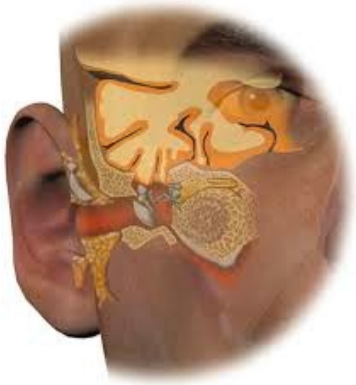
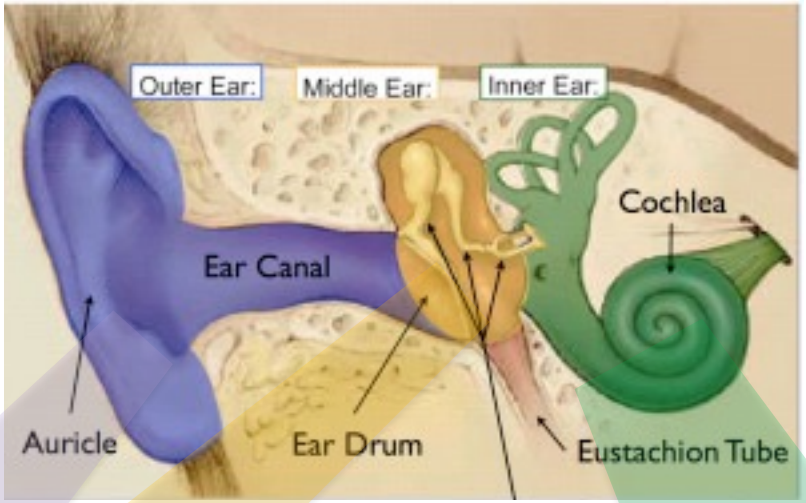
Congenital stapes fixation and juvenile otosclerosis

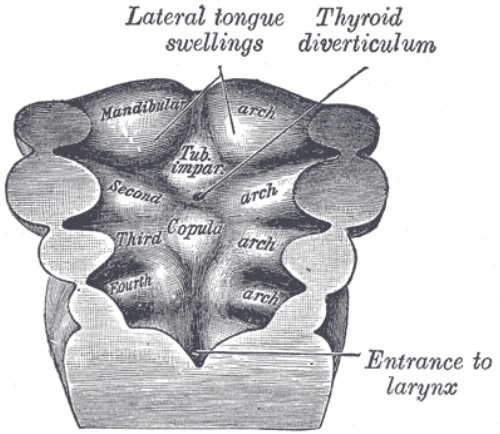


Journal club
01/20/21

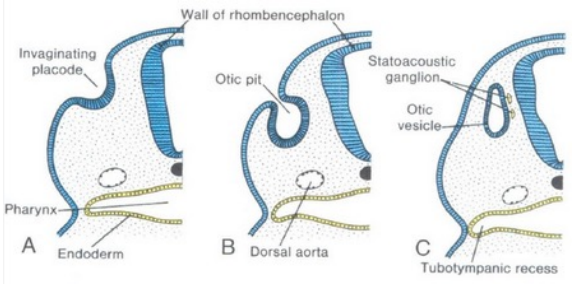
Judith Kempfle

Middle and inner ear development



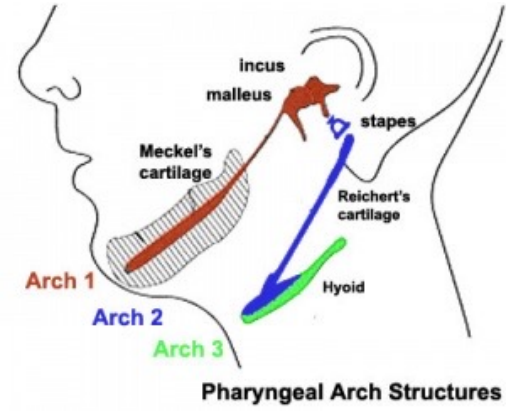


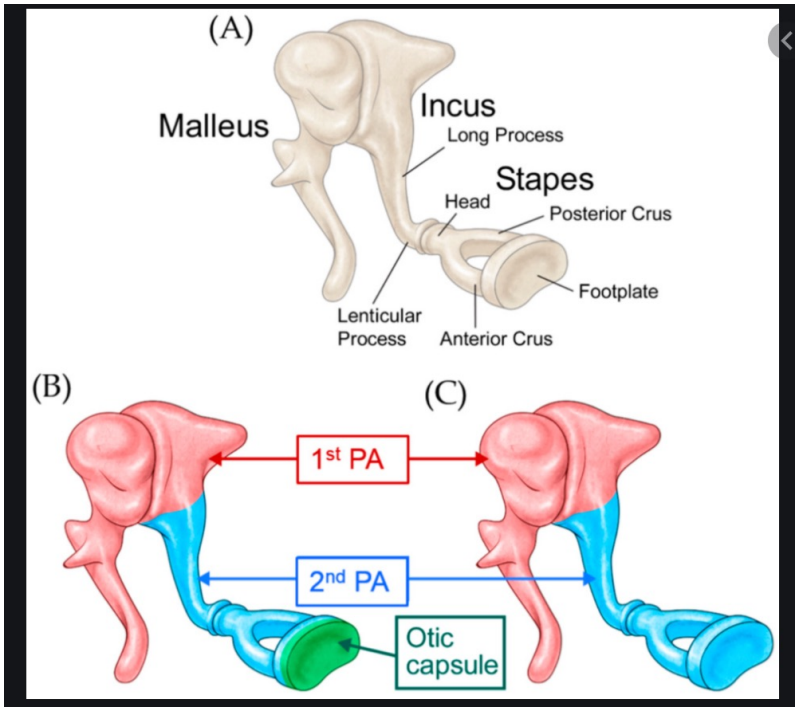
Pharyngeal arches



Otic capsule

First theory of stapes development

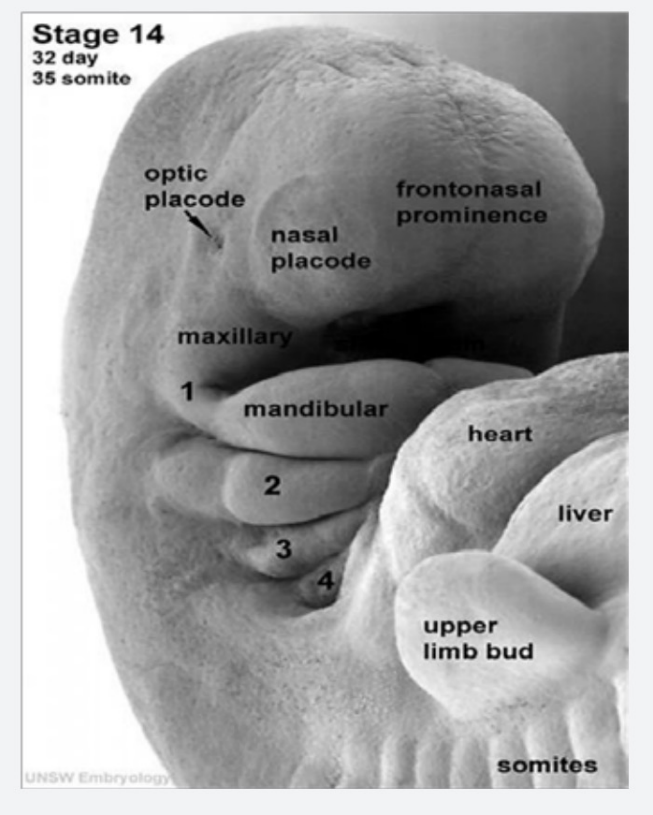


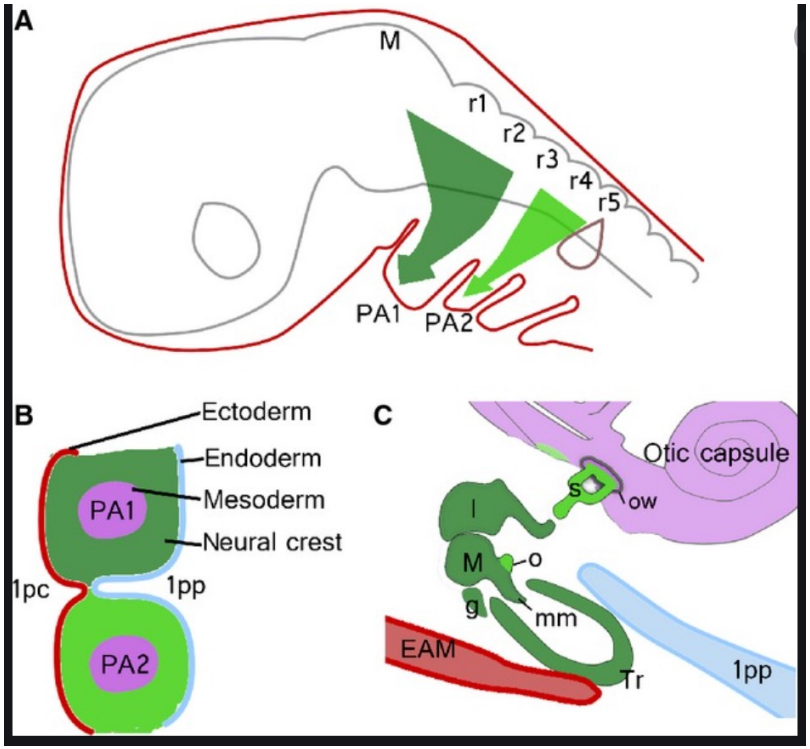


Vestibular side or the medial side is actually created by the otic capsule bone or otic capsule lineage, and the external surface of the foot plate is derived from the second arch, similar to the stapes superstructure.

https://embryology.med.unsw.edu.au/embryology/index.php/Hearing_-_Middle_Ear_Development

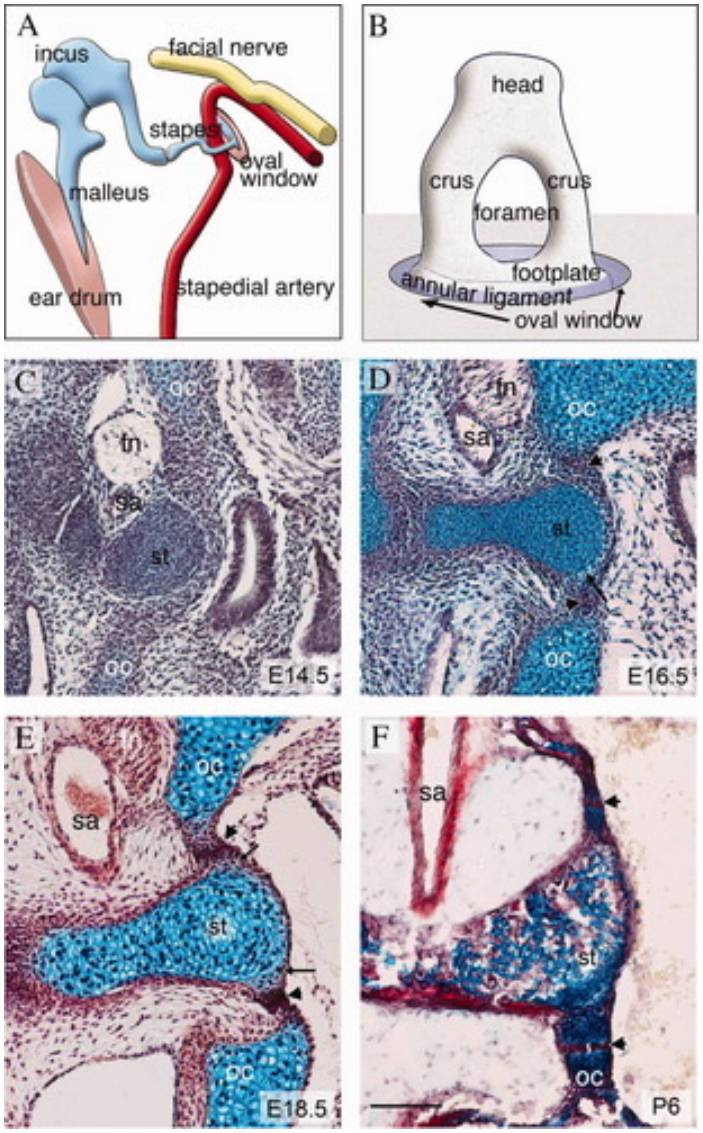
Second theory of stapes development





Anthwal et al, J. Anat., 2015

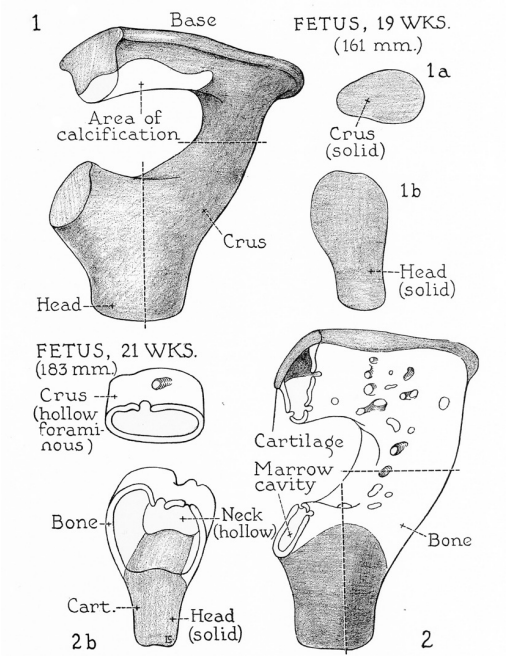
Stapes development

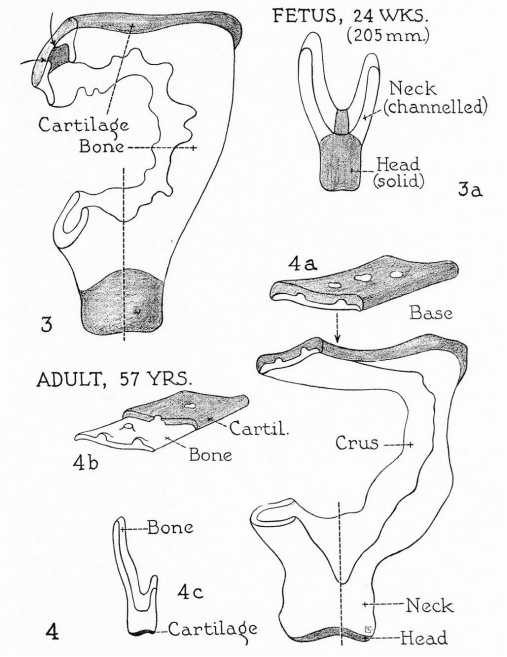


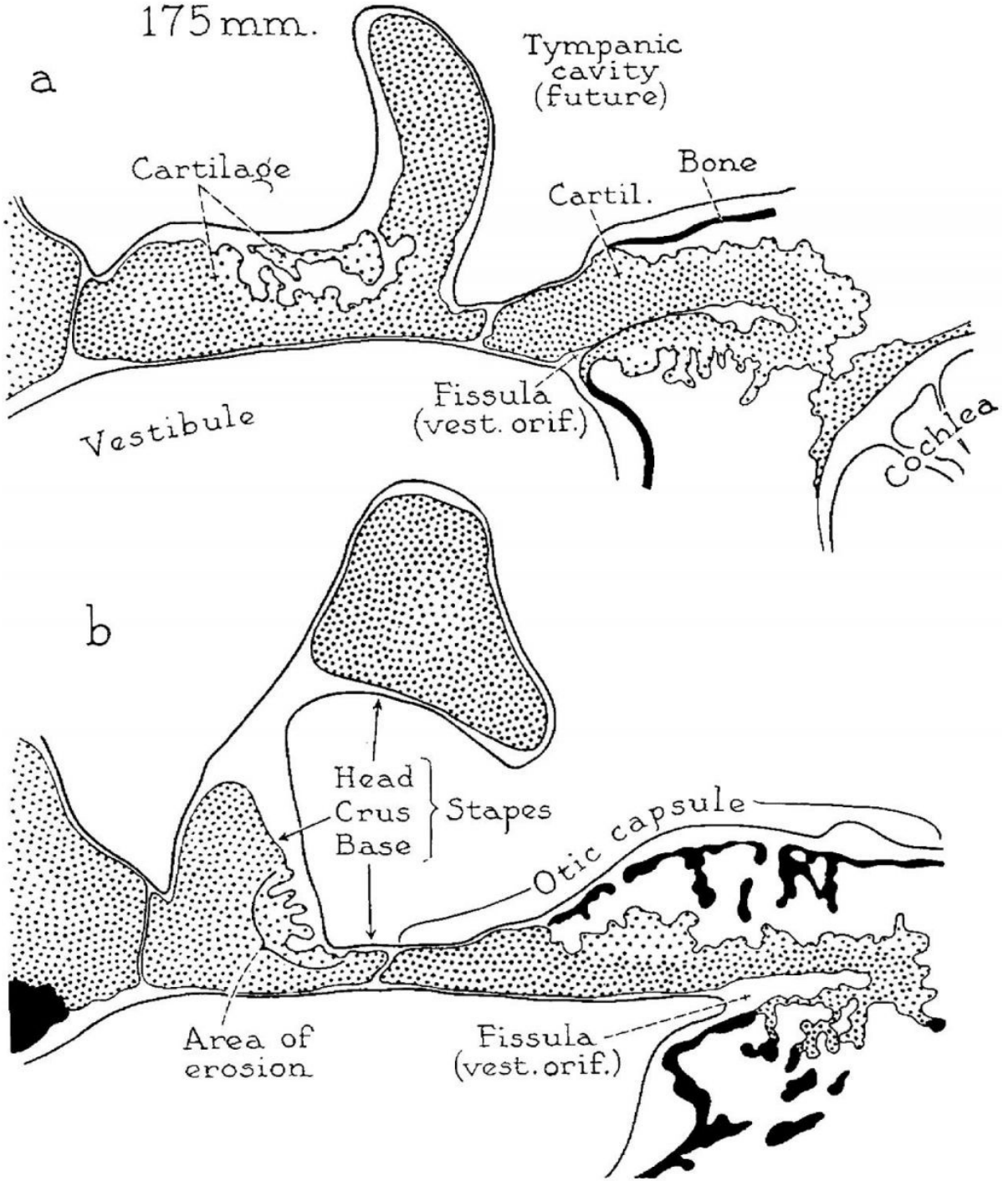
- Failure of embryogenesis
- Failure of differentiation
- Failure of mesenchymal specification

- Involvement of Wnt, BMP4, SHH pathway interaction
- Neural crest cells (NCCs) migrate from the dorsal hindbrain to specific locations in pharyngeal arch (PA) 1 and 2.
- Region-specific endodermal signals direct formation of specific middle ear ossicles: Gradients of Wnt, SHH, FGF and BMP4 signaling are instrumental (Billmyre and Klingensmith, 2015; Jeong et al., 2004).

Stapes development






175 mm.
a
Tympanic cavity (future)
Cartilage
Bone
Cartil.
Vestibule
Fissula (vest. orif.)
Cochlea
b
Head
Crus
Base
Stapes
Otic capsule
Area of erosion
Fissula (vest. orif.)

Classification of congenital ossicular anomalies

Table 1
Classification of congenital ossicular anomalies

Class 1	Ankylosis or isolated congenital fixation of the stapes (30.6%)
Class 2	Stapes ankylosis associated with other malformations of the ossicular chain (38.1%)
Class 3	Congenital anomalies of the ossicular chain with a mobile stapes footplate (21.6%)
Class 4	Congenital aplasia or severe dysplasia of the oval and round windows (includes persistent stapedial artery; 9.7%)

Adapted from Teunissen EB, Cremers WR. Classification of congenital middle ear anomalies. report on 144 ears. Ann Otol Rhinol Laryngol 1993;102(8 Pt 1):606–12.

Congenital stapes fixation/ ankylosis (CSFF)

- Isolated
- Associated with other ossicular abnormalities
- Fixation related to inner ear malformations
- Maximum conductive hearing loss (CHL) from birth, stable
- Pathophysiology: Annular ligament missing/abnormal

Associated malformations/syndromes can include:

- Pierre-Robin sequence (abnormal development of PA1,2, palatal abnormalities)
- X-linked gusher (wide cochlear aperture, absent modiolus)
- Teunissen-Cremers syndrome (NOG mutation, proximal symphalangism, conductive hearing loss, synostoses)- Wnt, SHH and BMP pathway abnormalities

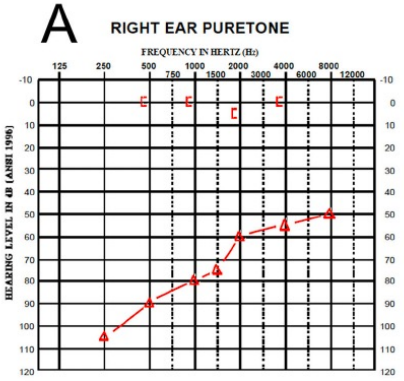
Juvenile otosclerosis (JO)

- Begins in childhood, before the age of 18
- Youngest presentation for surgery ~6-7 y/o
- 0.6% of individuals < 5 yrs have foci
- Conductive hearing loss is **progressive**, does not manifest initially with maximum CHL
- **Positive family history**
- Pathophysiology: Incomplete ossification of cochlea with foci of increased bone turnover- can affect stapes as vestibular side has otic capsule lineage
- Most common site of clinical manifestation: Unipolar location at anterior footplate, fissula ante fenestram (fissure anterior to the window)
- Can be associated with osteogenesis imperfecta

Clinical presentation

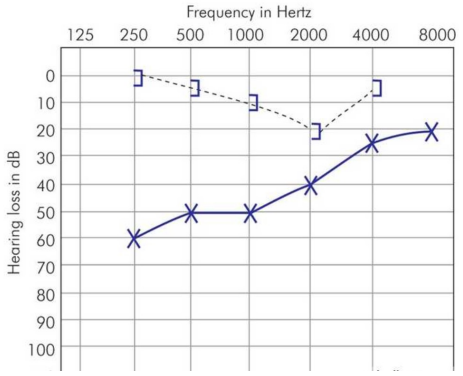
- Normal tympanic membrane/ ear exam
- Normal tympanometry, aerated middle ear
- CHL, absent acoustic reflex
- Differential diagnoses: Anomalies of the ossicular chain, osteogenesis imperfecta, atresia of the round window, tympanosclerosis

CSFF



Preoperative audiogram

JO



Fixation of the Stapes Footplate in Children: A Clinical and Temporal Bone Histopathologic Study Bachor et al., 2005

- Stapes footplate exam in 288 temporal bones from 181 children (age 20 weeks of gestation- 13 years)
- Histologic analysis and chart review of 12 children that underwent surgery for footplate fixation (age 7-13 years)
- Average age at diagnosis 6.6 years

- Diagnosis of otosclerosis: Progressive CHL and intraop finding of fixation of the anterior stapediovestibular joint
- Diagnosis of stapes ankylosis: Nonhomogeneous, thickened, fixed footplate and the absence of an annular ligament

Histopathology

TABLE 3. *Temporal bone collections studied*

	Temporal bones [Number]	Children [Number]	Sex [male/ female/ not known]	Ages distribution [months]	Mean [months]	Median [months]	Children with congenital anomalies in sample [%]	Footplate anomalies
Tufts University, Boston	130	76	43/32/1	0–144	15.26	1.35	51.3	1 bilateral atresia plate 1 bilateral congenital ankylosis
Southwestern Medical Center, Dallas	30	22	14/6/2	0–108	16.99	2.0	63.6	2 bilateral abnormal footplates
Temporal Bone Foundation, Boston	14	7	4/3	0–7.5	2.09	0.8	71.4	1 bilateral congenital ankylosis 1 abnormal thin footplate 1 tilted footplate
Wittmaack collection, Hamburg	114	76	38/15/21	0–144	19.8	8	2.6	None
Total	288	181	99/56/24	0–144	13.54			7

Histopathology of juvenile otosclerosis

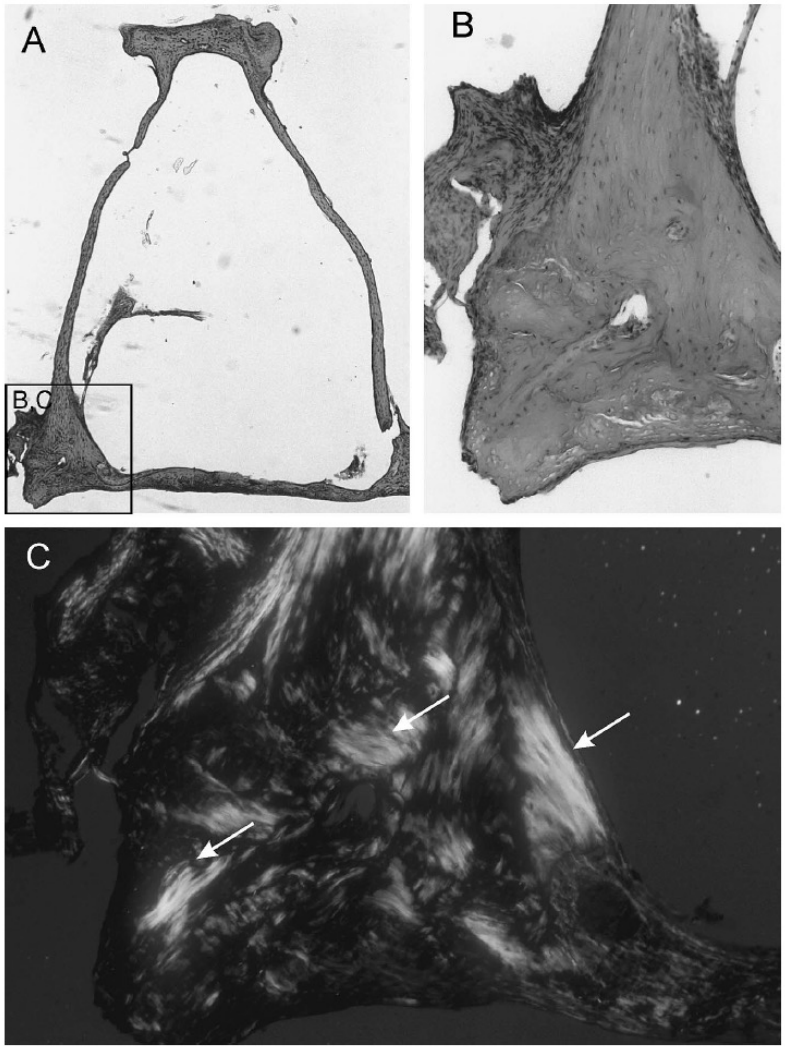


Figure 1

Histopathology of juvenile otosclerosis

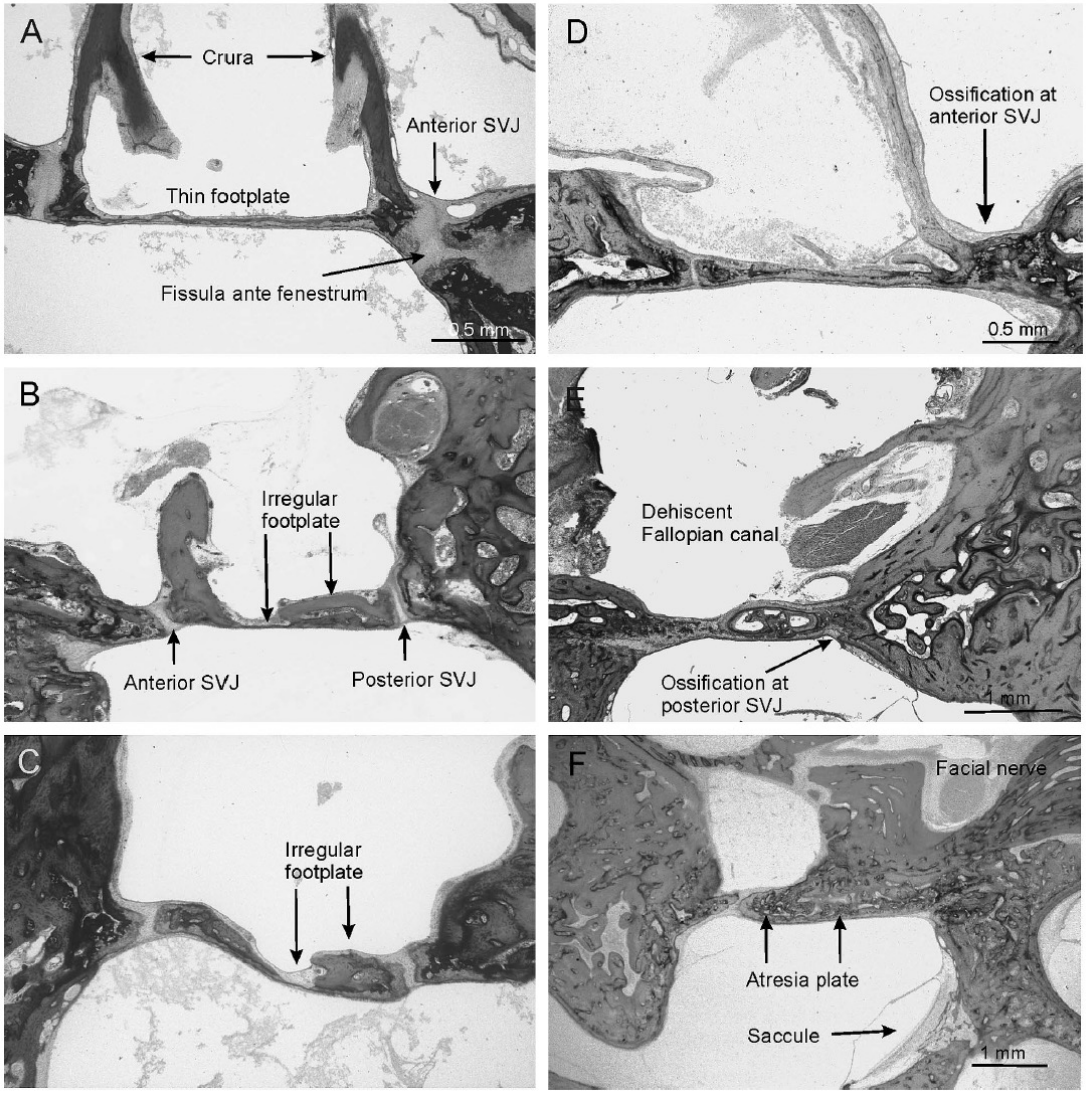


Figure 2

Histopathology of juvenile otosclerosis

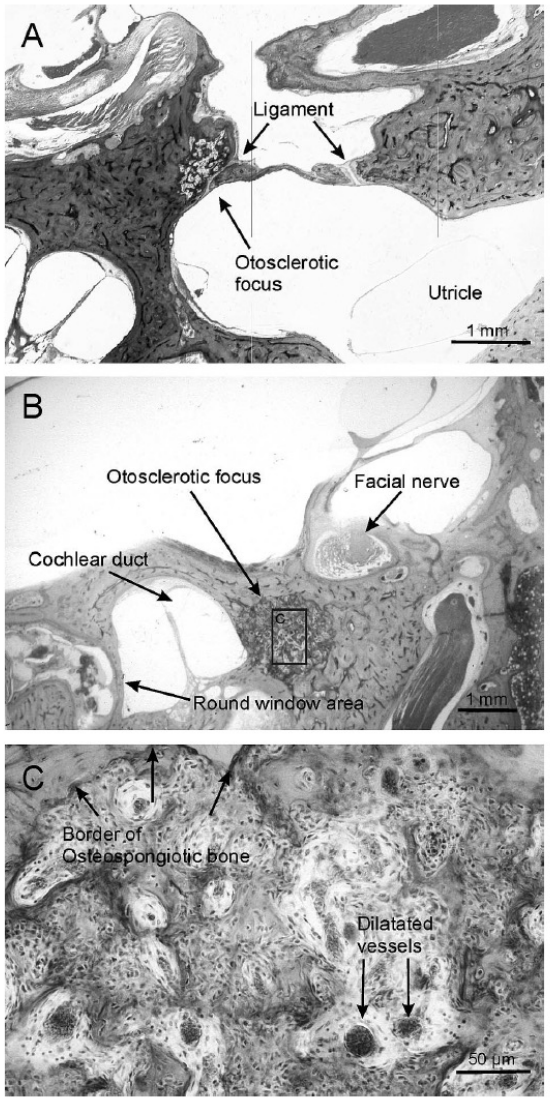


Figure 3

Intraoperative findings

TABLE 1. *Patient data and intraoperative findings of 12 children (15 tympanotomies) with the intraoperative diagnosis*

Patient ID	Sex [male, female]	History	Age at onset of hearing loss [years]	Age at surgery [years]	Intraoperative finding [visual inspection]	Histological findings	Most likely diagnosis
1*	M	Unilateral CHL	4	11	Sclerotic apposition on the posterior part, thickened white FP	–	Congenital stapes fixation
2*	F	Delay of speech development Bilateral CHL positive Family history of OS	3	10	Typical otosclerotic findings at the anterior part of the FP, gusher/OS	Sclerotic changes in the anterior crus (Fig.1)	Otosclerosis
3*	M	Bilateral CHL	6	10	Malformed anterior crus of the stapes, complete fixation of the FP	–	Congenital stapes fixation
4	M	Unilateral CHL	7	11	Fixation of the anterior part of the FP/OS	–	Otosclerosis
5	F	Bilateral CHL Positive family history of OS	6	13	Typical otosclerotic findings at the anterior part of the FP	–	Otosclerosis
6	F	Delay of speech development Bilateral CHL	2	13	Inhomogeneous, white, thick and fixed FP	No pathological changes of the stapes suprastructure	Congenital stapes fixation
7	M	Unilateral CHL	7	12	Filiform anterior crus and enlarged and thickened FP/OS	–	Otosclerosis
8	F	Unilateral CHL	4	8	Narrow oval window niche	–	Anomaly
9	M	Unilateral CHL	3	7	Inhomogeneous thick and fixed FP, malleus anomaly	–	Congenital stapes fixation
10	F	Unilateral CHL	10	12	Malformed anterior crus of the stapes, gusher/OS	No pathological changes of the stapes suprastructure	Otosclerosis
11	F	Unilateral CHL	3	7	Medial tilted stapes, gusher, complete fixed FP	–	Congenital stapes fixation
12	F	Unilateral CHL	6	8	Thick and complete fixed FP	–	Congenital stapes fixation

Children with congenital footplate fixation are shaded (summary from (11)).
FP, stapes footplate; CHL, conductive hearing loss; (*), revision; OS, otosclerotic bone apposition.

Table 1

Pre- and postoperative audiometric findings

TABLE 2. *Audiometric findings (1 day preoperatively and 3 weeks to 12 months postoperatively)*

Patient ID	Ear		Preoperative audiogram [kHz] 0.5	1	2	4	ABG [dB]	Postoperative audiogram (Hz) 0.5	1	2	4	ABG [dB]
1	right	BC	5	10	10	5	21	5	10	20	20	28
		AC	40	35	20	20		50	45	40	30	
2	left	BC	10	20	15	20	30	35	40	50	50	45
		AC	40	55	40	50		90	90	85	90	
3	left	BC	5	10	5	10	55	35	50	40	35	39
		AC	65	65	60	60		75	80	85	75	
4	left	BC	0	0	5	5	31	5	5	5	5	11
		AC	35	35	35	30		15	15	15	20	
5	right	BC	5	10	10	15	19	5	10	10	10	8
		AC	35	45	20	15		15	25	15	10	
6	left	BC	10	10	10	10	30	5	10	10	15	14
		AC	60	40	30	30		25	25	20	25	
7	right	BC	15	20	15	25	36	15	15	15	20	11
		AC	50	50	60	60		30	25	25	30	
8	left	BC	0	5	5	5	49	40	40	45	45	35
		AC	45	55	55	55		70	80	80	80	
9	left	BC	15	25	15	25	28	25	40	45	50	28
		AC	45	45	55	45		65	70	65	70	
10	right	BC	10	15	10	20	19	10	10	10	15	5
		AC	30	35	30	35		15	10	20	20	
11	left	BC	25	35	30	35	44	15	25	25	25	14
		AC	75	80	75	70		25	45	45	30	
12	right	BC	10	15	20	15	31	10	10	15	15	5
		AC	45	45	45	50		15	15	20	20	

ABG air bone gap for pure-tone average of 0.5, 1, 2 and 4 kHz, BC bone conduction, AC air conduction. Children with presumed congenital footplate fixation are shaded.

Low case number, multiple surgeons, various techniques

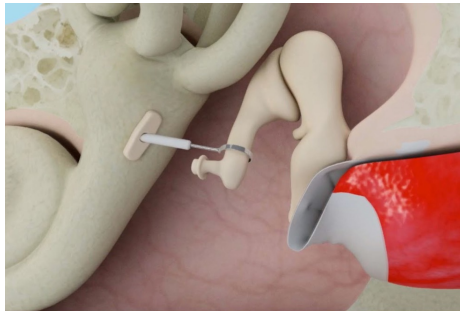
Table 2

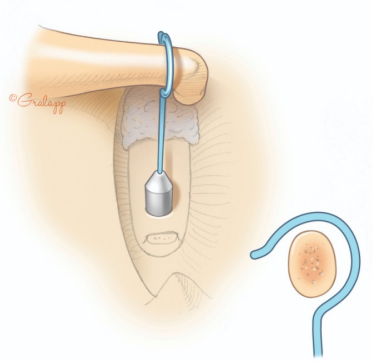
Outcomes

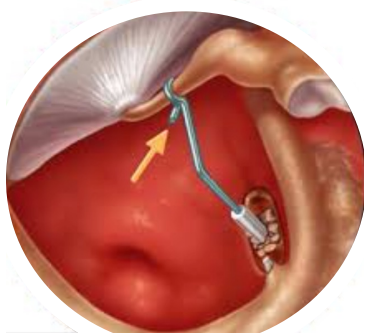
- Stapes surgery improved hearing postoperatively in only 7 of the 12 children, and the best hearing results were seen in children with presumed juvenile otosclerosis.
- In two of five children with congenital stapes fixation, both bone and air conduction thresholds worsened.
- Although the development of a gusher often results in total hearing loss, hearing deteriorated only in Patient 2.
- De la Cruz et al: 44% of children with congenital stapes ankylosis had a postsurgical air-bone gap < 10 dB, as compared with 82% in children with presumed otosclerosis.
- Raveh et al. achieved 0- to 10-dB airbone gaps in only 2 children, whereas 8 of 12 children with fixed stapes had postsurgical air-bone gaps greater than 30 dB.

Outcomes of Primary Pediatric Stapedotomy Dornhoffer et al., 2019

- 59 children (67 ears) underwent surgery for stapes fixation from 2001 – 2017, single surgeon
- 4–16 years of age
- All with preop CT to rule out facial nerve abnormalities and concurrent inner ear abnormalities
- Standardized technique: Traditional stapedotomy (88.1%, incus to footplate fenestra) or malleovestibulopexy (11.9%, malleus to footplate fenestra)







Otosurgery atlas

TABLE 1. *Demographic information and results of the patient group analyzed*

	Total	CSFF	TS	JO
Total cases (n)	67	49	14	4
Age	10.0 ± 3.3	9.9 ± 3.4	10.3 ± 2.96	11.5 ± 3.4
Gender				
F	37	30	5	2
M	30	19	9	2
Side				
L	31	24	5	2
R	36	25	9	2
Procedure				
Stapedotomy	59	42	13	4
MVP	8	7	1	0
Pre-op				
Air	51.2 ± 15.3	51.4 ± 16.8	50.7 ± 11.6	51.7 ± 4.3
Bone	12.4 ± 7.4	12.8 ± 8.3	10.8 ± 3.5	13.3 ± 5.93
ABG	38.8 ± 13.2	38.5 ± 14.4	39.9 ± 10.4	38.3 ± 7.6
Post-op				
Air	36.6 ± 17.2	35.6 ± 18.0	41.8 ± 13.1	31.3 ± 19.3
Bone	12.7 ± 7.5	13.2 ± 8.0	11.4 ± 6.1	10.8 ± 6.5
ABG	23.3 ± 12.0	21.0 ± 11.4	30.4 ± 10.9	22.8 ± 14.9
T&C, etc.				

ABG indicates air-bone gap; CSFF, congenital stapes footplate fixation; JO, juvenile otosclerosis; MVP, malleovestibulopexy; T&C, Teunissen and Cremers; TS, tympanosclerosis.

CSFF

TABLE 2. *Teunissen and Cremers classification breakdown*

T&C Classification	Total (%)
1	22 (44.9)
2	19 (38.8)
3	0
4	8 (16.3)
	49

1 – isolated congenital stapes fixation; 2 – stapes fixation with other ossicular chain anomaly; 3 – mobile footplate with ossicular chain anomaly; 4 – aplasia or dysplasia of oval or round window.

T&C indicates Teunissen and Cremers.

Outcomes

- Average follow-up time from procedure to most recent audiogram for the group was 34.6 months with 15 (22%) of patients having follow-up out to 5 years.
- No sensorineural hearing loss, bone conduction thresholds were not significantly different between preoperative and postoperative audiograms.
- JO and CSFF outcomes similar, which differs from current literature- better outcome historically expected for JO, given high likelihood for concurrent middle and inner ear malformations in CSFF

Other outcomes- De La Cruz et al., 1999

Table 6. Characteristics and hearing results for primary stapedectomies, congenital stapedial fixation, and juvenile otosclerosis

	Congenital stapedial fixation (n = 44)	Juvenile otosclerosis (n = 39)	*P* value
Age of onset of hearing loss (yr)	3.03 ± 2.8	10.18 ± 4.6	<0.001
Age at surgery (yr)	11.4 ± 3.9	14.8 ± 3.1	<0.001
Family history of hearing loss (%)	9.8	53	<0.001
Bilaterality (%)	77.6	90	NS
Severe malleus and incus abnormalities (%)	25	3 (n = 34)	<0.001
Preoperative AC (0.5, 1, 2, 3 kHz) (dB)	55.1 ± 13.9	49.7 ± 12.1	p = 0.05
Preoperative BC (0.5, 1, 2, 3 kHz) (dB)	20 ± 10.6	21.8 ± 9.8	NS
Preoperative ABG (0.5, 1, 2, 3 kHz) (dB)	35.2 ± 12.9	27.8 ± 8.9	0.002
Preoperative SNH (1, 2, 4 kHz) (dB)	20.6 ± 11.9	21.7 ± 9.4	NS
Postoperative SNH (1, 2, 4 kHz) (dB)	17.2 ± 12.5	17.3 ± 8.4	NS
Improvement (>10 dB PTA, >15% SDS) (%)*	76.7	82.9	NS
Within 10 dB ABG (%)	44.4	82.4	0.03

SNH, Sensorineural hearing; *NS*, no significant difference ($P > 0.05$)

*Improvement is defined as a decrease greater than 10 dB in the AC average (0.5, 1, 2, 3 kHz) or an increase greater than 15% in SDS.