
Rehabilitation of Patients with Reconstructed Mandibles Using Osseointegrated Implants: Clinical Report

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Experience with 9 patients who underwent mandibular reconstruction with autogenous free bone grafts and subsequent placement of titanium screw-type implants is reported. The interval between bone grafting and implant placement in these patients ranged from 8 to 34 months. A total of 33 implants was placed, followed up for 16 to 53 months, and achieved an 85% survival rate. Analysis of these patients reveals that the type of bone graft used is integral to successful prosthodontic reconstruction to ensure viability and minimal resorption as well as the timing of implant placement.
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Key words: mandibular reconstruction, oral cancer, osseointegration, titanium implants

Radical surgical treatment in patients with malignant or benign lesions of the mandible often results in problems with speech, deglutition, and masticatory function. Prosthodontic rehabilitation of these patients poses particular problems for the clinician. These problems include a lack of bony support for the prosthesis, movable soft tissue in the area that must support the prosthesis, and lack of stability. Spread of the tongue into the surgical site also limits the extension of the prosthesis, which may adversely affect its stability and patient acceptance.

The goal of maxillomandibular reconstruction for patients who require resection of the mandible is to reestablish anatomic form and oral function. A number of techniques have been used for reconstruction of the form, with bone grafting playing a primary role. Different types of bone grafts used may include vascularized grafts, such as radial and fibular, and free grafts, such as autogenous block and particulate cancellous bone marrow (PCBM) from the iliac crest.¹ After successful reconstruction, facial contour, architectural support, and occlusal relationships may be regained. The alterations that result from scar or replacement tissue, sensory changes, lack of sublingual sulcus or vestibular depth, and changes in muscle function often prevent the wearing of even the most skillfully designed and fabricated tissue-supported dentures. As a result, these patients will likely have poor speech, be unable to eat a solid diet, and exhibit cosmetic deformity.

Osseointegrated implants have become generally accepted for prosthodontic management of the dental patient.² The application of endosseous implants in combination with bone grafting, which has become more important in jaw reconstruction over the last decade, has allowed for improved results. Different types of osseointegrated implants have been placed, either simultaneously with bone

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grafts^{3,4} or at a later stage after the bone grafts have healed.^{5,6} Experience with 9 patients who underwent mandibular reconstruction with autogenous free bone grafts and subsequent placement of titanium screw-type implants is reported herein. The concerns and challenges that the oral and maxillofacial surgeon and the prosthodontist encountered in the reconstructed patients' rehabilitation are described.

Materials and Methods

Nine patients met the criteria for rehabilitation utilizing osseointegrated implants: 6 males and 3 females, ranging from 16 to 58 years of age, with a mean age of 31.2 years and a variety of histopathologic diagnoses, all of whom had undergone some degree of mandibular resection and reconstruction with bone grafting. All patients were reconstructed with autogenous bone grafts harvested from the anterior iliac crest via a lateral approach. Seven of these patients, all of whom had benign preoperative diagnoses, underwent immediate reconstruction at the time of the tumor resection, and 2 patients with diagnoses of malignant disease underwent delayed reconstruction. One patient with a preoperative diagnosis of squamous cell carcinoma also received radiation therapy (7020 cGy) 4 weeks after surgical resection.

Particulate cancellous bone marrow harvested from the iliac crest was used in 8 patients and an iliac corticocancellous block graft was used in 1 patient. In 6 of the 8 patients reconstructed with PCBM, particulate freeze-dried bone (PFDB) was combined with an autogenous bone graft in ratios of 4:1 to 2:1 to increase the quantity and bulk of the graft. Titanium mesh trays were used for support and contour of reconstructed segments in 5 patients, a reconstruction plate was used in 1 patient, an allogeneic freeze-dried rib graft was used in 2 patients, and an autogenous bone graft was used alone in the 1 remaining patient. The patient characteristics and summary of these data are included in Table 1. Sufficient time was allowed for primary bone healing, and radiographic evaluation was undertaken of any pathologic recurrence in those patients with a preoperative diagnosis of malignancy or those with benign neoplasms with significant recurrence before prosthodontic reconstruction (8 to 34 months). The patient who had received radiation as an adjunctive therapy for a squamous cell carcinoma received hyperbaric oxygen therapy before and after placement of the implants, consistent with the protocol recommended by Marx.⁷









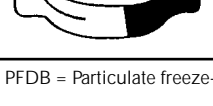
The patients were then evaluated for implant surgery. The selection criteria that determined whether these patients were candidates for this type of treatment included: adequate height and width of bone to successfully place the implants (minimum of 10 mm), ability of the patient to maintain good oral hygiene and soft tissue health, and the patient's desire for a fixed prosthesis. Alternative prosthetic reconstruction was offered to all patients. Some patients had already received treatment, but were not satisfied with the outcome.

The endosseous implants were all of the titanium screw type (Nobel Biocare USA, Westmont, IL) and were placed using a 2-stage surgical procedure. Diagnostic casts were mounted on a semi-adjustable articulator and after clinical and radiographic evaluation, pertinent factors were considered in each patient to determine the number of implants required, the extent of the defect, interocclusal space, buccolingual interarch space, the occlusal scheme of the maxilla and the mandible, bone height and width, and status of the remaining dentition. A surgical template was fabricated and used during stage 1 surgery to guide the position and angulation of the implants. The stage 2 procedure was performed after 6 months of healing and osseointegration time, and seating of the healing abutments was confirmed through radiographic evaluation. During this stage, the implants were tested for mobility. One of the 33 implants failed to osseointegrate at this stage and was removed. Eight of the 9 patients received fixed prostheses and 1 received a removable prosthesis. The follow-up period after prosthetic rehabilitation ranged from 16 to 53 months.

Patient Presentations

Patient 1. JJ was a 31-year-old female who was referred for evaluation and treatment of a recurrent odontogenic fibromyxoma that had been diagnosed and treated 17 years prior. Clinical evaluation revealed expansion of the buccal plate of the right mandibular body, and the patient complained of numbness of the lower lip. A panoramic radiograph revealed a radiolucent lesion with irregular borders extending from the right mental foramen to the mesial of the second molar (Fig 1). In light of the diagnosis, the patient underwent resection of the mandibular body from the second molar to the right canine region. Immediate reconstruction of the mandible was performed using a titanium mesh tray and PCBM harvested from her iliac crest. Three weeks after the reconstruction, she developed an infection with intraoral purulent

Table 1 Patient Characteristics

| Patient | Gender | Age | Diagnosis | Anatomic reconstruction | Material used for reconstruction |
|---------|--------|-----|-----------------------------------|---|--|
| AU | M | 16 | Ameloblastoma |  | PCBM |
| SH | F | 16 | Ameloblastoma |  | PCBM and PFDB (3:1 ratio), titanium mesh tray |
| DH | M | 58 | T4N0M0 squamous cell carcinoma |  | Corticocancellous block, reconstruction plate |
| BD | M | 51 | Ameloblastoma |  | PCBM and PFDB (4:1 ratio), titanium mesh tray |
| AL | F | 19 | Recurrent giant cell tumor |  | PCBM and PFDB (2:1 ratio), freeze-dried rib graft |
| RS | M | 41 | T4N0M0 squamous cell carcinoma |  | PCBM, freeze-dried rib graft |
| MJ | M | 20 | Recurrent giant cell tumor |  | PCBM and PFDB (3:1 ratio), titanium mesh tray |
| JJ | F | 36 | Recurrent odontogenic fibromyxoma |  | PCBM and PFDB (4:1 ratio), titanium mesh tray |
| SS | M | 24 | Odontogenic fibromyxoma |  | PCBM and PFDB (4:1 ratio), titanium mesh tray with condyle |

Mean age = 31.2. PCBM = particulate cancellous bone marrow; PFDB = Particulate freeze-dried bone.

drainage, which was treated with antibiotic therapy for 4 weeks. The patient did well and was asymptomatic for the following 2 months, when she developed another abscess with submandibular space involvement and intraoral dehiscence of the graft. The metal tray and infected bone graft were then removed, and the proximal and distal segments were stabilized with external fixation. Two months after removing the hardware and completely eliminating the infection, the mandible was reconstructed again in a similar fashion as the first reconstruction. This time the postoperative course was uneventful, and the external fixation was removed 2 months later.

Four implants were placed 8 months after the reconstruction in the grafted bone of the right mandible (Fig 2). The implants were exposed after a healing time of 4 months. After the creation of an implant impression and fabrication of a soft tissue cast, the design of the final prosthesis was determined and the final abutments were selected (standard abutments 5 to 7 mm, Nobel Biocare USA). The abutments had to be supragingival because of the lack of attached gingiva and the need to avoid any pressure on the lingual plate from the prosthesis.

Abutment replicas were placed on the master cast and a fixed provisional screw-retained acrylic

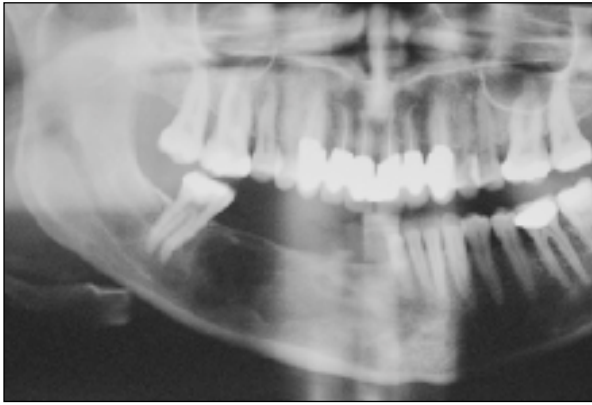


Fig 1 Patient 1: Preoperative panoramic radiograph showing the recurrent odontogenic fibromyxoma of the right mandible.



Fig 2 Patient 1: Panoramic radiograph showing 4 endosseous implants in the grafted mandible.



Fig 3 Patient 1: Clinical photograph showing the provisional acrylic resin prosthesis.



Fig 4 Patient 1: Clinical photograph showing the final frame before soldering.

resin prosthesis was fabricated. With the provisional prosthesis, osseointegration of the implants could be evaluated and progressive loading to the implant could be achieved. Also, the esthetic, functional, and phonetic results of the final prosthesis could be predicted, and it could be determined whether a gingival augmentation procedure was necessary, and need for changes could be planned. The patient was able to determine the successful outcome of the treatment and improve hygiene ability (Fig 3).

After a minimum of 4 months with the provisional prosthesis, no complications were reported by the patient. An abutment impression was made, and the definitive prosthesis was fabricated. During the metal frame try-in, it was decided that the frame needed to be soldered because of the importance of an accurate, passive fit of the frame on the abutments (Fig 4). The fit was confirmed again intraorally before applying the porcelain veneering material. Retrievability was ensured through the



Fig 5 Patient 1: Clinical occlusal photograph of the final prosthesis. The abutments needed to be supragingival to avoid any pressure from the prosthesis on the lingual plate.

screw access and the definitive prosthesis was placed (Fig 5). The implants have been successfully loaded for 16 months.

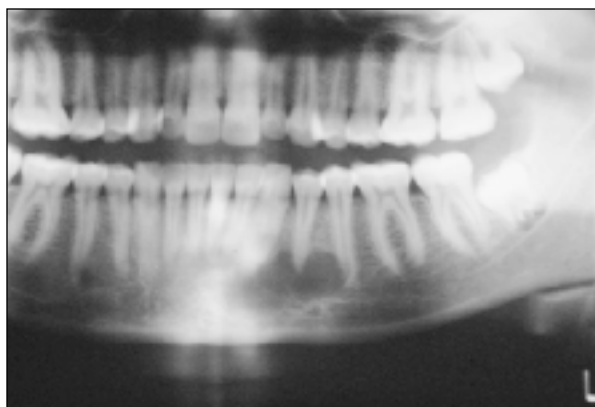


Fig 6 Patient 2: Panoramic radiograph showing the bone destruction caused by the giant cell lesion.

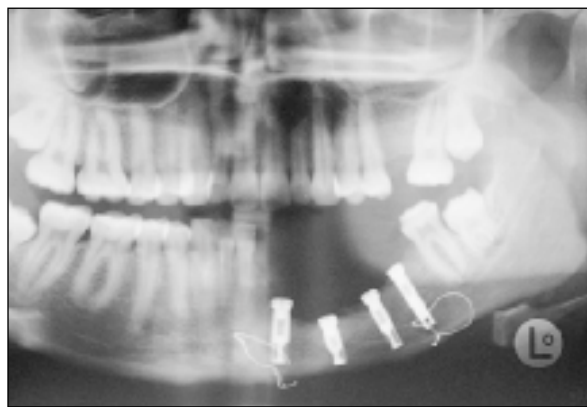


Fig 7 Patient 2: Panoramic radiograph showing the placement of 4 implants in the grafted bone.



Fig 8a Patient 2: Clinical photograph 48 months after surgical reconstruction showing the restored occlusion.




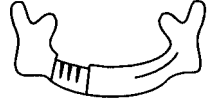







Fig 8b Patient 2: Clinical photograph 48 months after surgical reconstruction showing the restored facial symmetry.

Patient 2. AL was a 19-year-old female with a recurrent giant cell lesion. Radiographically, there was evidence of a radiolucent lesion in the left mandible extending from the left second premolar to the left lateral incisor with evidence of root resorption (Fig 6). The patient underwent an en-bloc resection of the left mandible and immediate surgical reconstruction with autogenous PCBM mixed with PFDB in a 2:1 ratio. A freeze-dried rib split longitudinally served as buccal and lingual plates for support of the particulate bone. An intraoral dehiscence developed postoperatively with particulate bone loss. Despite the bone loss, there was sufficient height and width to place 4 endosseous implants 16 months after reconstruction (Fig 7). The implants were uncovered 6 months later, followed by completion of prosthodontic reconstruction (Fig 8). The patient is functioning well 35 months after the completion of the prosthodontic treatment.

Results

Of the 33 implants placed in these 9 patients, 5 (15.3%) failed to osseointegrate. All implants that failed to integrate were placed in grafted bone; 1 was in corticocancellous block graft, and the other 4 were in PCBM mixed with PFDB. Two of the latter 4 were in a patient who developed an intraoral dehiscence postoperatively and the ratio of autologous to PFDB was 4:1; the other 2 failed in a patient in whom a 3:1 ratio of autologous to PFDB was used and who had poor bone density at the time of implant placement. One other patient (AL), who was reconstructed with autologous and PFDB in a 2:1 ratio, developed an intraoral dehiscence with substantial bone resorption and loss of alveolar height. The results are summarized in Table 2. Eight of the 9 patients were partially edentulous and were provided with fixed prostheses. The 1

Table 2 Prosthetic Reconstruction

| Patient | Post-reconstruction complications | Mo. between bone graft and implant placement | Location of implants | No. of implants | Length of implants | Implants lost | Mo. of follow-up | Prosthetic treatment |
|---------|--|--|---|-----------------|-------------------------------------|---------------|------------------|----------------------|
| AU | None | 12 |  | 2 | 13 mm (1) 15 mm (1) | 0 | 53 | Fixed prosthesis |
| SH | Dehiscence of bone graft | 8 |  | 3 | 15 mm | 0 | 45 | Fixed prosthesis |
| DH | None | 21 |  | 6 | 13 mm (4) 10 mm (2) | 1 | 39 | Fixed prosthesis |
| BD | Dehiscence of bone graft | 10 |  | 6 | 18 mm (2) 15 mm (4) | 2 | 39 | Fixed prosthesis |
| AL | Dehiscence of bone graft | 16 |  | 4 | 13 mm (2) 10 mm (1) 15 mm (1) | 0 | 35 | Fixed prosthesis |
| RS | None | 34 |  | 3 | 13 mm | 0 | 45 | Fixed prosthesis |
| MJ | None | 11 |  | 3 | 15 mm (2) 10 mm (1) | 2 | 23 | Fixed prosthesis |
| JJ | Infection resulted in reconstruction twice | 8 |  | 4 | 13 mm | 0 | 19 | Fixed prosthesis |
| SS | None | 9 |  | 2 | 15 mm | 0 | 16 | Fixed prosthesis |

completely edentulous patient had a complete denture fabricated. All patients reported that they were satisfied and pleased with the cosmetic result and their renewed facial contour. They were able to return to their normal diets, and their masticatory function improved.

Discussion

Several methods for mandibular reconstruction have been described, all of which restore facial contour but do not really provide an adequate base for a conventional removable prosthesis.

Komisar⁸ asserted that prosthetic rehabilitation is poor in reconstructed mandibles and that restorations did not enhance function in the majority of patients. In a series of 35 patients reconstructed with iliac crest free grafts, David et al⁹ reported on 5 patients with conventional denture prostheses, none of whom were able to eat effectively.

The surgical and prosthodontic reconstruction of these patients is not without challenge or difficulty. The first concern for all of these patients is to render them disease-free. In patients with benign neoplasms, disease-free surgical margins can more safely be determined intraoperatively

and thus these patients can be reconstructed immediately following resection. In patients with a preoperative diagnosis of malignancy, determination of disease-free surgical margins must await histopathologic analysis and, depending on the diagnosis and extent of disease, adjunctive therapy such as radiation or chemotherapy may be necessary. Two of the patients had a preoperative diagnosis of squamous cell carcinoma, 1 of whom received postoperative radiation therapy. Reconstruction of both patients was delayed for completion of therapy and reassurance of a disease-free state.

Postoperative infections are also a concern in these grafted patients. One patient (JJ) developed a severe infection, which resulted in removal of the metal tray and loss of the bone graft, followed by a second reconstruction. All patients were reconstructed via an extraoral approach. In patients who underwent immediate reconstruction, teeth were extracted 3 to 4 weeks prior, allowing for oral mucosal healing to take place, which minimized oral contamination of the grafted bone. Despite this effort, 3 of the patients developed an intraoral dehiscence of the bone graft, with 1 (AL) resulting in substantial bone loss.

Autogenous bone grafts have the greatest success rate for viability and minimal resorption.¹ Particulate cancellous bone marrow provides transplanted cells necessary for proliferation and the formation of new osteoid for a successful phase I, as proposed by Auxhausen in the 2-phase theory of osteogenesis.¹⁰ This phase I dictates the quantity of bone that the graft will form. Particulate cancellous bone marrow was used in the reconstruction of 8 patients, and in 6 it was mixed with PFDB. The combination with PFDB reduces the number of osteocompetent cells that can form new osteoid and in turn compromises the quantity of bone that is formed. This was mostly evident in patient AL, in whom autologous PCBM was mixed with PFDB in a 2:1 ratio.

The use of PCBM usually requires some type of structural support, especially in mandibular reconstruction and discontinuity defects. Although block grafts may provide better structure and support, the cell population transplanted in these grafts is relatively small, decreasing the phase I component of osteogenesis and making vascular ingrowth difficult. These grafts are about 50% weaker than normal bone for 6 weeks to 6 months after transplantation and they exhibit greater resorption.¹ Particulate cancellous bone marrow provides a large phase I cell population and can be packed and contoured for more predictable esthetic results. The addition of allogeneic or alloplastic

material, such as freeze-dried rib, titanium mesh trays, or bone plates, was used in 8 of the patients to add rigidity and better establish the form. Once the transplanted cells have survived and phase II osteogenesis, in which the recipient bed dictates the resorption and remodelling of the immature bone to mature bone, is complete, the new bone can be evaluated for support of a prosthesis.

For osseointegrated implants to be successful, approximately 10 mm of vertical bone height and a minimum width of 6 mm is required to accommodate the 3.75-mm self-tapping Brånemark screw-type implants (Nobel Biocare). These criteria can easily be met in reconstruction using PCBM, because it has the capability to be contoured and shaped in the desired location. There was sufficient bone height and width in all patients, including the 3 who experienced intraoral dehiscence and bone loss. When endosseous implants were placed in all these patients, the bone appeared very viable and healthy and showed no difference from normal host bone, except for 1 patient (MJ), in whom the grafted bone appeared less dense than expected. Two of the 4 implants placed in this patient failed to integrate.

The implants placed in all patients were delayed to allow complete osteogenesis of the transplanted bone graft. Implants have been placed simultaneously with bone grafts but have showed less osseointegration than those placed in nongrafted control sites. Shirota et al³ have shown that vascularized bone grafts do not have both intact medullary and periosteal blood supply, but only intact periosteal supply. Therefore, it is considered that in the early stage after graft transplantation, there is usually less osseointegration because survival of the osteocytes and marrow is not complete, even though the vascular supply to the graft is restored by microsurgical re-anastomosis. They also showed that the volume of vascularized bone graft decreased gradually over time.

Immediate versus delayed implant placement has also been compared in autogenous iliac bone grafts. There was more predictable bone formation around implants that were placed 90 to 180 days after bone grafting.⁴ Also, the rate of osseointegration has been compared in immediate implants placed in cortical block and particulate grafts. After 1 month, the implants in cortical block demonstrated a greater percentage of osseointegration than those placed immediately in particulate grafts.¹¹ Although the implant osseointegration success rates in normal host bone are high, they are lower in grafted bone. In this series, an 85% success rate of osseointegration was observed. A

clinical report by Hotz⁶ reported a 9.1% failure rate of osseointegration in patients reconstructed with nonvascularized free corticocancellous iliac crest block grafts.

The condition of the intraoral soft tissue also provided some concerns and restrictions for implant placement in some of these patients. Patient DH, who underwent intraoral soft tissue reconstruction with a myocutaneous flap, had very thick soft tissue overlying the grafted bone and his existing mandible. Reducing and debulking this tissue was necessary prior to implant placement. In other patients, soft tissue scarring, fibrosis, and banding of the mucosal tissue necessitated soft tissue plasty to prevent the tissue from closing over the prosthetic abutments and to allow for restoration. Multiple surgical procedures may be necessary for proper and successful implant placement for these patients, as also noted by Jacob et al.¹²

Motor and sensory deficits of the tongue, lip, and grafted soft and hard tissue are also present in these patients after reconstruction and usually cause a limitation of masticatory function. Schmelzeisen et al¹³ showed that patients with implant-supported dentures and vascularized bone grafts prefer the nonreconstructed site for chewing. It appears that the lack of neurosensitive feedback mechanisms may be responsible for diminished chewing pressure and inferior speech results. However, the ability to wear a prosthesis, as in patient DH, allowed eversion of the lower lip from its collapsed position into the oral cavity. This terminated the patient's drooling and improved his speaking ability.

Osseointegration of implants in irradiated bone has also been examined.^{8,14,15} When comparing implants placed in irradiated bone to those placed in nonirradiated bone, there is a significant decrease in histologic osseointegration of these implants. Irradiated tissue provides a hypoxic, hypovascular, hypocellular recipient bed,¹⁶ which compromises phase II of the osteogenesis. Hyperbaric oxygen therapy prior to and after implantation has been shown to improve the integration of implants.¹⁷ One patient in this series who had received radiation as part of the treatment for a malignant neoplasm received pre- and postimplantation hyperbaric oxygen with the successful integration of 5 of 6 implants.

Autogenous block grafts and vascularized bone grafts have been used successfully in mandibular reconstruction. Vascularized grafts, especially from the radius and fibula, have been useful in the treat-

ment of irradiated patients and when reconstructing smaller defects. The definition of successful reconstruction should go beyond that of bridging a discontinuity defect. Simply replacing a missing segment of bone is inadequate. Corticocancellous block grafts and vascularized grafts sometimes lack the height, width, and contour necessary for prosthodontic reconstruction. With the aid of structural support, PCBM has the ability to be compressed and contoured to follow the desired curvature of the jaws. The high cancellous-marrow-to-cortical-bone ratio can also result in a more predictable final bone height and width.

And finally, but not least, cosmetics is an important consideration when reconstructing these patients. The restoration of self-esteem and the ability to return to normal life is psychologically beneficial. From this series of patients, cosmetics was improved more ideally in patients with immediate reconstruction or with fewer surgical procedures. Multiple surgeries and delayed reconstruction resulted in scarring and fibrosis.

This experience demonstrated that the restoration of form and function can be accomplished using a 2-stage procedure, namely secondary implant placement in bone grafts. Despite some of the complications and challenges faced in treating and rehabilitating these patients, the final conclusion is that grafted bone can be an excellent host for endosseous implants. The clinically proven, long-term success of endosseous implants has markedly changed the rehabilitation of many patients for whom there was formerly no predictable method of providing retention and stability for a dental prosthesis. They are also proving to be successful in patients in whom implant placement was earlier considered to be contraindicated.

Summary

The results in the patients presented in this report suggest that osseointegrated implants can be successfully used in patients who have been surgically reconstructed with autogenous bone grafts. When anatomic reconstruction and maxillofacial prosthesis reconstruction are combined, they provide the best possibility for complete oral rehabilitation.

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