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ORIGINAL ARTICLE
Reconstructive

A Dynamic Costal Cartilage Platform Promotes Ocular Prosthetic Excursion: Preliminary Report

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Background: The quality of life of the face involves mainly its configuration, and it plays an important functional role in communication skills. Thus, having artificial eyes is extremely essential in maintaining the quality of life of patients who have lost their eyeballs. We will present the details of the technique, including tips and innovations for eye socket reconstruction using spherical costal cartilage implant, which leads to dynamic and aesthetic results.

Methods: There were 19 cases of eye socket reconstruction using 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.)*

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.

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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

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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 TPF	Dry	MRSA infection + 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 TPF	Wet	None	Poor	67
9	42	Female	Anophthalmia orbit	Costal cartilage graft	Wet	None	Good	53
10	39	Male	Phthisis	Costal cartilage graft TPF	Dry	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 TPF	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

MRSA, methicillin-resistant *Staphylococcus aureus*.

computer tomography (CT) examination. We harvested the sixth costal cartilage and created the spherical costal cartilage implant of 20–24 mm in diameter. For recipient bed preparations to insert this large implant, we made 4 sclera flaps with 4 extraocular muscles attached to them and provided space by annularly cutting posterior portion of sclera. Harvested sixth costal cartilage was cut into slices. A block of the cartilage sized about 1 cm was made, and slices of cartilage were sutured around the block using 6-0 nonabsorption nylon to create a round ball-shaped cartilage implant. The spherical costal cartilage implant was inserted into orbit and fixed to 4 sclera flaps with 6-0 nonabsorption suture (Fig. 1).

For cases with severe conjunctival sac contracture, transfer of temporoparietal fascial flap (TPF) and oral mucosa graft was performed. We placed temporary fenestrated conformer and performed tarsorrhaphy after operation. Postoperative CT scans were taken for follow-up to assess the condition of the cartilage implant. We have made an effort to preserve patient's privacy in our figures and obtained informed consent of the patients and ethical approval from the committee.

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.

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

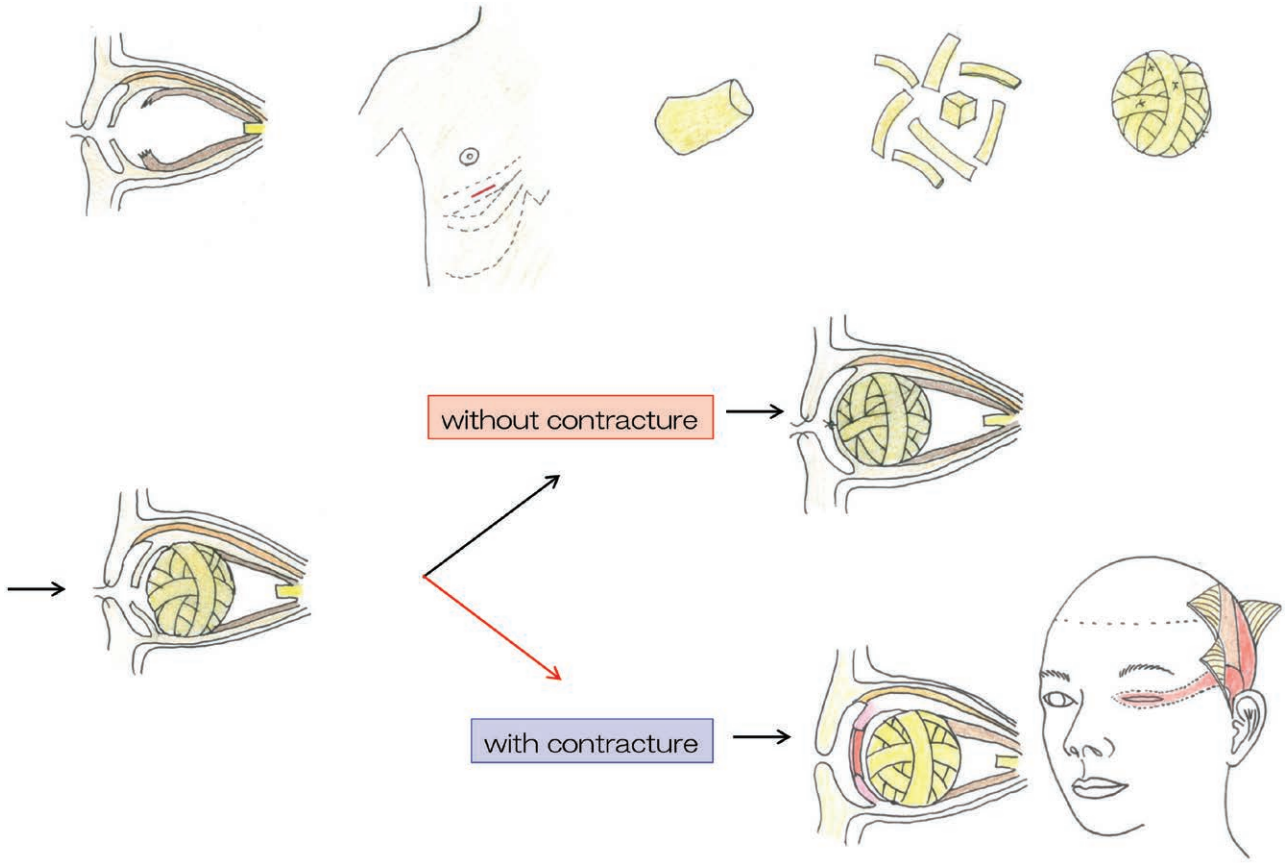

Fig. 1. Schema of procedure. We performed transfer of TPF and oral mucosa graft for cases with severe conjunctival sac contracture.

Fig. 2. Case 3. A, Because the eye socket was concaved, the patient had to wear a very thick artificial eye. B, Preoperative CT examination showed the existence of extraocular muscle in his orbit (red arrow). C, A round ball-shaped cartilage implant was created.

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

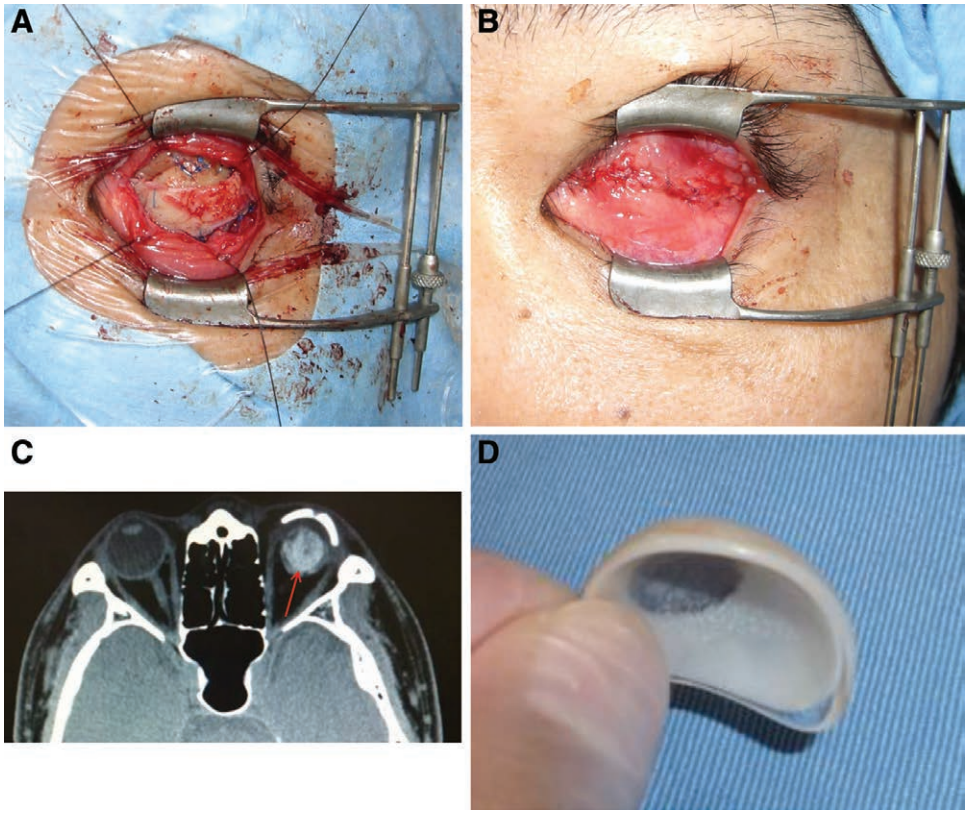

Fig. 3. Case 3. A, The spherical costal cartilage implant was inserted into orbit and affixed to 4 sclera flaps. B, Conjunctival sac was sutured. C, Postoperative CT examination showed the spherical costal cartilage implant in his orbit (red arrow). D, The patient was able to wear a thin artificial eye.

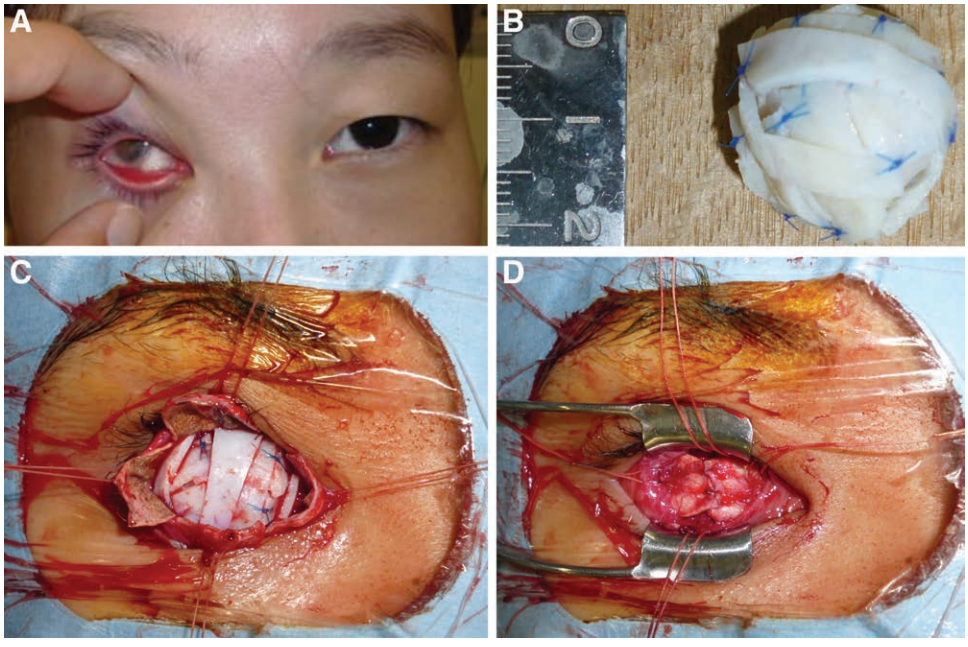

Fig. 4. Case 4. A, The patient suffered from severe pain of the phthisis bulbi by acute retinal necrosis. B, A round ball-shaped cartilage implant was created. Her costal cartilages were pliable and easy to conform. C, Four sclera flaps were prepared, and the costal cartilage implant was inserted into orbit. D, Four sclera flaps were sutured to each other.

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

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 exenteration, including the removal of eyelids for maxillary cancer and other orbital malignant tumors, and partial eye socket reconstruction after enucleation and bulbar exenteration.[1,2] The reconstruction of the orbital content 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.[3,4]

Additionally, artificial implants of materials such as silicon, acrylic, hydroxyapatite, or porous polyethylene may lead to infection and exposure with incidence rate ranging from 5% to 33%.[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 postoperative capacity[8,9]; thus, we choose costal cartilage as autologous material. Artificial eyes must be as thin as possible for less deformity in the base and for better conduction 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

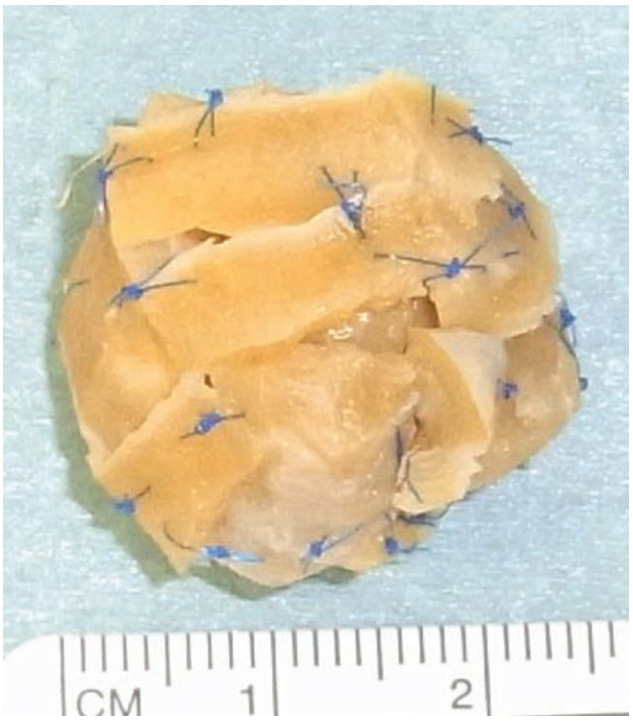

Fig. 6. Case 5. His cartilages showed calcification and were difficult to manipulate. However, creation of a round, ball-like cartilage implant was possible.

to be important. Additionally, the shape of an implant needs to be round to maintain the form of fornix conjunctiva 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 pliable and easy to manipulate. On the other hand, cartilages of older patients tend to show calcification and are difficult to conform. Although difficulty of making cartilage implant differs in ages, creation of round ball-like cartilage 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

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.[8,10] 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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