INTRODUCTION

Application of ocular prosthesis is inevitably necessary for patients who unfortunately lost their eyeballs to maintain their quality of life. Therefore, appropriate eye socket reconstructions are needed for patients who undergo enucleation of eyeballs. Generally, silicon and other artificial implants are inserted, and the conjunctiva is closed to reconstruct the eye socket for the defect after the enucleation surgery. However, the volume deficiency and possible exposure of an implant become common problems when artificial implants are used. Additionally, when replacement of an eyeball with an implant is not performed, the application of a thick artificial eye is required to cover the volume defect of the eye socket. When an eye socket is not an appropriate size, the shape of the base of the eye socket changes, which makes application of an artificial eye difficult. We use autologous costal cartilages to create ball-shaped implants that are as same size as normal eyeballs for the eye socket reconstruction. Using our operative procedure, application of thin prosthesis and mobile reconstructed eye socket become possible. We are to report the details of our operative method and pitfalls.

PATIENTS AND METHODS

There were 19 cases with 8 men and 11 women from April 2008 to August 2020. The average age was 48.6 years old. There were 10 cases of anophthalmia and 9 cases of ocular phthisis (Table 1). We performed this method for the patients with the existence of extraocular muscle in their orbits by preoperative reconstruction with costal cartilages from 2008 to 2020. The patient age range was 18–77 years old. There were 10 cases of anophthalmia and 9 cases of ocular phthisis. In our operative method, we created the costal cartilage implant by harvesting the sixth costal cartilage of the affected side. If extraocular muscle remained, we sutured each muscle to the cartilage.

Results: Our method made application of thin artificial eyes possible in all cases. Regarding postoperative complications, there were 1 case of postoperative infection and 1 case of vascular failure of temporoparietal fascial flap. Seventeen cases were wet socket, and 2 cases were dry socket. We had attained movement of the artificial eye in 15 cases.

Conclusions: Eye socket reconstruction is considered one of the most challenging operations, and various postoperative complications appear in the long term. Costal cartilages are considered as the most suitable materials to create the base of artificial eyes. (Plast Reconstr Surg Glob Open 2021;9:e3352; doi: 10.1097/GOX.0000000000003352; Published online 26 January 2021.)
Table 1. Demographic Data of Patients

| Case | Age | Sex | Condition | Reconstruction | Socket Type | Complication | Prosthetic Movement | Follow-up Time, mo |
|------|-----|-----|-----------|---------------|-------------|--------------|---------------------|-------------------|
| 1    | 18  | Female | Phthisis | Costal cartilage graft | Wet | None | Good | 143 |
| 2    | 51  | Female | Anophthalmia orbit | Costal cartilage graft | Dry | TPF failure + median forehead flap | Poor | 39 |
| 3    | 43  | Male | Anophthalmia orbit | Costal cartilage graft | Wet | None | Good | 126 |
| 4    | 18  | Female | Phthisis | Costal cartilage graft | Wet | None | Good | 96 |
| 5    | 77  | Male | Phthisis | Costal cartilage graft | Wet | None | Good | 58 |
| 6    | 24  | Female | Phthisis | Costal cartilage graft | Wet | None | Good | 82 |
| 7    | 42  | Male | Anophthalmia orbit | Costal cartilage graft | Wet | None | Good | 21 |
| 8    | 72  | Male | Anophthalmia orbit | Costal cartilage graft | Wet | None | Poor | 67 |
| 9    | 42  | Female | Anophthalmia orbit | Costal cartilage graft | Wet | None | Good | 53 |
| 10   | 39  | Male | Phthisis | Costal cartilage graft | Wet | TPF failure + median forehead flap | Good | 50 |
| 11   | 55  | Male | Anophthalmia orbit | Costal cartilage graft | Wet | None | Good | 49 |
| 12   | 70  | Female | Phthisis | Costal cartilage graft | Wet | None | Good | 41 |
| 13   | 73  | Female | Anophthalmia orbit | Costal cartilage graft | Wet | None | Good | 37 |
| 14   | 77  | Female | Phthisis | Costal cartilage graft | Wet | None | Good | 33 |
| 15   | 46  | Male | Anophthalmia orbit | Costal cartilage graft | Wet | None | Good | 26 |
| 16   | 47  | Male | Anophthalmia orbit | Costal cartilage graft | Wet | None | Good | 26 |
| 17   | 77  | Female | Anophthalmia orbit | Costal cartilage graft | Wet | None | Poor | 19 |
| 18   | 32  | Female | Phthisis | Costal cartilage graft | Wet | None | Good | 10 |
| 19   | 21  | Female | Phthisis | Costal cartilage graft | Wet | None | Poor | 9 |

Note: Socket movement in upward and downward gaze was slightly difficult, but that in lateral and medial gaze was satisfactory. From the follow-up CT scans, no absorption of cartilage graft was present in all cases.

Cases

Case 3

This case was trauma of a 43-year-old male patient. Because the eye socket was concaved, he had to wear a very thick artificial eye (Fig. 2A), but it was constantly falling out. We checked the existence of extraocular muscle in his orbit by preoperative CT examination (Fig. 2B). A round ball-shaped cartilage implant was created (Fig. 2C). The spherical costal cartilage implant was inserted into orbit and attached to 4 sclera flaps (Fig. 3A). Finally, conjunctival sac was sutured (Fig. 3B). Postoperative CT examination showed the spherical costal cartilage implant in his orbit (Fig. 3C). He was able to wear a thin artificial eye (Fig. 3D), and the eye movement was satisfactory. (See Video 1 [online], which demonstrates that the postoperative eye movement was satisfactory.)

Case 4

This patient is an 18-year-old woman who suffered from severe pain of the phthisis bulbi by acute retinal necrosis (Fig. 4A). Preoperative CT examination indicated the existence of extraocular muscle in her orbit. A round ball-shaped cartilage implant was created (Fig. 4B). Her costal cartilages were pliable and easy to conform. The spherical costal cartilage implant was inserted into orbit and affixed to 4 sclera flaps (Fig. 4C, D). Finally, conjunctival sac was sutured. Donor site of the inframammary fold was primarily closed. Postoperative CT examination showed the spherical costal cartilage implant in her orbit (Fig. 5). She was able to wear a thin artificial eye, and the eye movement was satisfactory.

Results

Follow-up periods ranged from 9 to 143 months (mean = 51.8 months). Application of thin artificial eyes became possible in all cases. There were 4 TPF transfer cases. There were a case of infection and a case of vascular failure of TPF as postoperative complications. For both cases, median forehead flap reconstructions were performed as salvage operations; thus, the results were dry sockets. Temporary fenestrated prosthesis was made 2 weeks after the operation, and this was exchanged to a permanent one in a month postoperatively. Excluding the cases with postoperative complications, we achieved satisfactory mobile eye sockets in 15 cases (78.9%). Prosthetic movement in upward and downward gaze was slightly difficult, but that in lateral and medial gaze was satisfactory. From the follow-up CT scans, no absorption of cartilage graft was present in all cases.

**MRSA**, methicillin-resistant *Staphylococcus aureus.*
was satisfactory. (See Video 2 [online], which demonstrates the postoperative eye movement.)

Case 5
This case is a 77-year-old man with radiation-induced phthisis. (See Video 3 [online], which demonstrates preoperative eye movement. The 77-year-old man has radiation-induced phthisis.)

This patient was the oldest among our series of patients. His cartilages showed calcification and were difficult to conform (Fig. 6). However, creation of round ball-like cartilage implant was possible. The operation was performed under the same procedures. The postoperative good eye movement was attained. (See Video 4 [online], which demonstrates that the postoperative eye movement was satisfactory.)

Case 6
She is a 24-year-old woman, who was diagnosed with retinoblastoma. The operation with the same procedures was performed. The movement of a conjunctiva sac is good in all directions. (See Video 5 [online], which demonstrates that the postoperative movement of a conjunctiva sac is satisfactory in all directions.)

Prosthetic movement in upward and downward gaze was slightly difficult, but that in lateral and medial gaze was satisfactory. (See Video 6 [online], which indicates that prosthetic movement in upward and downward
Fig. 3. Case 3. A, The spherical costal cartilage implant was inserted into orbit and affixed to 4 sclera flaps. B, Conjunctival sac was sutured. C, Postoperative CT examination showed the spherical costal cartilage implant in his orbit (red arrow). D, The patient was able to wear a thin artificial eye.

Fig. 4. Case 4. A, The patient suffered from severe pain of the phthisis bulbi by acute retinal necrosis. B, A round ball-shaped cartilage implant was created. Her costal cartilages were pliable and easy to conform. C, Four sclera flaps were prepared, and the costal cartilage implant was inserted into orbit. D, Four sclera flaps were sutured to each other.
gaze was slightly difficult, but that in lateral and medial
gaze was satisfactory.) Due to atrophy of orbital fat and
other surrounding soft tissues of the eye socket caused
by radiation therapy, a slight hypoglobus appearance
was present.

**DISCUSSION**

We perform 2 types of eye socket reconstructions:
total eye socket reconstruction after orbital exentera-
tion, including the removal of eyelids for maxillary can-
cer and other orbital malignant tumors, and partial
eye socket reconstruction after enucleation and bulbar
exenteration.\textsuperscript{1,2} The reconstruction of the orbital con-
tent is extremely important for selection and creation
of implants in partial eye socket reconstruction. When
there is no insertion of implants or small-sized implants
are inserted, not only concavity and ptosis occur, but long-
term eye socket deformity becomes inevitable due to the
necessity of inserting large and thick artificial eyes.\textsuperscript{3,4}
Additionally, artificial implants of materials such as sili-
con, acrylic, hydroxyapatite, or porous polyethylene may
lead to infection and exposure with incidence rate rang-
ing from 5% to 33%.\textsuperscript{5-7} Insertion of such implants may
even lead to mobility failure due to friction between the
implant and conjunctiva. Use of allografts can be another
option for implant material, but unfortunately it is not
clinically permitted in Japan. Thus, we choose to use
an autologous implant for the reconstruction. It is said
that dermal fat graft, subcutaneous fat graft, and fascial/
bone graft lead to postoperative absorption. However,
cartilage graft has an advantage of being constant in post-
operative capacity\textsuperscript{8,9}; thus, we choose costal cartilage as
autologous material. Artificial eyes must be as thin as possi-
bile for less deformity in the base and for better conduc-
tion of extraocular muscle mobility. Therefore, creation
of costal cartilage implant with similar size to that of the
normal eyeball is necessary, and less friction between the
implant and conjunctiva for better mobility is considered
to be important. Additionally, the shape of an implant
needs to be round to maintain the form of fornix conjunc-
tiva and natural mobility. To fulfill these conditions,
we then cut costal cartilage into slices and fix them around
the cartilage block to create a round ball-shaped cartilage
implant. The advantages to this procedure are that (1)
slight adjustment in volume and shape of cartilage ball is
possible, (2) adhesion between spaces of the surface and
surrounding tissues enables to create less slippage and
better mobility, and (3) round shape provides stability in
the long term. The only disadvantage for this procedure
is that the creation of this implant is time-consuming and
usually takes approximately 30 minutes. Additionally, we
must keep in mind that the condition of costal cartilage
differs in ages. Costal cartilages of young people are pli-
able and easy to manipulate. On the other hand, cartilages
of older patients tend to show calcification and are dif-
ficult to conform. Although difficulty of making cartilage
implant differs in ages, creation of round ball-like carti-
geous implants was possible in all cases with a wide range
of ages. To insert the implant, which is as same size as a
normal eyeball, we made 4 sclera flaps with extraocular
muscles. However, in severe conjunctival sac contraction
cases due to wearing thick artificial eyes for a long time,
the closure of conjunctival sac becomes difficult. For these
cases, the oral mucosa grafted TPF is transplanted to the
defect in the conjunctiva for closure. The artificial eye
movement becomes possible in these cases. On the other
hand, there was no extraocular muscle movement in dry
socket cases, which underwent salvage flap reconstruction
due to postoperative infection. Not only does dry socket

\textbf{Fig. 5.} Case 4. Postoperative CT examination showed the spherical
costal cartilage implant in her orbit (red arrow).

\textbf{Fig. 6.} Case 5. His cartilages showed calcification and were diffi-
cult to manipulate. However, creation of a round, ball-like cartilage
implant was possible.
not provide mobility, but it is also unfavorable in a way that it causes inflammation in the remaining conjunctiva.

Our procedure enables application of thin artificial eyes, maintains the form of eye socket in the long term, and conducts the movement of extraocular muscles through conjunctiva. In the past, there were a few articles that reported usage of autologous cartilage graft for eye socket reconstruction. However, our report with video clips is the first article to suggest and evaluate good postoperative eye movement after ocular reconstruction using cartilage graft.

Thus, our reconstructive procedure is considered an effective method for anophthalmia with remaining extraocular muscles caused by ocular phthisis. Artificial eye movement in upward and downward gaze is still not adequate in our cases due to limitation of shape of the artificial eye. To prevent postoperative contracture of fornix, we currently use prosthesis with enough thickness to create space in the fornix. This thickness probably causes limitation in the prosthesis movement of upward and downward gaze. Therefore, we hope for invention of an artificial eye with the shape close to a contact lens in the future, so that it can adhere more to conjunctiva for better eye movement.

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