INTRODUCTION

Graves’ orbitopathy (GO), occurring in up to 50% of patients, represents the most common extrathyroidal manifestation of Graves’ disease.1 The proptosis results from infiltration and deposition of collagen and glycosaminoglycan in the retrobulbar and extra-ocular connective tissues. Edema, vascular congestion, fatty hyperproliferation, muscular hypertrophy and fibrosis increase intraorbital volume and pressure. Clinical ramifications include severe proptosis, lid retraction with exposure keratitis, diplopia, compressive myopathy, and in severe cases, compressive optic neuropathy (CON) and vision loss. GO is typically characterized by two phases—an active inflammatory phase followed by a chronic, or fibrotic, phase.2

The 2016 European Group on Graves’ Orbitopathy (EUOGO) guidelines for GO management recommend high-dose IV glucocorticoids as first line therapy for moderate-to-severe and active GO.3 Rituximab, radiotherapy, and cyclosporin represent second-line options. Indications for orbital decompression surgery include urgent vision-threatening optic neuropathy in active-disease phase and elective decompression for mild exposure keratitis, diplopia, and disfiguring exophthalmos after six months of disease inactivity.3 Leong et al. performed a systematic review including studies from 1990 to 2008 and found that the most common indications for surgery were cosmesis (42.4%), CON (40.6%), and exposure keratitis (7.9%).4

Orbital decompression surgery was first described by Dollinger in 1911 and performed through a lateral approach.5 Since then, multiple variations of the surgery aimed at increasing orbital volume and reducing compressive effects on the orbital structures and ophthalmic nerve by removing the surrounding bony walls, peri- orbita and/or fat have been developed (Fig. 1). The superior orbital roof decompression has been avoided due to the potential complications of cerebrospinal fluid leak and pulsating proptosis resulting from transmission of intracranial pressure changes. The trans-antral technique which removes the inferior and medial orbital walls via a Caldwell-Luc antrostomy was popularized by Walsh and Ogura in the 1950s.6 While effective a reducing proptosis, bothersome complications like permanent infraorbital nerve hypesthesia, oroantral fistula, facial swelling, and dental issues were not uncommon.7–10 Furthermore, post-operative diplopia rates reached 65% due to the “setting sun” phenomenon caused by hypoglobus.11 Similar complications plague so-called “minimal access” external approaches, including transconjunctival, transpalpebral, and transcaruncular approaches.12–14

The implementation of endonasal endoscopic techniques in orbital decompression surgery has allowed easier access and superior visualization of the medial and inferomedial orbital walls while also avoiding undesirable complications attendant with external approaches. Still, inferomedial orbital wall decompression is associated with
some of the highest rates of postoperative diplopia. As such, endoscopic approaches alone can also result in postoperative, new-onset diplopia as seen with other techniques. Endoscopic decompression can also be a component of a “balanced decompression,” where the medial and lateral walls (2-wall decompression) or the medial, lateral, and inferior walls (3-wall decompression) are removed with or without fat. A balanced decompression can offset the globe’s shift in axis and reduce the incidence of postoperative diplopia and dystopia. Graham et al. showed that balanced decomposition of the medial and lateral walls could reduce new-onset diplopia rates to as low as 10%. In a subsequent retrospective study including 73 patients undergoing 115 decompressions, the use of the orbital sling technique was associated with decreased new-onset diplopia and increased likelihood of resolution in preoperative diplopia. The results of these studies indicate that preservation of a medial periorbital sling is an effective technique in cases where maximal decompression is not necessary and vision is not threatened. Moreover, the studies suggest that the orbital sling can serve as a support mechanism that reduces the inferomedial displacement of the globe to prevent new-onset or worsening diplopia without affecting reduction in proptosis.

**Endoscopic Preservation of the Inferomedial Strut**

The inferomedial strut is a conceptual structure formed by bones that make up the inferior and medial wall dissection to support the medial rectus and prevent its prolapse (Fig. 2). The initial study population included 13 patients undergoing decompression for exposure keratitis or cosmesis and 24 historical controls who had not undergone a sling technique decompression. All patients underwent a standard total ethmoidectomy, maxillary antrostomy, sphenoidotomy, and resection of middle turbinate to allow for maximal decompression. Twelve patients in the study group had a concurrent lateral wall decompression. They did not note the rate of lateral wall decompression for the control group. Notably, the inferomedial strut (IOS, discussed in detail below) was removed in all patients. There was no new-onset or worsening diplopia in the study group compared to 16.7% new-onset and 20% worsening diplopia in the control group. Reduction in proptosis remained unchanged between the two groups (5.1 mm mean reduction). Notably, the authors noted a resolution of proptosis in 50% of the sling group patients. In a subsequent retrospective study including 73 patients undergoing 115 decompressions, the use of the orbital sling technique was associated with decreased new-onset diplopia and increased likelihood of resolution in preoperative diplopia. The results of these studies indicate that preservation of a medial periorbital sling is an effective technique in cases where maximal decompression is not necessary and vision is not threatened. Moreover, the studies suggest that the orbital sling can serve as a support mechanism that reduces the inferomedial displacement of the globe to prevent new-onset or worsening diplopia without affecting reduction in proptosis.

**The Endoscopic Orbital Sling Technique**

Citing a high incidence of postoperative diplopia with endoscopic techniques, Metson et al. introduced the orbital sling technique. The authors describe leaving a 1 cm strip of periorbita along the entire length of the
orbital walls. It serves as a major support mechanism preventing the inferomedial displacement of orbital contents and the resultant shift in globe axis that can result in diplopia or dystopia. Anteriorly, it is formed by thick maxillary bone at the orbital rim, centrally, it is formed by the junction of the thin maxillary bone and ethmoid lamina, and posteriorly towards the orbital apex, and it is made up of the thick triangulated junction of the palatine and ethmoid bones (Fig. 3). The anterior IOS contains strong fibrous attachments to the globe and act as the major support mechanism for the orbit. Goldberg first described preservation of the IOS via a transconjunctival approach, but this was quickly translated to the endoscopic approach. However, until recently, preservation of the IOS was considered by many a technically challenging pursuit, as it limits access to the orbital floor during endoscopic decompression.

Bleier et al. recently described an endoscopic technique for isolated orbital floor decompression with preservation of the entire IOS. In a proof-of-concept study, the authors employ angled frontal sinus instruments and cite a 100% successful completion rate in their series of 12 consecutive patients. Finn et al. subsequently published a retrospective review in 26 patients (45 orbits) that evaluated diplopia and proptosis outcomes after 2- and 3-wall decompressions with or without IOS preservation. Forty percent of the patients in this study were decompressed for CON. The entire IOS was preserved, except in select cases of CON, exposure keratopathy, and disfiguring proptosis. The authors found IOS preservation was associated with decreased new-onset diplopia, a high incidence (36%) of diplopia resolution, and a mean of 3.39 mm reduction in proptosis. The authors’ results advocate for a balanced, 3-wall decompression with strut preservation to promote maximum proptosis reduction while minimizing diplopia.

Yao et al. conducted a retrospective review of 73 patients undergoing 115 balanced decompressions of the medial and lateral orbital walls. Clinical indications for surgery included exophthalmos, exposure keratopathy, gaze restriction, and optic neuritis. In this study, the authors describe a modified endoscopic inferomedial strut (mIOS) preservation technique in which the posterior IOS is removed endoscopically, but the anterior strut is left intact (Fig. 4). The authors also performed an orbital sling procedure, except in patients with disfiguring exophthalmos (exophthalmopathy measured >28 mm) or threatened vision loss. Mean proptosis reduction achieved was 5.0 +/- 2.1 mm, and the preservation of an orbital sling did not influence the degree of reduction in proptosis. Diplopia resolved in 26% of cases, and 57% of patients undergoing sling technique had resolution in their diplopia compared to 17% in the non-sling group. The authors in this study advocate for the orbital sling technique in select patients as a measure to resolve pre-operative diplopia. This study also highlights the importance of posterior, inferior orbital strut removal in augmenting the degree of proptosis reduction without increasing the risk of diplopia.

Selective Endoscopic Orbital Apex Decompression for Compressive Optic Neuropathy

Compressive optic neuropathy, occurring between 2–8.6% of patients with GO, is the most serious consequence of Graves’ ophthalmopathy.22,23 The onset can be heralded by visual field loss, changes in visual acuity, optic nerve edema, and afferent pupillary defect. Nerve compression occurs at the intracanalicular portion of the nerve formed by the two struts of the lesser wing of the sphenoid and the annulus of Zinn. High-dose IV steroids are first line treatment for CON, and decompression surgery is indicated when medical therapy fails or in

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Fig. 3. Coronal CT scan on a patient that underwent a medial and inferior wall orbital decompression with the preservation of the inferomedial orbital strut (patterned arrow). Asterisks show the orbital contents displaced into the sinonasal cavities.

Fig. 4. Endoscopic view of the left orbit following modified inferomedial orbital strut technique (IOS) (cadaver). The arrow represents the anterior, middle and posterior aspect of the IOS. The dotted line is the posterior half of the IOS that has been removed. ER = ethmoid roof; M = maxillary sinus; MT = previously resected area of the middle turbinate; P = periorbita; S = sphenoid sinus.
presence of recent-onset choroidal folds and globe subluxation. The goal of decompressing the orbital apex is to reduce the compressive forces within the optic canal. Approaches for orbital apex decompression include transorbital, transantral coronal, external ethmoidectomy, and endonasal endoscopic approaches. The endonasal endoscopic technique provides unparalleled visualization of the orbital apex and represents an effective modality for improving visual acuity in patients with GO and CON. Traditional endoscopic apex decompression involves total sphenoidethmoidectomy with inferior and lateral wall removal. Some endoscopic surgeons also advocate removal of optic canal bone 1 cm posterior to the sphenoid face and, in some cases, incision of the nerve sheath. Mueller et al. have performed a morphometric analysis of the orbital process of the palatine bone and have noted that its surgical removal improves surgical exposure within the inferomedial apex. The indications for optic nerve decompression with sheath fenestration in the setting of CON are unclear.

## Table I
Summary of Outcomes from Selected Studies Employing Different Endoscopic Decompression Techniques. Reduction in proptosis values were reported as a mean. CON = compressive optic neuropathy; IOS = inferomedial orbital strut; NR = not reported.

| Technique details                                           | Reduction in proptosis (mm) | Diplopia resolution | New-onset diplopia | Reported complications                        | Citations |
|-------------------------------------------------------------|------------------------------|---------------------|--------------------|----------------------------------------------|-----------|
| Endoscopic 2-wall decompression without IOS preservation    |                              |                     |                    |                                              |           |
| Endo medial and inferior wall removal                       | 3.06–4.7                     | 0–5%                | 20–50%             | Epiphora, acute sinusitis                     | 21,34,35  |
| Endoscopic 2-wall decompression with IOS preservation      | 1.63–4.6                     | 0–12%               | 0–47%              | Periorbital hematoma                          | 19,21,36  |
| Endoscopic balanced 3-wall decompression with IOS preserved| Combined endo and external medial, inferior and lateral wall removal | 3.4–5.0              | 11–44%             | V2 anesthesia, corneal abrasion, epiphora, sinusitis, chemosis | 15,17,21  |
| Endoscopic sling preservation                              | Endo preservation of medial periorbital sling as part of combined, balanced approach | 5.1                  | 50–57%             | 0–6%                                         | See Yao et al. 17 16,17 |
| Endoscopic orbital fat decompression                        | Endo medial wall and intraconal fat removal | 6.2                  | NR                 | 0%                                           | Epistaxis 32 |
| Endoscopic sling preservation                              | Endo preservation of medial periorbital sling as part of combined, balanced approach | 5.1                  | 50–57%             | 0–6%                                         | See Yao et al. 17 16,17 |
| Endoscopic orbital fat decompression                        | Endo medial and intraconal fat removal | 6.2                  | NR                 | 0%                                           | Epistaxis 32 |
| Endoscopic selective decompression for CON                  | Posterior medial wall decompression | 2.2–3.1             | NR 28, 6.7% 15     | 0%                                           | See Kingdom et al. 15 15,29 |
|                                                            | IOS preserved                |                     |                    |                                              |           |
|                                                            | some with floor removal      |                     |                    |                                              |           |

Endoscopic orbital fat decompression
The increased retro-orbital fat characteristic in GO represents a critical driving factor of disease severity. Olivari described transpalpebral intraorbital fat removal as a decompression maneuver in 1988 and since then,

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this technique has proven safe and effective for a variety of clinical indications in GO.\textsuperscript{30,31} Traditionally an external procedure, intraorbital fat removal has long been within the purview of the oculoplastic surgeon. More recently, intraorbital fat removal has been performed via a endonasal endoscopic approach in GO. Lv et al. have very recently described an endoscopic transethmoidal fat decompression technique.\textsuperscript{32} The authors perform: 1) standard sphenoidectomy, 2) removal of medial wall periorbital, and 3) creation of an orbital sling, which prevents medial rectus prolapse but allows manipulation of fat for removal. The IOS is preserved in this study. A blunt-tipped low-powered suction cutting device is then used to remove extracanal and intracanal fat around extraocular muscles. The authors retrospectively evaluated outcomes employing this technique in 43 patients (72 orbits) with CON. Ninety-five percent demonstrated improvements in visual acuity, and the mean proptosis reduction was 6.2 +/- 1.2 mm. Furthermore, symmetry was achieved within 2 mm in 90.7% of patients. They cite no new-onset diplopia and two patients with worsening diplopia. This study provides evidence for another highly effective and versatile approach to GO decompression via a totally endonasal endoscopic route.\textsuperscript{32}

Conclusions and Future Directions

Orbital decompression surgery is not standardized, and literature reviewing techniques reveal considerable heterogeneity. A systematic review published in 2009 cited 15 different approaches.\textsuperscript{4} Similarly, a prospective study performed over a single year conducted by the EUOGO highlighted 18 different approaches across 11 different centers.\textsuperscript{7} This marked heterogeneity underscores a recent evolution in orbital decompression surgery characterized by refinement in techniques. Endonasal endoscopic orbital decompression provides unequalled access to the inferomedial orbital wall and apex while avoiding many risks of external approaches. The investigations highlighted in this review reveal a trend towards a more personalized approach towards decompression, where effects of decompressive maneuvers are tailored to decompression areas targeting each individual's needs. Unfortunately, the overwhelming majority of literature published on this subject is retrospective in nature and heterogenous in design. Thus, a comparison of outcomes across techniques has not yet proven feasible.\textsuperscript{2,3,33} Nonetheless, the available literature supports the rapid ascension of the endonasal endoscopic approach as one of the more versatile techniques in orbital decompression surgery.

BIBLIOGRAPHY

1. Clausier L, Galie M, Sarti E, Dallera V. Rationale of treatment in Graves' ophthalmopathy. Plast Reconstr Surg. 2000;107(8):1880–1884.
2. Boboridis KG, Uddin J, Mitropoulos DG, et al. Critical appraisal on orbital decompression for thyroid eye disease: a systematic review and literature search. Adv Ther. 2015;32(7):605–611.
3. Bartalena L, Baldeschi L, Boboridis K, et al. The 2016 European Thyroid Association/European Group on Graves' Ophthalmopathy Guidelines for the Management of Graves' Ophthalmopathy. Eur Thyroid J. 2016;5(1):9–26.
4. Leong SC, Karkos PD, Macewen CJ, White PS. A systematic review of outcomes following surgical decompression for dysostosis mongoloid. Laryngoscope 2009;119(6):1106–1115.
5. Shepard KG, Levin PS, Terris DJ. Balanced orbital decompression for Graves' ophthalmopathy. Laryngoscope 1998;108(11 Pt 1):1648–1653.
6. Walsh TE, Ogura JH. Transantral orbital decompression for malignant exopthalmos. Laryngoscope 1957;67(4):544–551.
7. Warren JD, Spector JG, Burde R. Long-term follow-up and recent observations on 305 cases of orbital decompression for dysthyroid orbitopathy. Laryngoscope 1989;99(1):35–40.
8. DeSanto LW. The total rehabilitation of Graves' ophthalmopathy. Laryngoscope 1980;90(10 Pt 1):1652–1678.
9. Murray JP. Complications after treatment of chronic maxillary sinus disease with Caldwell-Luc procedure. Laryngoscope 1983;93(3):282–284.
10. DeFreitas J, Lucente FE. The Caldwell-Luc procedure: institutional review of 670 cases: 1975–1985. Laryngoscope 1988;98(12):1297–1300.
11. Long JA, Baylis HI. Hypoglobas following orbital decompression for dysthyroid ophthalmopathy. Ophtal Plast Reconstr Surg 1990;6(3):185–189.
12. Goldberg RA, Shorr N, Cohen MS. The medical orbital strait in the prevention of postdecompression dystopia in dysthyroid ophthalmopathy. Ophthal Plast Reconstr Surg 1992;8(1):32–34.
13. Graham SM, Brown CJ, Carter KD, Song A, Nerad JA. Medial and lateral orbital wall surgery for balanced decompression in thyroid eye disease. Laryngoscope 2005;113(7):1296–1299.
14. Cruz AA, Leme VR. Orbital decompression: a comparison between transforaminal/transcaruncular inferomedial and coronal inferomedial plus lateral approaches. Ophtal Plast Reconstr Surg 2003;19(4):440–445; discussion 445.
15. Kingdom TT, Davies BW, Durairaj VD. Orbital decompression for the management of thyroid eye disease: An analysis of outcomes and complications. Laryngoscope 2015;125(9):2034–2040.
16. Metson R, Samaha M. Reduction of diplopia following endoscopic orbital decompression: the orbital sling technique. Laryngoscope 2002;112(10):1753–1757.
17. Yao WC, Sedaghat AR, Yadav P, Fay A, Metson R. Orbital decompression in the endemic age: the modified inferomedial orbital strut. Otolaryngol Head Neck Surg 2015;154(5):983–985.
18. Kim JW, Goldberg RA, Shorr N. The inferomedial orbital strait: an anatomic and radiographic study. Ophtal Plast Reconstr Surg 2002;18(5):355–364.
19. Wright ED, Davidson J, Codere F, Desroziers M. Endoscopic orbital decompression with preservation of an inferomedial bony strut: minimization of postoperative diplopia. J Otolaryngol 1999;28(3):252–256.
20. Bleier BS, Lefevvre DR, Freitag SK. Endoscopic orbital floor decompression with preservation of the inferomedial strut. Int Forum Allergy Rhi- nol 2014;4(1):82–84.
21. Finn AP, Bleier B, Cestari DM, et al. A retrospective review of orbital decompression for thyroid orbitopathy with endoscopic preservation of the inferomedial orbital bone strut. Ophtal Plast Reconstr Surg 2017;33(3):334–339.
22. Nadeau S, Pouliot D, Malgat Y. Orbital decompression in Graves’ orbitopathy: a combined endoscopic and external lateral approach. J Otolaryngol 2005;34(2):109–115.
23. Graham SM, Carter KD. Combined-approach orbital decompression for thyroid-related orbitopathy. Clin Otolaryngol Allied Sci 1999;24(2):109–113.
24. Fletcher SD, Sindwani R, Metson R. Endoscopic orbital and optic nerve decompression. Otolaryngol Clin North Am 2006;39(3):943–958, vi.
25. Schaefer SD, Soliemanzadeh P, Della Rocca DA, et al. Endoscopic and transconjunctival orbital decompression for thyroid-related orbital apex nerve compression. Laryngoscope 2002;112(13):508–513.
26. Luxenberger W, Stammberger H, Jебelas JA, Walch C. Endoscopic optic nerve decompression: the Graz experience. Laryngoscope 1998;108(8):873–882.
27. Mueller SK, Freitag SK, Bleier BS. Morphometric analysis of the orbital process of the palatine bone and its relationship to endoscopic orbital decompression. Ophthal Plast Reconstr Surg 2017. Epub, ahead of print.
28. Kazim M, Trokel SL, Acaroglu G, Elliott A. Reversal of dysthyroid optic neuropathy following orbital fat decompression. Br J Ophthalmol 2000;84(6):600–605.
29. Chu EA, Miller NR, Lane AP. Selective endoscopic decompression of the orbital apex for dysthyroid optic neuropathy. Laryngoscope 2009;119(6):1236–1240.
30. Olissari N. [Transpalpebral decompression operation in endocrine orbite- ropathy (exophthalmos). Wien Med Wochenschr 1988;138(18):453–455.
31. Richter DF, Stoff A, Olissari N. Transpalpebral decompression of endocrine ophthalmopathy by intraorbital fat removal (Olissari technique: experience and progression after more than 3000 operations over 20 years. Plast Reconstr Surg 2007;119(1):109–123.
32. Lv Z, Selva D, Yan W, Daniel P, Tu Y, Wu W. Endoscopic orbital decompression with medial orbital wall surgery for dysostosis mongoloid optic neuropathy. Curr Eye Res 2016;41(2):150–158.
33. Boboridis KG, Bunce C. Surgical orbital decompression for thyroid eye disease. Cochrane Database Syst Rev 2011;12:CD007630.
34. Malik R, Cormack G, MacEwen C, White P. Endoscopic orbital decompression for dysostotic thyroid eye disease. J Laryngol Otol 2006;122(6):595–597.
35. Kennedy DW, Goodstein ML, Miller NR, Zinreich SJ. Endoscopic transnasal orbital decompression. Arch Otolaryngol Head Neck Surg 1990;116(7):795–799.
36. Stiglmayer N, Madina R, Tomic M, et al. Endonasal endoscopic orbital decompression in patients with Graves' ophthalmopathy. Croat Med J 2004;45(3):318–322.

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