMD)[9].

Currently, the relationship between bisphosphonates and dental implants is relatively researched[10,11]. It has been reported that when bisphosphonates were used locally, there are positive effects on implant osseointegration, such as better stability, less peri-implant bone loss, high implant survival rate, and no toxicity[10]. However, the relationship between systemic administration of bisphosphonates and osseointegration remains controversial[11]. In studies using bisphosphonates systemically in an patients with osteoporosis, bone-to-implant contact (BIC) was higher in the group administered with bisphosphonates; however, the results were not significant[11].

Although many comparative studies have been conducted on bisphosphonates, research on the relationship between teriparatide and osseointegration of implants is currently in progress.

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Corresponding Author: Ho-Kyung Lim, Department of Oral & Maxillofacial Surgery, Korea University Guro Hospital, 148 Gurodong-ro, Guro-gu, Seoul 08308, Korea, Tel: +82-2-2626-3272, Fax: +82-2-837-6245, E-mail: ungassi@naver.com

Therefore, this study aimed to summarize the latest knowledge on the relationship between teriparatide and osseointegration through a review of animal studies.

MATERIALS AND METHODS

1. Search strategy

The search terms '(parathyroid OR teriparatide) AND dental implants AND osseointegration' were searched on the databases of PubMed/Medline until September 2021, and a total of 32 studies were obtained. Among these, we excluded the following: review articles and non-English studies, as well as studies not conducted on animals, focused on systemic diseases other than osteoporosis, implemented bone grafting, and those that were not related to osseointegration. As a result, 10 studies remained, half of which induced osteoporosis, while the other half did not.

2. Data extraction

In each study, we extracted the following information: author(s), year of publication, type and number of animals, method for inducing osteoporosis, type of parathyroid hormone (PTH), control group, type and system of the implant, observation period, method for ensuring osseointegration, and research results.

RESULTS

The results of studies conducted with osteoporosis induction in animals are summarized in Table 1, and those conducted without osteoporosis induction are summarized in Table 2.

Three out of 10 studies used New Zealand white rabbits[11-13], and two studies used Sprague-Dawley rats[14,15]. The remaining studies used Wistar rats[16-20]. The number of animals used in the study varied from 14 to 45[12-21]. The diameter and length of the implants used ranged from 1 mm to 3.8 mm and from 3 mm to 13 mm, respectively[12-21]. The postoperative observation period varied from 1 week to 60 days[12-21]. For teriparatide, rhPTH was used in all 10 studies (Forteo-Eli Lilly, Indianapolis, IN, USA 12,15,17; hPTH [1-34], Peptide Institute, Osaka, Japan[16]; 1-34 synthetic PTH, R&D Systems Inc., Minneapolis, MN[14]; Forsteo®; Eli Lilly, Houten, the Netherlands[13]; pTH [1-34], BACHEM, Bubendorf, Switzerland[18]; PTH, Sigma, St. Louis, MI, USA[20]; Forteo, Eli Lilly do Brasil Ltda, São Paulo, Brazil[21]). In the five studies that induced osteoporosis, one study performed orchiectomy[17], and the rest performed ovariectomy[12-14,16]. In all studies that did not induce osteoporosis, saline or placebo was administered to the control group[15,18-21], whereas in studies that induced osteoporosis, saline[12,13,16], bisphosphonates[16], and placebo were used as controls[13,14,17].

As a radiological analysis index, five studies investigated the peri-implant bone volume per tissue volume (BV/TV), and these studies showed that the BV/TV value significantly increased in the PTH-administered group[12,15-17,20]. Two studies investigated peri-implant trabecular thickness (Tb.Th), trabecular number (Tb.N), and trabecular separation (Tb.Sp), which showed significantly higher values of Tb.Th when PTH was administered[15,17].

For histological analysis, six studies investigated BIC, all of which showed that when PTH was administered, the BIC value was significantly increased compared to the control group[13,15-17,19,20]. Two studies have investigated the bone turnover rate around implants[14,17]. As a result, when PTH was administered, both the bone turnover rate and generation of new bone were significantly higher[14,17]. Mafra et al. investigated the bone filling (BF) within the implant threads and peri-implant proportion of mineralized tissue (PMT), including BIC[19]. It has been reported that the values of BF and PMT in the dense bone regions were significantly higher in the group treated with PTH than in the controls[19]. In a study by Uchida et al., the ratio of peri-implant bone, density of osteoblasts, number of osteoclasts, and ratio of collagen were investigated through histological examination[18]. In the group administered with PTH, a significant increase was observed in the number of osteoclasts, osteoblasts, osteocytes around the implants, ratio of bone inside the implant thread, and amount of collagen[18].

In addition, one study investigated the implant stability quotient (ISQ) and two other studies investigated the removal torque to confirm the stability and osseointegration of the implant[12,16,21]. All of these studies reported that the ISQ or removal torque significantly increased when PTH was administered[12,16,21]. Two studies investigated the peri-implant BMD, and both of them reported a significant increase in peri-implant BMD when PTH was administered[13,15].

DISCUSSION

Osseointegration is the structural and functional direct bonding between the bone and the implant surface microscopically[22,23].

Table 1. Studies on the relationship between teriparatide and osseointegration after osteoporosis induction in animals

Author and year	Animals	Method for inducing osteoporosis	Sample size	PTH	Control group	Implant system	Observation period	Parameters	Results
Yoshifumi Oki et al. 2017	New Zealand white rabbits	Ovariectomy	15	Subcutaneous PTH (Forteo–Eli Lilly, Indianapolis, IN, USA)	Saline	Titanium implants (diameter, 3.8 mm; length, 6.5mm) (SETiO®, GC, Itabashi–ku, Tokyo, Japan)	4 weeks	ISQ total bone ratio	The ISQ values of the PTH groups were significantly higher than those of the control group ($P < 0.05$) The bone was thicker and more trabecular around the implant sockets in the PTH specimens than in the control specimens. The bone area around the implant socket was significantly greater in the PTH group than in the control group ($P < 0.05$).
Aya Shibamoto et al. 2018	Wistar rats	Ovariectomy	44	Subcutaneous PTH (hPTH [1–34]; Peptide Institute, Osaka, Japan)	Saline Alendronate	Titanium implant (diameter, 2.0 mm; length, 13 mm) (cp–Titanium Grade 2, machine surface)	4 weeks	Removal torque test BIC BV/TV	PTH administration significantly increased the biomechanical strength of the implant - bone interface compared with the saline–treated ($P < 0.01$). BIC was significantly increased by PTH administration ($P < 0.01$) BV/TV were significantly enhanced by PTH administration ($P < 0.01$)
P. H. S. Gomes–Ferreira et al. 2020	Wistar rats	Orchiectomy	24	Subcutaneous PTH (Forteo–Eli Lilly, Indianapolis, IN, USA)	Orchiectomized Sham control	Titanium implant (diameter, 1.5 mm; length, 3.5 mm) (Neodent®, Curitiba, Paraná, Brazil)	60 days	BV/TV Tb.Th Tb.N Tb.Sp BIC MAR NBA	The experimental group revealed statistically significant higher values for BV/TV, Tb.Th, and BIC parameters than those of the orchiectomized group ($P < 0.05$) In the bone turnover analysis (MAR, NBA), the experimental group presented the highest results followed by the sham surgery and orchiectomized groups ($P < 0.05$)
Hyun–A Heo et al. 2015	Sprague–Dawley rats	Ovariectomy	27	PTH (1–34 synthetic PTH R&D Systems Inc., Minneapolis, MN)	Ovariectomized Sham control	Titanium implant (diameter, 1.2 mm length, 3.0 mm) (Ti–Al–V; Leibinger Stryker, Freiburg, Germany)	1, 2, 4 weeks	New bone on the implant surface	The amount of newly formed bone around implants in the PTH group was comparable to that of the control group. Ovariectomized group displayed relatively small amount of new bone.
M. Isabel Almagro et al. 2012	New Zealand white rabbits	Ovariectomy	38	PTH (Forsteo®; Eli Lilly, Houten, the Netherlands)	Healthy Saline (Ovariectomized)	Titanium implants (diameter, 2.5 mm; length, 7.0 mm) (Branemark System® with Ti UniteTM Surface Dental Implants; Nobel Biocare AB, Göteborg, Sweden)	6, 20 weeks	Peri–implant BMD BIC	PTH increased BIC compared with control rabbits ($P < 0.005$). PTH–induced new bone formation around external and internal surfaces of titanium implants led to a significantly increased BMD at the peri–implant area in osteoporotic rabbits compared with vehicle ($P < 0.005$).

PTH, parathyroid hormone; rhPTH, recombinant human parathyroid hormone; ISQ, implant stability quotient; BIC, bone–to–implant contact; BV/TV, bone volume per tissue volume; Tb.Th, trabecular thickness; Tb.N, trabecular number; Tb.Sp, trabecular separation; MAR, mineral apposition rate; NBA, neoformed bone area; BMD, bone mineral density.

Table 2. Studies on the relationship between teriparatide and osseointegration without inducing osteoporosis in animals

Author and year	Animals	Sample size	PTH	Control group	Implant system	Observation period	Parameters	Results
Yusuke Uchida et al. 2020	Wistar rats	14	human PTH (pTH [1–34], BACHEM, Bubendorf, Switzerland)	Saline	Titanium implant (diameter, 2.0 mm; length, 3.5 mm) (Kyocera Co. Ltd., Kyoto, Japan)	5 weeks	BAF Osteocyte density N.Oc/BS CAF Type I collagen Type III collagen	PTH significantly increased the number of osteoblasts, osteocytes, and osteoclasts in the total inside and outside areas of all implant threads PTH significantly increased bone area and the amount of collagen within the total inside areas of all implant threads
Liting Jiang et al. 2018	Sprague–Dawley rats	36	subcutaneous PTH (Forteo® by Eli Lilly Company, Indianapolis, USA)	Saline	Titanium implant (diameter, 2.0 mm; length, 8.0 mm)	5 weeks	BMD BV/TV Tb.Th Tb.N Tb.Sp BIC	PTH group presented significantly increased in BMD, BV/TV, and Tb.Th around the peri–implant region compared to controls ($P < 0.05$). PTH group presented significantly increased BIC ($P < 0.05$) when compared to controls. Vascular volume fraction increased significantly in the PTH group ($P < 0.01$)
Carlos Eduardo Secco Mafra et al. 2019	Wistar rats	45	subcutaneous PTH [1–34]	Saline	Titanium implant (diameter, 2.2 mm; length, 4.5 mm)	30 days	BIC BF PMT	PTH groups presented significantly higher values of BIC in the cortical region than that of the control group ($P < 0.05$). PMT in the cortical region and concentrations of PTH positively influenced bone density when compared to the control group ($P < 0.05$). In the cancellous bone, no differences between groups were observed ($P > 0.05$). PTH groups presented significantly higher BF value in the cortical region than that of the control group ($P < 0.05$).
Marcelo Soeiro Corsini et al. 2008	New Zealand white rabbits	20	rhPTH [1 - 34] (Forteo, Eli Lilly do Brasil Ltda, São Paulo, Brazil)	Placebo	Titanium implant (diameter, 3.75 mm; length, 8.0 mm) (ACE, Surgical Supply, Brockton, Mass)	4, 8 weeks	Removal torque test	The mean removal torque values at 28 days were 37.0 ± 4.36 Ncm and 47.4 ± 6.77 Ncm for the control and test groups, respectively ($P < 0.05$). The mean removal torque values at 56 days were 45.8 ± 3.96 Ncm and 55.8 ± 2.86 Ncm for the control and test groups, respectively ($P < 0.05$). Removal torque was significantly higher in the test groups than that in the control groups ($P < 0.05$).
Birgit Mair et al. 2009	Wistar rats	20	rhPTH [1–34] (PTH, Sigma, St. Louis, MI, USA)	Vehicle injection	Titanium implant (diameter, 1.0 mm; length, 3.0 mm)	4 weeks	BIC BV/TV	PTH groups represent significantly higher BV/TV and BIC value in the medullary compartment than that of the control groups ($P < 0.05$).

PTH, parathyroid hormone; rhPTH, recombinant human parathyroid hormone; BAF, bone area fraction around implants; N. Oc, BS, number of osteoclasts per bone perimeter in each area of interest; CAF, collagen area fraction; BMD, bone mineral density; BV/TV, bone volume per tissue volume; Tb.Th, trabecular thickness; Tb.N, trabecular number; Tb.Sp, trabecular separation; BIC, bone–to–implant contact; BF, bone filling within the implant threads; PMT, proportion of mineralized tissue.

Generally, it means that a functioning implant is firmly fixed without mobility and clinical problems[22,23]. Several factors influence osseointegration, such as the material, surface, design of the implant, surrounding bone density, and bone quality[2,23]. In addition, steroids, radiation exposure history, and metabolic diseases such as liver disease and diabetes, could affect osseointegration[3-5,23].

Osteoporosis is a bone disorder that increases the risk of fracture by decreasing bone density and quality[24]; the unbalanced bone turnover rate can affect bone strength[24]. Normally, the bone resorption action of osteoclasts and the osteogenic action of osteoblasts are balanced, thereby obtaining sufficient strength to resist fracture[24]. However, especially in postmenopausal women, estrogen is deficient[24]. Reduced estrogen levels prolong the lifespan of osteoclasts and shorten that of osteoblasts, thereby increasing bone resorption and reducing bone formation[24]. Moreover, postmenopausal women have a higher risk of osteoporosis due to lower bone mass[24]. In the early 1990s, hormone therapy using conjugated equine estrogens and medroxyprogesterone acetate was attempted as a treatment for osteoporosis[25]. Although hormone therapy certainly reduces the risk of fractures due to osteoporosis, it has disadvantages in that it increases the risk of cardiovascular or cerebrovascular disease and breast cancer[25].

Therefore, pharmacological treatment of osteoporosis focuses on reducing bone resorption and increasing bone formation[26]. Bisphosphonates are used as the first option, and it restrict osteoclasts to reduce bone resorption and prevent fractures due to osteoporosis[8,9,27]. However, recently, issues regarding MRONJ brought about by bisphosphonates have been raised[28]. According to the American Association of Oral and Maxillofacial Surgeons, MRONJ is defined when a bone has been exposed for more than 8 weeks, and the patient has previously taken a bone resorption or an angiogenesis inhibitor, without history of irradiation or metastatic lesions in the maxilla[29]. If bisphosphonates are taken within 4 years, dental procedures can be performed relatively safely for MRONJ[29,30]. However, as bisphosphonates are administered for a long period of time, formulations with a long half-life are continuously accumulated in the body, thereby increasing the risk of MRONJ[29,30].

Considering the abovementioned reasons, a drug that has recently gained attention is teriparatide. Currently, it is administered instead of bisphosphonate to prevent fractures that may occur during drug holidays after long-term bisphosphonate use or to prevent MRONJ in patients with severe osteoporosis[30]. Teriparatide is an rhPTH; hence, unlike bisphosphonates, it does not inhibit bone resorption but improves bone quality and bone mass by stimulating osteoblastic action of osteoblasts[26]. Teriparatide also increases the activity of osteoclasts, but because the activity of osteoblasts is increased beyond normal, the rate of bone turnover increases, and overall bone mass and quality are improved[31].

However, temporary side effects, such as pain and swelling at the injection site, nausea, headache, leg cramps, and dizziness may occur even when teriparatide is administered[32]. A previous study showed that long-term continuous administration of teriparatide at a dose of 75 mg/kg/day in rats is associated with the development of osteosarcoma[30,32]. Therefore, the Food and Drug Administration discourages the continuous administration of teriparatide for more than 2 years. Moreover, it is contraindicated to those with a high risk of osteosarcoma (e.g. patients with Paget's disease)[30,32].

In this study, the relationship between teriparatide and osseointegration was investigated using animal studies. PTH was administered to the animals used in the study, and various methods were employed to check the stability and fixation of the implant, ratio of bone around the implant, density, and contact[12-21]. In addition, the formation of a new bone around the implant has been investigated[12-21]. Based on the study results, it was observed that the abovementioned indicators significantly increased in the group administered with PTH compared to the group not administered with PTH[12-21]. Although it was an animal study, it could be expected that the administration of PTH had a positive effect on the osseointegration of the implant and bone[12-21].

To date, the study by Kuchler et al. is the only human study that could be obtained by searching PubMed/Medline databases. They conducted a study on 24 patients with edentulous mandible[33]. Originally, four implants were placed in the mandibular interforaminal area, and another two (length, 4 mm; width, 2 mm) were placed during their study[33]. Of these, 12 patients self-administered 20 μg of teriparatide daily, and the others did not[33]. Nine weeks after implantation, the study implant was removed during the second operation, and BV/TV and BIC were investigated, but no significant difference was observed between the experimental and control groups[33].

This study reviewed various animal experiments and found that the clinical use of PTH had a positive effect on the osseointegration of implants[12-21]. However, animal studies cannot quantify the side effects of PTH administration, such as pain and swelling, nausea, headache, leg cramps, and dizziness[30,32]. In addition, since fatal side effects such as osteosarcoma may occur depending on the PTH dose, more studies are needed in the future to determine the effectiveness of PTH for the purpose of increasing osseointegration in humans[30,32].

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