

表2 液晶モニターを斜め方向から見たときの視力の変化

症例	1		2		3		4		5	
	R	L	R	L	R	L	R	L	R	L
0°	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.2	1.2
5°	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.2	1.2
10°	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.2	1.2
15°	1.5	1.2	1.5	1.5	1.5	1.5	1.5	1.5	1.2	1.0

結果

1. SC-2000と従来の視力検査装置との視力の比較

成人および小児の、SC-2000とA社製標準視力検査装置で得られた視力値を図3.4に示す。視力は、得られた小数視力値をlog MAR換算して用いた。

成人の視力は、換算log MAR値平均が、SC-2000では-0.126、A社製標準視力検査装置では-0.119であった。2機種で視力値に1段階の差があったのは、成人40眼中6眼、小児28眼中10眼であった。2段階以上差のあったものはなかった。SC-2000のほうが、視力不良の症例が多い傾向がみられたが、統計学的には2機種間で有意差はなく相関性のある結果が得られた(相関係数0.962, $p < 0.0001$)。

小児の視力は、換算log MAR値平均が、SC-2000では-0.088、A社製標準視力検査装置では-0.086であり、2機種間に有意差はなく高い相関を認めた(相関係数0.8705, $p < 0.0001$)。

2. SC-2000の液晶モニターを斜めから見たときの視力への影響

液晶モニター正面0°~15°までの4ヵ所での視力の変化を表2に示す。5名10眼中、2名2眼で、正面から15°移動した位置で初めて1段階の低下がみられたが、それ以外の変化はみられなかった。

考按

1. SC-2000と従来の視力検査装置との視力の比較

2回の視力検査を同日に行うことは、常に検査の順番の影響を考慮しなくてはならない。また、検討を行ったSC-2000と従来の視力検査装置では、視標の提示方法が異なるために、全く同じ結果が得られるとは限らない。そこで、さらにこの2点について考察を加える。

2機種間で視力差があったものを、検査を行った順で

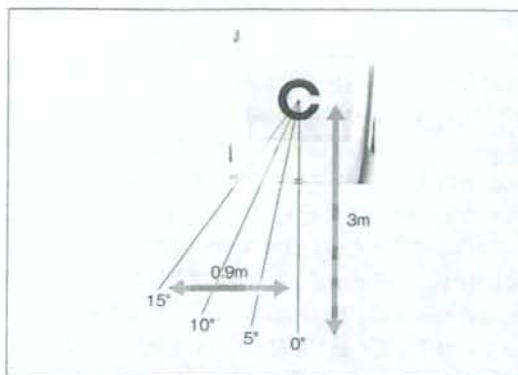


図2 斜め方向からの視力の測定場所
液晶モニター正面を0°とし、モニター面に対して水平に5度間隔で15°までの4ヵ所で視力を測定した。検査距離3mで、15°の位置は正面0°の位置より約0.9m離れた位置となる。

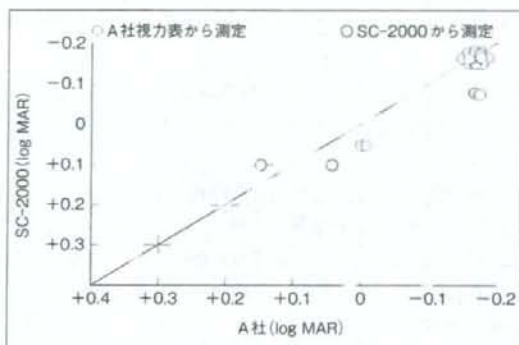


図3 2機種間の視力比較(成人)

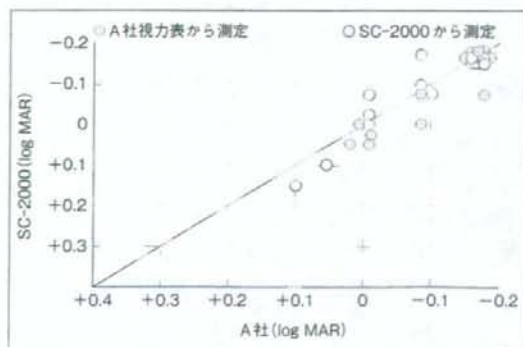


図4 2機種間の視力比較(小児)

検討すると、後で行った視力検査のほうが不良だったものは、成人40眼中4眼(10%)、小児28眼中6眼(21%)、先に行った検査のほうが不良であったのは、成人40眼中2眼(5%)、小児28眼中4眼(14.6%)であり有意ではなかった。検査の順番が視力検査に影響を及ぼしたと思われる被検者もあるが、全体の結果に影響を与えるほどではなかった(成人： $p=0.18$ ，小児： $p=0.12$)。

視標の提示方法では、SC-2000では字ひとつ表示、准標準視力検査表では字づまり表示であることが問題になる可能性がある。特に8歳頃までcrowding現象がみられるとされる小児の視力を測定する上で重要になると考えられた⁴⁾。しかし、平均視力の差は成人より小児のほうが小さく、crowding現象が結果に影響したとは考えにくい。

2. SC-2000の液晶モニターを斜めから見たときの視力への影響

小児が対象の場合には、検査中、頭を動かすなど液晶モニターを斜めに見ることが懸念される。被検者の頭位ずれによるモニター面に対する視線の角度は、検査距離が短いほど大きくなる。今回の検討で、3mの距離で15°の位置まで視力結果に変化がみられなかったことから、通常の検査条件の範囲であればその影響は少ないと考えられた。

今回の検討では、比較的視力の良い被検者のみを対象としたため、検査装置間での視力の差が明らかにならなかった可能性が残る。液晶視力検査装置は0.03までの低視力用の視標が表示でき、モニターと被検者間の距離や視標の提示場所を一定にしたまま測定できるという利点がある。そのため、視力不良な者、中心固不良な者、視野障害のある者で、視標を見つけやすい可能性がある⁵⁾。それによって従来の視力検査と異なる視力値が得られることも考えられ、興味をもたれるところである。

逆に、視標の作成にあたって液晶モニターの本質的な

問題が指摘されている。それは、液晶モニターのドット数に限界があるため、印刷されたもののようにスムーズな表示が不可能な点である。特に小さい視標では視標の輪郭に灰色を用いて滑らかに見せる技法を用いているが正確さにかける。一般臨床の場面では問題ないと考えられるが、高視力者の視力測定の際問題になる可能性がある。今後は、さらに高解像度のモニターを用いることで、より正確な視標表示が可能になると考える。さらなる改良が期待される。

結論

液晶視力表 システムチャートSC-2000[®]は、従来から用いられている准標準視力検査装置と関連のある視力結果が得られた。また、視標正面から15°以内の測定位置のずれであれば、正面から見ているのと同等の視力が得られた。

ハロゲンランプを光源とし、1視標につきランプ1つか2つで後方から照らす従来の視力検査装置に比べ、安定した条件で検査が可能であり、多施設で視力の比較をする場合、共通の視力検査装置として使用可能であると考える。

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間欠性外斜視 小児の両外直筋後転術

Bilateral lateral rectus muscle recession for intermittent exotropia

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【要約】 間欠性外斜視の小児に対する両外直筋後転術の効果を検討した。

1995～2002年に名古屋大学、2002～2006年に浜松医科大学で手術を行った症例のうち、術後3ヵ月以上経過を観察できた47名の術後結果を報告する。うち1年以上経過を追えたものは26例である。年齢の平均は6.5(3～15)歳で、術前近見眼位の平均は32.3pd(12.0～50.0)、遠見眼位の平均は34.0pd(20～50)、術量は各眼平均6.8mm(4.0～8.5)であった。

術後1ヵ月の眼位は、近見4.7(-18～30)pd、遠見6.0(-8～25)pd、3ヵ月後は近見6.6(-20～30)pd、遠見7.7(-14～35)pd、1年後は近見8.7(-25～35)pd、遠見9.3(-25～30)pdであった。20プリズムを超える眼位異常が残ったのは1ヵ月で2/45名、3ヵ月で5/40名、6ヵ月で5/32名、1年で3/26名であった。内斜視が残存した1名は再手術を受けたが、それ以外は斜位を保てるため、再手術とはなっていない。

術前眼位が40プリズム未満のものでは、術後のもどりが少なく、満足のいく結果であったが、40プリズム以上のものでは、術後残余斜視角が大きく、術式や術量に再考が必要であると思われた。

【キーワード】 間欠性外斜視、手術、外直筋後転術、前後転術

緒言

我々は、基礎型および開散過多型外斜視の手術方法として、両眼の外直筋後転術を第一選択として行っている。両外直筋後転術の利点としては、術後の瘢痕形成が少なく、術後の異物感が少ないことが挙げられる。しかし、眼位の矯正については、前後転術に劣るという報告や、術後早期から眼位が安定するという報告があり、一定していない。今回は、1人の術者が行った両眼外直筋後転術の小児症例をレトロスペクティブに検討したので報告する。

対象および方法

1. 対象

対象は1995～2002年に名古屋大学、2002～2006年浜松医科大学で間欠性外斜視に対して両外直筋後転術を行った症例のうち、術後3ヵ月以上経過を観察できたものである。術前の近見立体視がTitmusステレオテストで5/9未満のもの、矯正視力に二段階以上の差があるもの、斜筋手術を同時に受けているものを除外した。その結果、47名が選出された。うち1年以上経過を追えたものは26例である。

2. 方法

術前検査は、視力検査、アトロピンまたは塩酸シクロペントラートをを用いた調節麻痺下屈折検査、前眼部細隙灯顕微鏡検査、眼底検査、眼位眼球運動検査、立体視検査、両眼視機能検査を行った。術前の眼位検査は交代ブ

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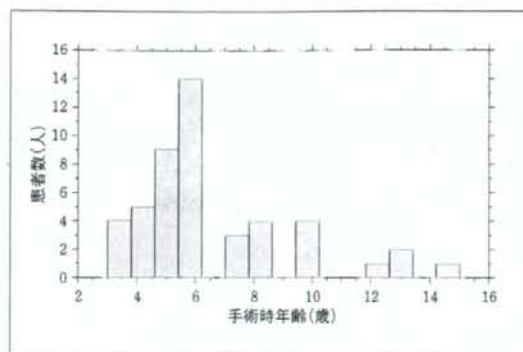


図1 手術時年齢別分布

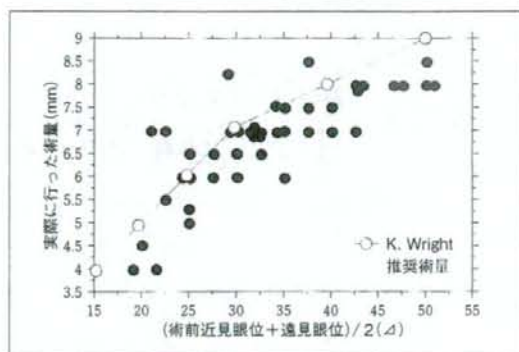


図2 術前斜視角と術量
近見眼位と遠見眼位の間値を目標とし、推奨値に基づいて手術量を決定したが、年齢が若い症例が多いため、実際には、やや推奨量より少なかった。

リズム遮閉検査を行い、できる限り最大斜視角を引き出すために、片眼遮閉30分、プリズムアダプテーションテスト、超遠方視での眼位測定、+3D加算した上での近見眼位測定などを適宜組み合わせで行った。手術量は、上記の眼位測定の結果に基づき、遠見眼位と近見眼位の間値を目標に、Kenneth Wrightの術量¹⁾を参考にして、両眼に等量の外直筋後転を行った。

結膜切開は輪部切開あるいは、円蓋部切開を行う。輪部切開では、12時と6時の角膜輪部に制御糸をかけ、円蓋部切開では、制御糸は用いずに外直筋を露出する。外直筋露出に際して、前部テノン囊の剥離は鈍的に行い、外直筋上下の筋間膜を切開するが、外直筋表面と眼窩をつなぐ筋間膜の剥離は最小限とした。外直筋上の血管をバイポーラーで止血した後、両端針の6-0バイクリル糸を外直筋に通し筋付着部で切断する。後転部位をピオクタンで強膜上にマーキングをした後、通糸して縫合する。結膜を元の位置に戻すか、数mm後転した位置に8-0バイクリル糸で縫合し、手術を終了する。

1995～2001年までは、結膜下にベタメタゾン注射液エコリシン眼軟膏を塗布し、両眼に眼帯をした。2002年以降は、副腎皮質ステロイドの結膜下注射を中止、また2005年以降は眼軟膏の代わりに、オフロキサシンまたはレボフロキサシン点眼を行い、術後の眼帯も中止した。

術後は、抗生物質内服、フルオロメトロン点眼、抗生物質点眼を行い、術翌日、1週間後、1ヵ月後、3ヵ月後に診察を行った。

術後診察は、視力検査、屈折検査、近見および遠見での交代プリズム遮閉検査、立体視検査を行った。

結果

手術時年齢の平均は6.5(3～15)歳で、術前近見眼位の平均は32.3pd(12.0～50.0)、遠見眼位の平均は34.0pd(20～50)、術量は各眼平均6.8mm(4.0～8.5)であった。そのうち、遠見斜視角が、近見斜視角より15プリズム以上大きい開散過多型が6名、それ以外は基礎型であった。手術時年齢の分布を図1に示す。経過観察中に、斜視の再発あるいは低矯正のために再手術となったものはなく、過矯正となって追加手術を受けたものが1例あった。

小児が対象であったことから、眼球が小さい症例も多く、実際には推奨されていた値よりも、少ない手術量を行っていた。近見斜視角と遠見斜視角の間値と実際に行った手術量の関係を示す(図2)。

術後の1ヵ月、3ヵ月、6ヵ月の眼位を図3～5に示す。術後1ヵ月の近見眼位の平均は、4.7pd(-18～30)、遠見眼位の平均は6.0pd(-8～25)であった。術後3ヵ月では、近見眼位の平均は6.6(-20～30)pd、遠見7.7(-14～35)pdとわずかな戻りがみられた。

術前眼位別に術後眼位を提示する(図6)。術前眼位が40プリズム未満の症例では、術後6ヵ月間の眼位の戻りがほとんどみられないのに対し、術前眼位が40プリズムを以上の症例では、術後6ヵ月まで徐々に眼位の戻りがみられた。術後3ヵ月目における、後転量に対する斜視角の矯正効果は、術前眼位25プリズム未満の場合、後転1mmあたり1.5プリズム、25プリズム以上では後転1mmあたり2.0プリズムであった。

図3 術前眼位と術後1カ月の遠見眼位
術前眼位が30プリズム以内のものは全例15プリズム以内に入っていた。

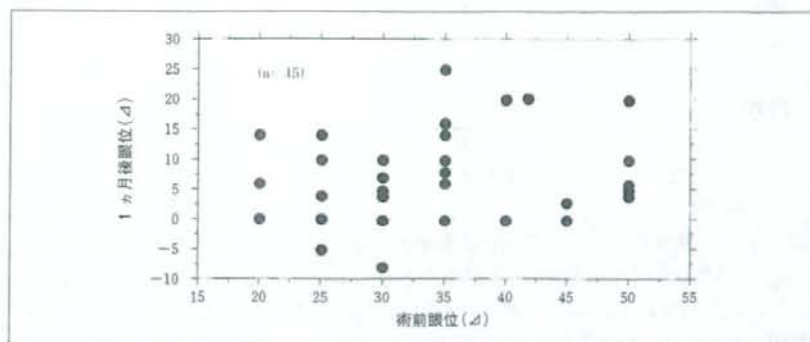


図4 術前眼位と術後3カ月の遠見眼位

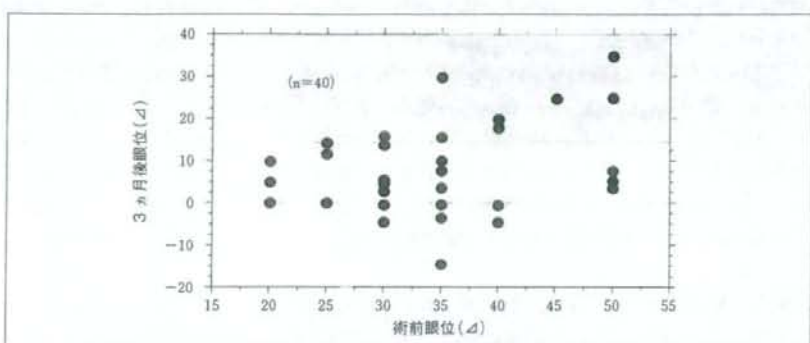


図5 術前眼位と術後6カ月の遠見眼位

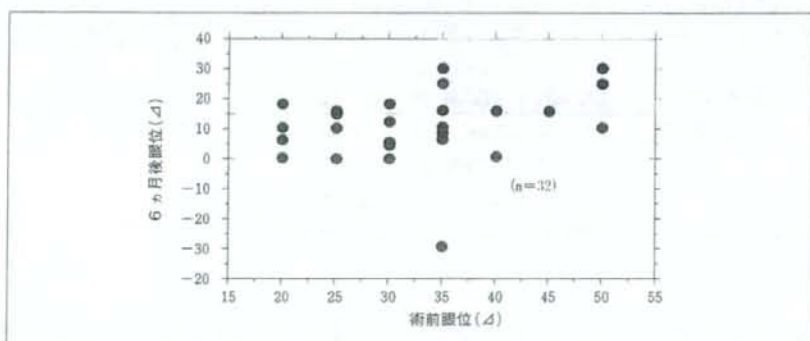
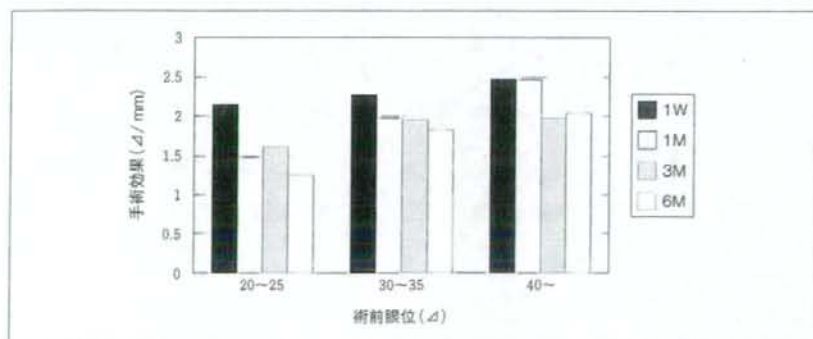


図6 術前眼位別、1mm後転あたりの眼位矯正量
術前斜視角が大きいほど、1mmあたりの矯正量は多くなっていった。



就学前と就学後に手術を受けた場合の、手術効果および術後の戻りには差が認められなかった。

考按

今回の検討では、経過観察期間が短く、長期経過については触れることができないが、術後6ヵ月以内であれば、術前斜視角40プリズム未満の間欠性外斜視では術後斜視の戻りが少なく、満足のいく結果であった。

しかし、術前斜視角40プリズム以上の場合には、術後眼位が術直後から低矯正になることが多く、術後の戻りも斜視角の小さいものに比べると大きいことが明らかとなった。この理由としては、①斜視角の大きい症例では、推奨されている後転量よりも実施された術量が少なかった。②Wrightも述べているが、外眼筋のまつわり量が影響しており、大量の後転では、1mmあたりの矯正効果が大きいため、過矯正と同様に低矯正も起こりやすい。③筋間膜の剝離、前部テノン囊の剝離を最小限にしているために、これらの組織の張力が影響した、などが考えられる。

両外直筋後転と前後転術の比較では、両外直筋後転のほうが、lateral incomitanceが起こりにくい、術後の疼痛や炎症が少ない、定量が正確である、筋への侵襲が少ない、長期的な戻りが少ない、などの利点が知られている。

基礎型斜視には、前後転術を、開散過多型あるいは見かけ上の開散過多型では、両外直筋後転術が一般的には、勧められている²⁾。見かけ上の開散過多型の中にはプリズムアダプテーションテストによって、近見眼位が増加するものがあり、それらはtenacious proximal fusion

とよばれる³⁾。今回の我々の症例では、真の開散過多型外斜視は、わずか6例しかみられていない。見かけ上の開散過多型をプリズムアダプテーションテストや、+3Dを加入して眼位を測定することによって、基礎型と診断したことによる。

また多施設による無作為試験では、眼優位性のある斜視に対しては、両眼外直筋後転術より、前後転術のほうが術後眼位は統計的に有意に良好であったが、両外直筋後転では過矯正がなかったのに対して、前後転術では術後過矯正がみられ、両眼視機能が不良となる可能性が高かった、との報告もある⁴⁾。

両眼手術に対する本人および家族の心理的抵抗が予測されたが、多くの場合、家族や本人はどちらの眼も偏位することに気づいており、両眼手術への抵抗は少ない。さらに、手術終了時の眼軟膏を点眼にしたこと、眼帯をしなないことによって、手術室での覚醒時に患者が安心して落ち着きが早期にみられた。

両眼外直筋後転術は、40プリズム以下の間欠性外斜視にとつて、早期から眼位の安定を得られ、眼位の予測も良好であると思われた。

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Superior Oblique Palsy with Class III Tendon Anomaly

MIHO SATO, EMI AMANO IWATA, YOSHIKO TAKAI, AKIKO HIKOYA, AND YUKA MARUYAMA KOIDE

• **PURPOSE:** To describe the clinical findings and surgical results of superior oblique palsy with class III tendon anomaly.

• **DESIGN:** Observational case series.

• **METHODS:** One hundred and forty-one cases of congenital and idiopathic superior oblique palsy were operated on by one surgeon (M.S.) between September 1, 1995 and August 31, 2007. The superior oblique tendons were explored in 26 cases. Among these, five cases were found to have the distal end of the tendon inserted into the Tenon capsule. Preoperative eye alignment, visual acuity, stereopsis measured with Titmus stereo acuity tests (Stereo Fly SO-001; Stereo Optical Co, Chicago, Illinois, USA), and magnetic resonance imaging findings were collected from the patients' records. Main outcome measures included preoperative eye position, surgical results, and stereoscopic acuity. Stereopsis and the amount of vertical deviation were compared in cases with class I, II, and IV tendon anomalies.

• **RESULTS:** A total of eight surgeries were performed on five patients with class III superior oblique tendon anomaly. Three muscles were operated on for each patient. The amount of vertical deviation was not significantly different from other types of tendon anomaly. Patients with class I to III tendon anomalies obtained good stereopsis after strabismus surgery, whereas cases with class IV anomaly achieved only limited stereopsis. The number of surgeries performed was significantly higher in cases with class IV anomaly.

• **CONCLUSIONS:** Without careful search of the Tenon capsule, the condition can be misdiagnosed as an absent tendon. Strengthening the superior oblique tendon in the Tenon capsule can improve the alignment significantly. (*Am J Ophthalmol* 2008;146:385-394. © 2008 by Elsevier Inc. All rights reserved.)

CONGENITAL SUPERIOR OBLIQUE PALSY OFTEN IS associated with anatomic abnormalities of the superior oblique tendon,¹ hypoplasia of the superior oblique muscle,^{2,3} or poor contractility of the superior oblique muscle.⁴ Helveston and associates proposed a

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classification of congenital superior oblique palsies based on the congenital anomalies of the superior oblique tendon.¹ Eyes classified as class I included those with loose tendon that were raised easily from the sclera, whereas eyes classified as class II had an insertion of the superior oblique muscle in the sclera more nasally than usual. Eyes classified as class III had a thin tendon that inserted in the Tenon capsule, and those classified as class IV lacked a tendon.

The clinical characteristics of eyes with a class IV tendon anomaly, the most severe form of tendon anomaly, have been reported by several authors.^{5,6} However, a computerized search of MEDLINE extracted only one report on the clinical characteristics and surgical results on eyes with class III congenital anomaly of the superior oblique tendon. Helveston and associates found only two cases of class III anomaly in the 82 patients they studied.¹ In an article in Japanese, Lo reported two cases among the 100 cases of superior oblique palsy.⁷ We reported two cases of class III congenital tendon anomaly at the IX International Orthoptic Congress in 1999.⁸ The purpose of this study was to determine the clinical characteristics and surgical results of five cases of class III anomaly of the superior oblique tendon and to compare these findings with the characteristics of other types of anomalies of the superior oblique tendon.

METHODS

ONE HUNDRED AND FORTY-ONE CASES OF CONGENITAL OR idiopathic superior oblique palsy that had undergone surgery by one surgeon (M.S.) between September 1, 1995 and August 31, 2007 were studied. A diagnosis of superior oblique palsy was made by the following clinical findings: 1) hypertropia in the primary position, 2) increase in the hypertropia on contralateral gaze, and 3) positive Bielschowsky head tilt test results. Patients known to have these signs from infancy or early childhood or patients without a clear documentation of the onset were considered to have disease of congenital or idiopathic origin.

Magnetic resonance imaging (MRI) or computed tomography (CT) of the orbit was carried out on 96 patients. The belly of the superior oblique muscle was confirmed to be present in coronal or horizontal MRI sections in 94 cases, and the superior oblique muscle was not detected in either coronal and horizontal images in two cases.

The traction test of the superior oblique tendon was performed during surgery under general anesthesia. All of the superior oblique tendon traction tests were performed

TABLE 1. Profiles of Patients with Class III Superior Oblique Tendon Anomaly

Case No.	Gender	Affected Side	Head Tilt	Age at Presentation (yrs)	Side	VA	Deviation in Primary Position (PD)	SPD in ADD	IFD in ADD	Image of SO	TST Results (before Surgery)
1	M	L	R	3	R	1.2	12 LHT, 16 XT	+3	-3		7/9
					L	1.2		0	0	Attenuated LSO	
2	M	R	L	2	R	0.7	20 RHT, 25 XT	+2	-3		Fly (-)
					L	1.0		0	0	Attenuated RSO	
3	M	L	R	2	R	0.8	8 LHT, 14 XT	0	0		Fly (-)
					L	1.0		+1	-3	Attenuated LSO	
4	F	R	L	11	R	1.0	20 RHT, 10 XT	+3	-2		9/9
					L	1.2		0	0	Attenuated RSO	
5	F	L	no	2	R	1.0	18 LHT	0	0		4/9
					L	1.0		+2	-3	Attenuated LSO	

ADD = adduction; F = female; HT = hypertropia; IFD = infraduction; L = left; LH = left hyperphoria; M = male; PD = prism diopters; R = right; SO = superior oblique muscle; SPD = supraduction; TST = Titmus stereo test; VA = visual acuity; XT = exotropia.

TABLE 2. Intraoperative Findings and Surgical Results of Patients with Class III Superior Oblique Tendon Anomaly

Case No.	Age at Surgery (yrs)	Traction Test of SO Tendon	Surgery	Postoperative Eye Position	TST Results (after Surgery)
1	3	R, 0; L, -1	LIO myectomy	Orthophoria in primary position, small XT in upgaze	
	5	R, 0; L, -1	LSO reposition, LLR recess 5 mm	V pattern XT	9/9
2	2	R, -3; L, 0	RIO myectomy, RSO reposition, RSR recess 2 mm	Orthophoria in primary position, -1 SPD in ADD, OD	Fly (-)
3	2	R, -4; L, 0	LIO myectomy, LSO reposition	8 PD LH	
	5	R, -1; L, 0	RIR recess 2 mm	Orthophoria	9/9
4	11	R, -4; L, 0	RIO myectomy, RSR recess 3 mm	18 PD LHT, 7 XT	
	12		RSR advance to original insertion	5 LHT, -1 SPD in ADD, OD	9/9
5	4	R, 0; L, -1	LIO myectomy, LSO reposition, LSR recess 3 mm	5 RHT, 7 XT, -1 SPD in ADD, OS	9/9

ADD = adduction; L = left; LH = left hyperphoria; HT = hypertropia; IO = inferior oblique muscle; LR = lateral rectus muscle; OD = right eye; OS = left eye; PD = prism diopters; R = right; RSR = right superior rectus muscle; SO = superior oblique muscle; SPD = supraduction; TST = Titmus stereo test; XT = exotropia; yrs = years.

by one surgeon (M.S.) and were graded on a 9-point scale from -4 to 4.^{9,10} To do this, the surgeon sat at the head of the supine, anesthetized patient. Two toothed forceps were used to grasp the limbus at the 2- and 8-o'clock positions of the left eye and the 4- and 10-o'clock positions of the right eye. The eye was rotated upward to the superior nasal quadrant by elevating and adducting the eye while the globe was retropulsed. Then the eye was moved nasally and temporally, and this movement allowed the surgeon to feel the tendon as a band as it moved across the globe as it was rocked. The laxity or tightness of the tendon was recorded on a scale of -4 to 4 as: 0, normal; -1 (+1), mild laxity (tightness); -2 (+2), moderate laxity (tightness); -3 (+3), severe laxity (tightness), but the tendon was present and the eye moved past the midline; and -4 (+4), no tendon (limited supraduction above the midline).

When the patients had one of the following findings, we explored the superior oblique tendon in the scleral space through a superior temporal incision: 1) the superior oblique tendon was attenuated significantly on the MRI or CT scans; 2) the traction test of the superior oblique tendon was graded as -3 or -4; 3) cases with residual head tilt after ipsilateral inferior oblique weakening; and 4) the vertical deviation was more than 20 prism diopters (D).

Among the 26 cases, the superior oblique tendon was found to be attached to the sclera in 18 eyes. Fifteen of these were confirmed to have a class I anomaly and three had a class II anomaly. In the other eight eyes, the superior oblique tendon was not attached to the sclera, that is, a class III or IV anomaly. After a careful search for the Tenon capsule during surgery, the superior oblique tendon was found to be inserted into the Tenon capsule in five

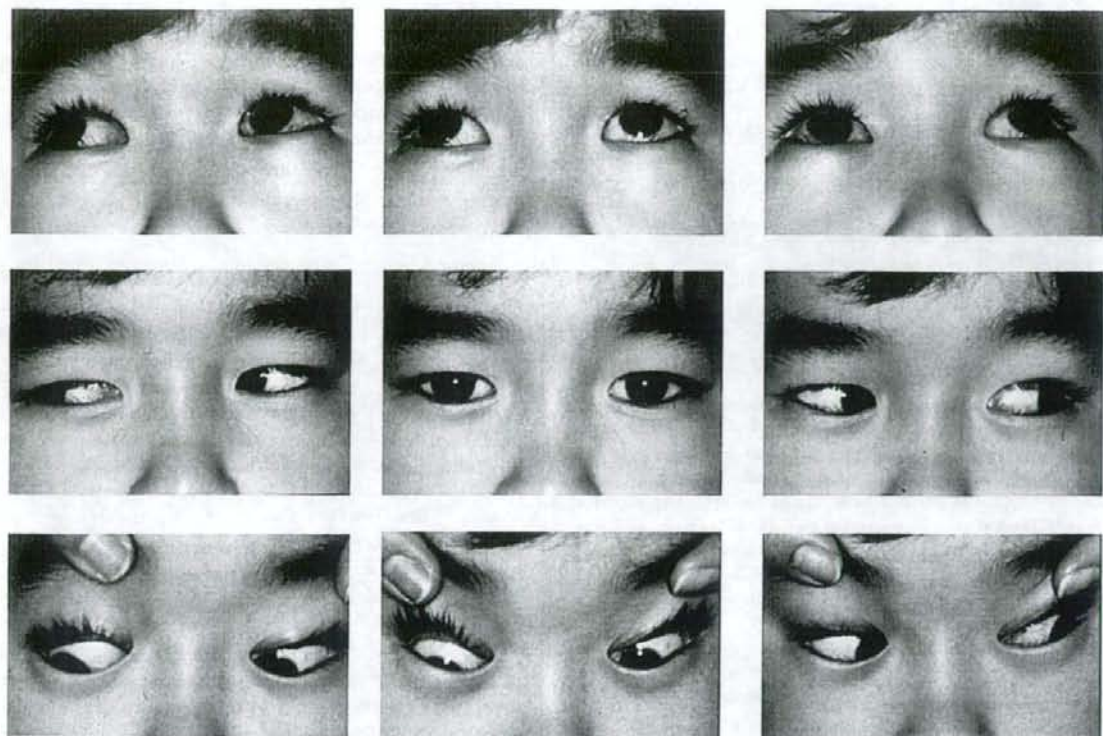


FIGURE 1. Photographs demonstrating the eye positions of a 4-year-old-boy with class III superior oblique tendon anomaly (Case 1). The positions of the eyes in the nine fields of gaze after inferior oblique muscle myectomy show an underaction of infraduction in the adducted position of the left eye.

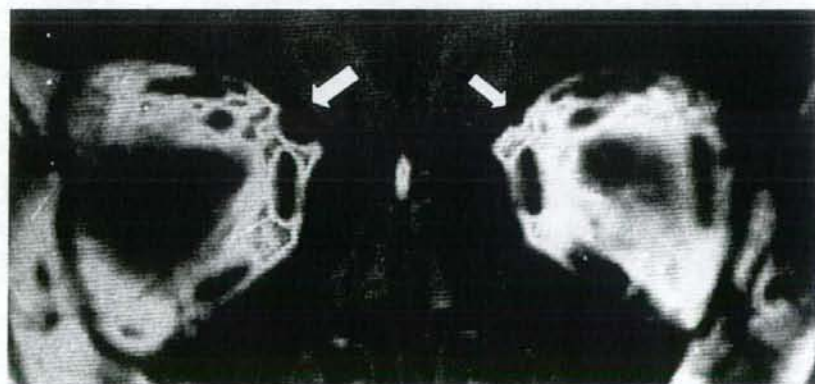


FIGURE 2. Coronal magnetic resonance imaging scan of a 4-year-old boy with class III tendon anomaly (Case 1) showing a marked hypoplasia of the left superior oblique muscle. The larger white arrow points to the right superior oblique tendon and the smaller white arrow points to the left superior oblique tendon.

cases, and these cases were diagnosed as a class III anomaly. The superior oblique tendon was not found in three cases, and these were diagnosed as a class IV anomaly. Two of the class IV cases were diagnosed as an absent superior oblique

muscle on MRI, but one of them appeared to have it on MRI.

We analyzed the vertical deviation, postoperative stereo acuity, and the number of surgeries performed among the



FIGURE 3. Intraoperative photograph obtained during the second surgery performed one year later in Case 1 for inferior oblique muscle myectomy. The patient was 5 years of age. The superior rectus muscle was detached from the sclera, and its insertion site was grasped by a pair of forceps. The superior oblique tendon was identified in the Tenon capsule and was pulled with a black suture (surgeon's view). The superior oblique tendon was dissected from the Tenon capsule and sutured to the sclera. Then, the superior rectus muscle was sutured on to the original site.

four types of tendon anomalies statistically. For statistical purposes, the stereo acuity of a patient who failed the Titmus fly (3000 seconds of arc) was set at 5000 seconds of arc. We performed an analysis of variance and used the Fisher Protected Least Significant Difference (PLSD) as a post hoc test with Stat View software for Windows version 5 (SAS Institute Inc, Cary, North Carolina, USA). *P* values of less than .05 were considered to be statistically significant.

RESULTS

THE PROFILES OF THE FIVE PATIENTS ARE SUMMARIZED IN Table 1, and the surgical results are summarized in Table 2. Eight surgeries were performed on the five patients with a class III tendon anomaly, and three muscles were operated on in each patient.

• **CASE 1:** A boy with a head tilt to the right underwent a left inferior oblique muscle myectomy at 4 years of age. Forced traction testing of the superior oblique tendon during the surgery revealed a -1 laxity. His head tilt was reduced, but some degree of head tilt was still present after the surgery (Figure 1). A second surgery was performed when he was 5 years of age. A preoperative MRI scan demonstrated a marked hypoplasia of the left superior oblique muscle (Figure 2). A forced traction test of the superior oblique tendon during the surgery revealed a -1 laxity. The superior oblique tendon was found at the nasal

edge of the superior rectus muscle, and it was traced to its insertion into the Tenon capsule (Figure 3). The tendon was advanced and sutured to the sclera at the temporal border of the superior rectus muscle. The superior rectus muscle was reattached at its original position. After surgery, a small V-pattern exotropia was detected, but otherwise his eyes were well aligned and the abnormal head posture was no longer present (Figure 4). His stereo acuity was 40 seconds of arc.

• **CASE 2:** A 2-year-old boy with a severe head tilt to the left (Figure 5) had a marked hypoplasia of the right superior oblique muscle on MRI (Figure 6). The traction tests of the right superior oblique tendon demonstrated a marked laxity (-3), but the tendon was believed to exist. A myectomy of the right inferior oblique muscle was performed, and during the surgery, the superior oblique tendon was identified under the superior rectus muscle as a thin and loose structure that inserted into the Tenon capsule. When traction was placed on the tendon, an indentation was seen on the external surface of the upper lid, suggesting that the tendon not only had migrated into the Tenon capsule, but also was firmly attached to the levator aponeurosis.

The superior oblique tendon was dissected and sutured to the sclera 4 mm temporal to the temporal border of the superior rectus muscle and 14 mm posterior to the limbus. The superior rectus muscle was recessed 2 mm from its original insertion. Interestingly, the shape of the right upper lid crease changed after the surgery (Figure 7). His left eye was diagnosed as having anisometropic amblyopia with a visual acuity (VA) of 0.7. The patient was treated by optical correction and occlusion of the left eye. The final VA was 1.0 in the left eye at 5 years of age, but stereopsis was not present with the Titmus stereo acuity test because of suppression of the left eye.

• **CASE 3:** Patient 3 had a -4 laxity of the superior oblique tendon, but the tendon was found in the Tenon capsule (Figure 8) and was repositioned. Myectomy was performed on the left inferior oblique muscle, but he still had a residual head tilt and left hypertropia. Three years later, the contralateral inferior rectus muscle was recessed by 2 mm, and a postoperative MRI scan showed a marked hypoplasia of the superior oblique muscle.

• **CASE 4:** Patient 4 underwent surgery, and forced traction test of the superior oblique tendon during the surgery revealed -4 laxity. The right superior oblique tendon was found in the Tenon capsule. The tendon was too thin to match the tightness of the fellow eye. Therefore, the superior rectus muscle was recessed for 3 mm, and myectomy was performed on the inferior oblique muscle. After the surgery, the patient had a left hypertropia and the head tilt was reversed. A second surgery was performed to advance the recessed superior rectus muscle one year later.

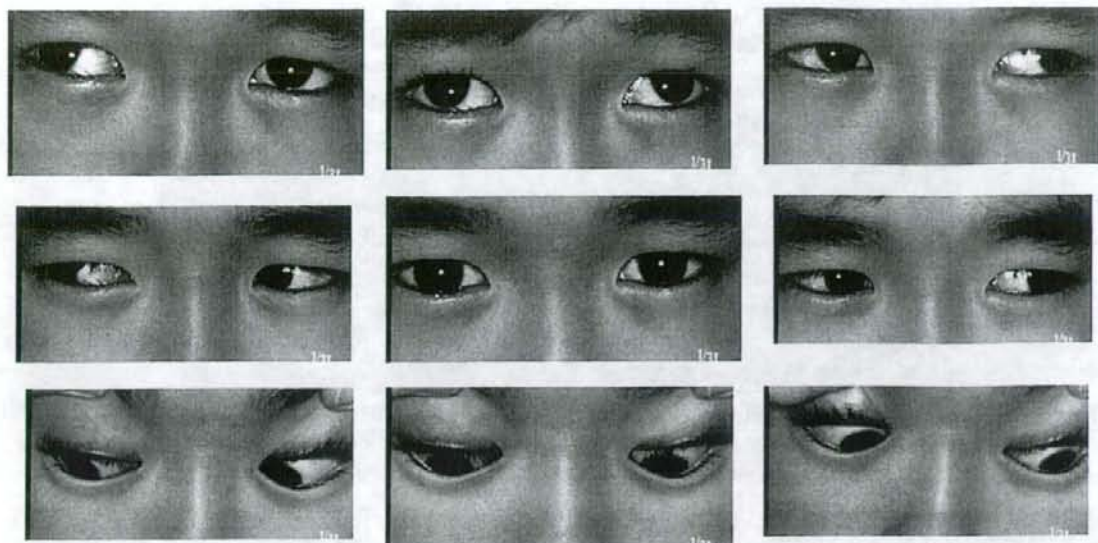


FIGURE 4. Photographs demonstrating the eye positions of a 5-year-old boy with class III tendon anomaly (Case 1) after repositioning of the superior oblique tendon found in the Tenon capsule. Infraduction in the adducted position is improved in the left eye without Brown syndrome. Mild V-pattern exotropia is present.



FIGURE 5. Photographs demonstrating the preoperative eye positions in the nine fields of gaze of a 2-year-old boy with class III superior oblique tendon anomaly (Case 2). Underaction of infraduction in the adducted position (-3) and overaction of supraduction in the adducted position (+2) of the right eye can be seen.

During the second surgery, a traction test of the superior oblique tendon was graded as -4, and the superior rectus muscle was found to be attached to the sclera 6 mm posterior from the original insertion rather than at 3 mm.

• CASE 5: Patient 5 did not have a head tilt and the left eye fused well in the primary position. Her vertical deviation increased to 18 prism D after prolonged occlusion of the left eye (Figure 9). However, the patient had a

large hypertropia when the head was tilted to the left, which was a cosmetic problem. Her CT scan showed a marked hypoplasia of the left superior oblique muscle, and the left trochlea was found to be located more posterior than on the right side (Figure 10). Forced traction testing of the superior oblique tendon revealed only a mild looseness (-1). Myectomy was performed on the left inferior oblique muscle. However, a thin superior oblique tendon was found in the Tenon capsule not attached to

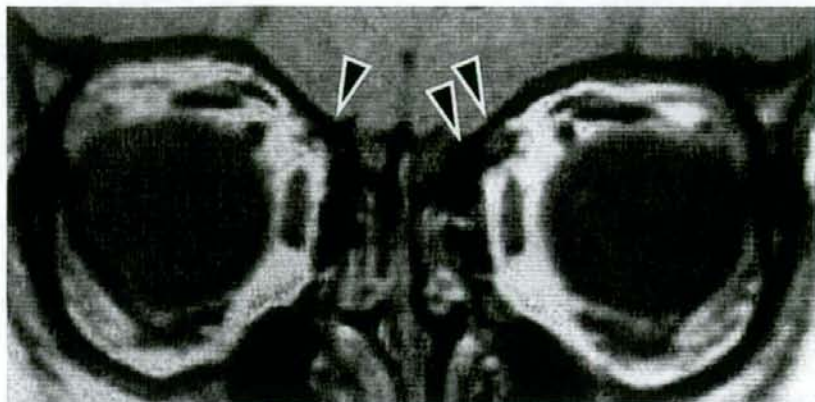


FIGURE 6. Coronal magnetic resonance imaging scan from a 2-year-old boy with class III superior oblique tendon anomaly (Case 2). The black triangles indicate superior oblique tendons. The right superior oblique tendon is markedly hypoplastic.

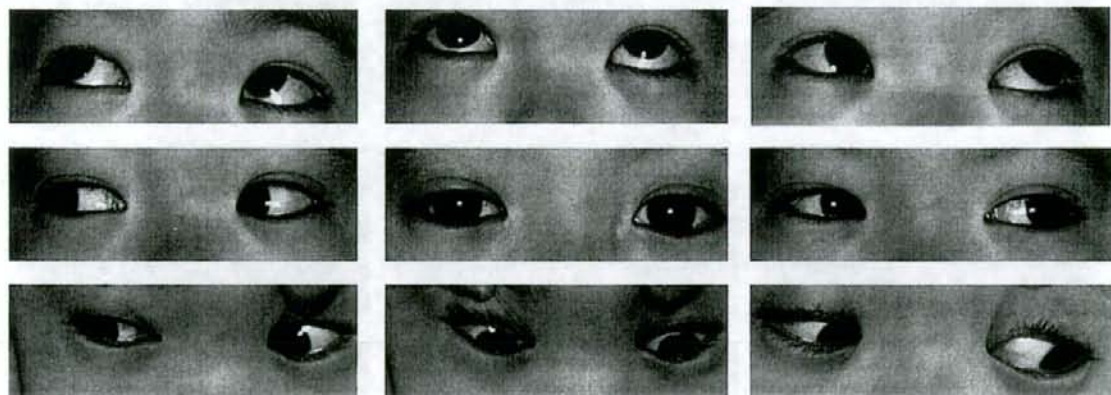


FIGURE 7. Photographs demonstrating the eye positions in Case 2 obtained one year after inferior oblique myectomy, superior oblique tendon repositioning, and 2-mm superior rectus muscle recession of the right eye performed when he was 2 years of age. The superior oblique tendon was attached firmly to the levator aponeurosis. Note that the single lid crease of the right eye changed to a double crease after surgery.

the sclera (Figure 11). The tendon was detached from the Tenon capsule and sutured to the sclera 6 mm temporal to the temporal border of the superior rectus muscle and 12 mm posterior to the limbus. The superior rectus muscle was sutured 3 mm posterior to the original insertion. After surgery, she showed mild supraduction limitation in the adduction position, but it was not a problem cosmetically.

The degree of vertical deviation, number of surgeries performed, and postoperative stereopsis of the 26 cases classified into the four types of tendon anomalies confirmed by exploration of the superior oblique tendons are shown in Table 3. The average vertical deviation was largest in class IV, but it was not statistically significant. The stereo acuity measured with the Titmus stereo test of class III anomaly was significantly better than that of the class IV anomaly ($P < .05$), but it was indistinguishable

with class I and II anomalies. The number of surgeries was significantly higher in the class IV anomaly than in the class I anomaly ($P < .05$).

In summary, two cases obtained satisfactory results with one operation (Cases 2 and 5), but three cases required additional surgery. A total of eight operations were performed on these five children: two for undercorrection (Cases 1 and 3) and one for overcorrection (Case 4). All but Case 5 had an abnormal head tilt contralateral to the affected eye. All but one case (Case 2) achieved 40 seconds of arc on the Titmus stereo acuity test after surgery. All cases showed significantly attenuated superior oblique muscle bellies on CT or MRI, and horizontal images showed superior oblique tendons and trochlears. The evaluation of the traction testing varied from -1 to -4.

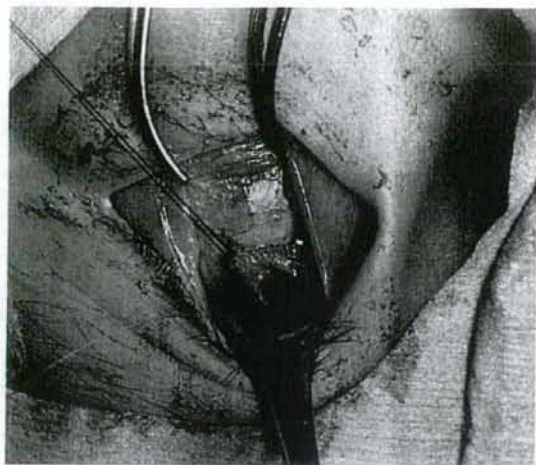


FIGURE 8. Intraoperative photograph from Case 3, a 2-year-old boy with class III superior oblique tendon anomaly. The superior rectus muscle was detached and the insertion of the superior rectus muscle was grasped by two pairs of fixation forceps. The superior oblique tendon was identified and pulled up by a black suture. The tendon was connected to the deep orbit and was not attached to the sclera.

DISCUSSION

AMONG 141 CASES OF CONGENITAL OR IDIOPATHIC SUPERIOR oblique palsy, we identified five cases of class III superior oblique tendon anomaly that had an insertion of the tendon into the Tenon capsule. Because we did not explore the superior oblique tendon in all cases, we cannot report the real incidence of class III tendon anomaly. Despite this, the incidence in our series is comparable to that of Lo, who explored the superior oblique tendons on 100 superior oblique palsy cases and reported that two of them had class III anomaly.⁷ The incidence of class III tendon anomaly among the patients who had at least one of the following findings was five (19.2%) of 26: vertical deviation more than 20 prism D, traction test of the superior oblique tendon under general anesthesia of -3 or -4 , attenuated superior oblique muscle in coronal images, and the patient with a residual head tilt after the first surgery.

Wallace and von Noorden reported that the clinical characteristics of eyes with a congenital absence of the superior oblique tendon were: 1) large horizontal deviation, 2) amblyopia, 3) poor binocularity, 4) spread of comitance, and 5) pseudooveraction of the contralateral superior oblique muscle.⁵ Chan and Demer reviewed the clinical findings of six patients whose superior oblique muscle could not be detected by imaging methods.⁶ They reported that the findings in these cases overlapped the clinical findings in cases with a demonstrable superior

oblique muscle on neuroimaging scans. None of their patients was amblyopic and two had good stereopsis.

The characteristics of class IV tendon anomaly in our cases are summarized in Table 4. The amount of vertical deviation was larger than that of class III cases, but the difference was not statistically significant. None of the patients had measurable stereopsis after surgery.

When both the coronal and horizontal images did not show a superior oblique tendon, this indicated a class IV anomaly. Although imaging studies may indicate an absence of the superior oblique muscle and tendon (class IV anomaly), the skeletal muscle portion may be attenuated severely, and a superior oblique tendon in fact may be present. However, if the superior oblique tendon is found in the images, it does not necessarily indicate that the superior oblique tendon is attached to the sclera. Therefore, these tendons need to be explored surgically to make a definitive diagnosis.

There are some clues to differentiate class III from class VI tendon anomalies. Stereopsis seems to be more likely to be achieved for class III tendon anomalies. In our series, two of our class III patients had more than 100 seconds of arc of stereo acuity at their initial evaluations. Four of five cases obtained 40 seconds of arc stereopsis after surgery. Only the patient who had anisometropic amblyopia with suppression did not pass Titmus fly (3000 seconds of arc). Vertical deviations of more than 30 prism D can be an indicator of the class IV tendon anomaly.

Because the superior oblique tendon in class III anomaly does not attach to the globe, the result of the traction test is expected to be -3 or -4 laxity. But in our five patients, the traction test of Cases 1 and 4 showed only a mild laxity. Because of the subjective nature of this test, minor differences between examiners are expected,¹¹ and the consistency of the test has not been evaluated. However, all of the tendons were evaluated by one surgeon (M.S.) and the test between the first and second surgery were consistent. Therefore, variations in the traction test should be the result of other factors. One possible reason is that although the globe was repulsed and rotated upward during the traction test, the insertion of the superior oblique tendon in the Tenon capsule also moved backward with the globe. This stretched the tendon, which would cause some tension during the traction test.

The mechanisms that led to the clinical differences between class III and class IV tendon anomalies also are unclear. We suspected that the tendon inserted into the Tenon capsule still has some torsional effect on the globe by transmitting its contractility to the globe through the connective tissue surrounding the tendon. This may result in less vertical deviation and less disruption of stereopsis.

One or more of the following surgical procedures generally is recommended for treating superior oblique palsy: inferior oblique muscle weakening, inferior oblique muscle anterior transposition, superior oblique tendon strengthening, superior rectus muscle recession, contralateral inferior rectus muscle



FIGURE 9. Photographs demonstrating the preoperative eye positions of a 4-year-old girl with class III superior oblique tendon anomaly (Case 5). Underaction of infraduction of the left eye (-3) and overaction of supraduction in the adduction (+2) position can be seen. The patient did not have an abnormal head tilt before surgery but showed a marked positive Bielschowsky head tilt test.

TABLE 3. Comparison of Clinical Findings of Patients with Different Types of Superior Tendon Anomaly

	No.	Vertical Deviation (PD)	Stereopsis (Seconds of Arc)	No. of Surgeries
Class I	15	20.4	418	1.27 ^a
Class II	3	19.7	1080	1.33
Class III	5	16.2 n.s.	1032 ^a	1.80
Class IV	3	31.7	5000	2.33
Total/average	26	22.0	1882	1.68

n.s. = not significant; PD = prism diopters.

^aP < .05.

^bP < .005.

^cP < .0001.

recession with or without nasal transposition, or a combination thereof. The surgical procedures for treating superior oblique palsy with an absent tendon have not been well established, and one of the procedures¹² or combinations of the above procedures are recommended.^{6,5} In our series, eight procedures were performed on five patients (Table 3). The incidence of reoperations was significantly higher in cases with class IV tendon anomaly compared with cases with class I and II anomalies. Three muscles were operated on in each patient. Although the number of our cases is limited, repositioning and strengthening of the superior oblique tendon seem to be a reasonable approach, but may be associated with

postoperative limitation of upward gaze, as seen in Cases 2, 4, and 5. This iatrogenic Brown syndrome may be a result of the inferior oblique myectomy rather than the excessive tightness of the superior oblique tendon. Simultaneous superior rectus muscle recession should be reserved for cases with a large hypertropia. Alternatively, a contralateral inferior rectus muscle recession may be considered to treat a large hypertropia.

A class III tendon anomaly is not frequently diagnosed in the management of superior oblique palsy. However, when identified, a strengthening of the superior oblique tendon in the Tenon capsule can improve the eye alignment and good binocularity may be achieved.

TABLE 4. Clinical Findings of Patients with Absent Superior Oblique Tendon (Class IV Anomaly)

Case No.	Gender	Affected Side	Head Tilt	Age at Presentation (yrs)	Visual Acuity	Deviation in Primary Position (PD)	SPD in ADD	IFD in ADD	MRI Findings	TST Results (before Surgery)
1	F	L	R	2	R 1.2 L 1.2	45 LHT, 25 ET	0 +2	0 -1	Attenuated LSO	Fly (-)
2	M	L	R	6	R 1.0 L 1.0	20 LHT	0 +1	0 -1	Absence of LSO	Fly (-)
3	M	R	L	0	R 1.0 L 1.0	30 RHT, 25 XT	+3 0	-3 0	Absence of RSO	Fly (-)

ADD = adduction; ET = esotropia; F = female; HT = hypertropia; IFD = infraduction; L = left; LH = left hyperphoria; M = male; MRI = magnetic resonance imaging; PD = prism diopters; R = right; SO = superior oblique muscle; SPD = supraduction; TST = Titmus stereo test; XT = exotropia; yrs = years.

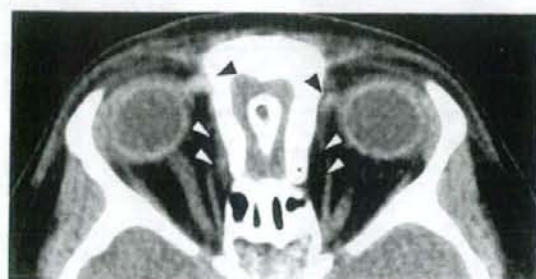


FIGURE 10. Horizontal computed tomography image from a 4-year-old girl with class III superior oblique tendon anomaly (Case 5). Black triangles show the locations of the trochlea. The left trochlea is located posterior to the right trochlea. White triangles indicate the muscle bellies. The right superior oblique muscle cannot be seen in the image.

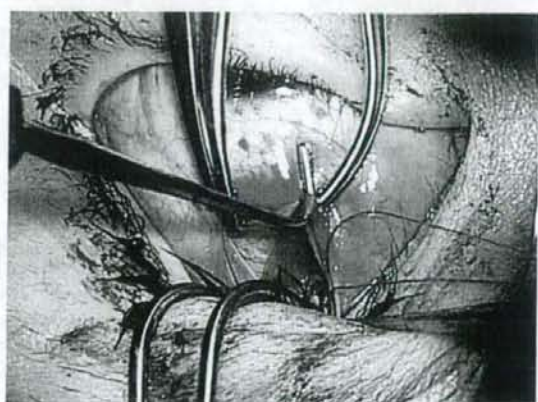


FIGURE 11. Intraoperative photograph of a 4-year-old girl with class III superior oblique tendon anomaly (Case 5). The superior rectus muscle was detached from the sclera and was grasped by two pairs of forceps. The superior oblique tendon was identified from the Tenon capsule and was separated by a small hook.

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REPORTING VISUAL ACUITIES

The AJO encourages authors to report the visual acuity in the manuscript using the same nomenclature that was used in gathering the data provided they were recorded in one of the methods listed here. This table of equivalent visual acuities is provided to the readers as an aid to interpret visual acuity findings in familiar units.

Table of Equivalent Visual Acuity Measurements

Snellen Visual Acuities			Decimal Fraction	LogMAR
4 Meters	6 Meters	20 Feet		
4/40	6/60	20/200	0.10	+1.0
4/32	6/48	20/160	0.125	+0.9
4/25	6/38	20/125	0.16	+0.8
4/20	6/30	20/100	0.20	+0.7
4/16	6/24	20/80	0.25	+0.6
4/12.6	6/20	20/63	0.32	+0.5
4/10	6/15	20/50	0.40	+0.4
4/8	6/12	20/40	0.50	+0.3
4/6.3	6/10	20/32	0.63	+0.2
4/5	6/7.5	20/25	0.80	+0.1
4/4	6/6	20/20	1.00	0.0
4/3.2	6/5	20/16	1.25	-0.1
4/2.5	6/3.75	20/12.5	1.60	-0.2
4/2	6/3	20/10	2.00	-0.3

From Ferris FL III, Kassoff A, Bresnick GH, Bailey I. New visual acuity charts for clinical research. *Am J Ophthalmol 1982;94:91-96.*

CLINICAL INVESTIGATION

Central Corneal Thickness in Japanese Children

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Abstract

Purpose: To determine the central corneal thickness (CCT) in Japanese children and to investigate the changes in CCT with increasing age.

Methods: Pachymetry was performed on 338 eyes of 169 patients undergoing eye muscle surgery under general anesthesia, and the intraocular pressure (IOP) was measured on 312 eyes of 156 of those same patients. Patients with abnormalities other than refractive errors and strabismus were excluded. Patients were divided into four groups: group 1, ≤ 1 year of age; group 2, 2-4; group 3, 5-9; and group 4, 10-18 years of age. Analysis of variance (ANOVA) was performed to determine the significance of the changes in CCT.

Results: The average CCT of the right eye was $544.3 \pm 36.9 \mu\text{m}$. The CCT was thinner in group 1 than in groups 3 and 4 (ANOVA, $P = 0.02$). There was a positive but weak correlation between IOP and CCT (IOP = $6.253 + 0.014 \times \text{CCT}$; $r^2 = 0.047$, $P = 0.007$).

Conclusions: CCT reaches the adult thickness in Japanese children by age 5 years. The average CCT is thinner in Japanese children than in Caucasians but thicker than in African American children.
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Key Words: central corneal thickness, child, general anesthesia, intraocular pressure, ultrasound pachymeter

Introduction

Measuring central corneal thickness (CCT) has become increasingly important, particularly for the diagnosis and management of glaucoma. The Ocular Hypertension Treatment Study reported that subjects with ocular hypertension had greater CCT,¹ and subjects with smaller CCT had a higher risk of developing glaucoma.²

Goldmann applanation tonometer measurement is based on the assumption that CCT is 500 μm , a thickness obtained from measurements of cadaver eyes. Because a permanent thinning or flattening of the cornea induces lower intraocu-

lar pressure (IOP) after refractive surgery,^{3,4} special attention has been paid to the variability of CCT in the healthy population and in patients with various eye diseases. To obtain an accurate IOP value, measurements with the Goldmann applanation tonometer should be corrected by the CCT value.⁵ Thus, measuring CCT has become essential for determining true IOP for glaucoma management.

Children with congenital glaucoma also have significantly thinner CCT than healthy children.^{6,7} However, aphakic^{8,9} and pseudophakic¹⁰ children with glaucoma have significantly thicker CCT than healthy children. These findings then raise the question of why up to 45% of aphakic children who have thicker than average CCT develop glaucoma.¹¹ Muir et al.¹² speculated that CCT increases after cataract surgery because of endothelial cell damage, or because increased IOP injures the endothelial cells. Thus, measuring CCT in children who are at high risk for glaucoma, such as children with aphakic or pseudophakic eyes, is important.

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Another important factor that influences the CCT is race or ethnicity. The CCT of African American adults is thinner than that of Caucasian adults,^{2,13} and lower IOP in African Americans may delay the diagnosis of glaucoma and determination of an appropriate treatment target.¹⁴ CCT in the Japanese population has been found to be thinner than in Chinese and Filipino populations.¹⁵

These racial differences are also found in the pediatric population. African American children have thinner CCT than do Caucasian¹⁶ or Hispanic children.¹⁷ A literature search on PubMed did not extract any CCT data regarding healthy Japanese children. Knowing the normal range of CCT of Japanese children is important for diagnosing and treating pediatric glaucoma.

Thus, the purpose of this study was to determine the CCT in Japanese children and to investigate the changes in CCT with increasing age. To accomplish this, we measured the CCT of 338 eyes of 169 children ≤ 18 years of age by ultrasound pachymetry under general anesthesia.

Subjects and Methods

All patients scheduled for strabismus surgery under general anesthesia were recruited from Hamamatsu University School of Medicine and Aichi Children's Health and Medical Center from December 2005 to August 2007. Patients with corneal disease, a history of intraocular surgery, glaucoma, cataract, or eyelid abnormalities were excluded. Patients known to have abnormally thin corneas such as those with Down syndrome¹⁸ or with Marfan syndrome,¹⁹ or abnormally thick corneas such as those with aniridia,²⁰ were also excluded.

This study was approved by the Institutional Review Board of the Hamamatsu University School of Medicine and Aichi Children's Health and Medical Center. Full explanation of the research, including the measurement procedures for CCT and IOP was given, and written informed consent was obtained from a parent or legal guardian of each of the patients.

For controls, we measured the CCT of eight healthy subjects aged 26 to 52 years under topical anesthesia.

CCT was measured between 9:00 and 16:00 in the operating room with an ultrasound pachymeter (SP-100 Handy,

1640 Hz; Tomey, Nagoya, Japan). Measurements started within 5 min of endotracheal intubation. All patients were sedated by inhalation or intravenously, and a muscle relaxant was given before insertion of the airway tube. Sevoflurane and nitrous oxide were used to maintain surgical anesthesia during the surgery. The patient's eyelid was held open manually, with special care taken not to press on the eye. One drop of topical anesthesia (4% oxybuprocaine) was administered, and the central cornea was defined as the center of the pupil. The pachymeter probe was placed perpendicularly on the center of the cornea, and the average of eight measurements was recorded as the CCT. Next, the IOP was measured with a Tono-Pen XL (Reichert, Depew, NY, USA). All measurements were performed first on the right eye and then on the left eye.

For statistical purposes, only the data from the right eye were used. The patients were divided into four groups: group 1, ≤ 1 year of age; group 2, 2-4; group 3, 5-9; and group 4, 10-18 years of age. Statistical analysis was performed using StatView version J-5.0 for Windows (SAS Institute, Cary, NC, USA). Analysis of variance (ANOVA) with a Bonferroni post hoc test was used to determine the significance of any differences among the age groups. Paired *t* tests were used for comparisons between eyes. Linear regression was used to determine the correlation between CCT and IOP. A *P* value of <0.05 was considered to be statistically significant.

Results

We measured the CCT of 338 eyes of 169 subjects (87 boys, 82 girls) with a mean age of 6.01 ± 3.87 years and an age range of 8 months to 18 years. The patient age distribution and the IOP and CCT measurements are summarized in Table 1.

The average CCT of the right eye was $544.3 \pm 36.9 \mu\text{m}$ (range, 429-648 μm). The CCT distribution is shown in Fig. 1. The CCT was significantly different between age groups (ANOVA $P = 0.0198$); it was significantly thinner in group 1 than in groups 3 or 4 ($P = 0.0071$ and 0.0157 , respectively, Bonferroni; Table 1). The average CCT in group 4 was $550.6 \mu\text{m}$, which was not significantly different from the mean CCT of the eight healthy adult subjects (525-586 μm).

Table 1. Subjects' characteristics and measurement of CCT and IOP

	<i>n</i> (%)	CCT (μm)	IOP (mmHg)
All patients	169 (100)		
Age distribution (years)		(right eye)	(right eye)
0-1	14 (8)	522 ± 26.7	14.07 ± 2.89
2-4	50 (30)	538 ± 36.6	14.14 ± 2.55
5-9	77 (45)	550 ± 36.7	14.13 ± 2.13
10-18	28 (17)	550 ± 37.5	12.88 ± 2.45

Values are means \pm SD.

CCT, central corneal thickness; IOP, intraocular pressure.

* $P = 0.0071$.

** $P = 0.0157$.

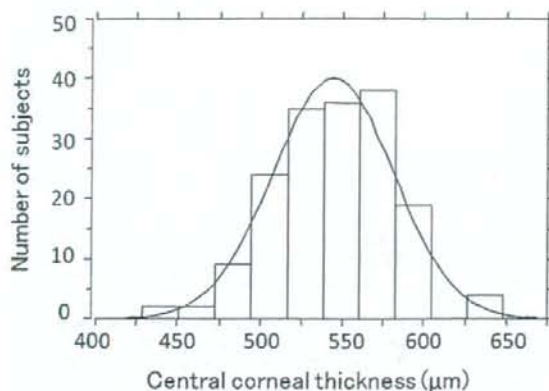


Figure 1. Distribution of central corneal thickness (CCT) in the right eye of children aged 0 to 18 years. CCT is normally distributed. The average CCT was $544.3 \pm 36.9 \mu\text{m}$.

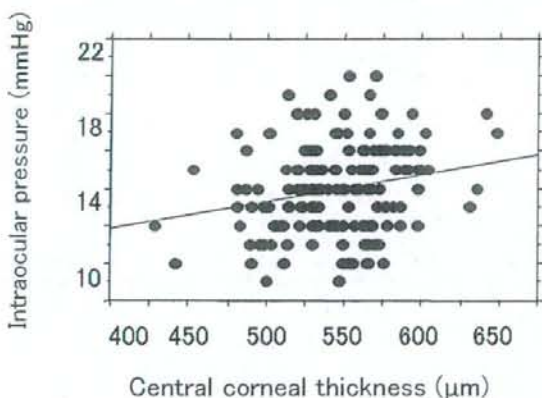


Figure 2. Relationship between CCT and intraocular pressure (IOP). There is a positive but weak correlation between CCT and IOP.

The mean CCT in our adults was comparable to the published average range for the adult Japanese population.^{21,22}

The average IOP in the right eye was $13.9 \pm 2.4 \text{ mmHg}$ (range, 9.0–10.0 mmHg). The IOP did not differ significantly among the different age groups. IOP (y) and CCT (x) were positively correlated, but the correlation coefficient was low ($y = 6.253 + 0.014x$, $r^2 = 0.047$; $P = 0.007$; Fig. 2).

Discussion

Differences in CCT values measured with different instruments have been reported,^{23–25} but the values obtained by ultrasound pachymetry and by noncontact optical low-coherence reflectometry are reported to be highly correlated.²⁶ Bovellet et al.²⁷ reported that the Topcon specular microscope gives significantly lower values than the ultra-

Table 2. Comparison of CCT values of children by race

Race	Hussein ²⁹ (μm)	Dai ¹⁷ (μm)	This study (μm)
Caucasians	551	563	
Hispanic	550	568	
Japanese			544
African Americans	532	523	

sound pachymeter. Suzuki et al.²¹ compared CCT values obtained using Orbscan scanning-slit corneal topography/pachymetry, the Topcon SP-2000P, noncontact specular microscopy, and Tomey ultrasonic pachymetry in a Japanese population. The mean CCT was not significantly different between scanning-slit topography ($546.9 \pm 35.4 \mu\text{m}$) and ultrasonic pachymetry ($548.1 \pm 33.0 \mu\text{m}$). However, contact specular microscopy gave a significantly smaller mean ($525.3 \pm 31.4 \mu\text{m}$) than did the other two instruments.²¹ Therefore, it is advisable not to compare CCT values obtained using different instruments.

The SP100 ultrasonic pachymeter is compact and easy to use in the operating room. The measurements are accurate if the instrument is used appropriately. We took special care to place the probe on the center of the cornea because the cornea is thinnest at the center.^{28,29}

In adults, CCT is negatively correlated with age in men,³⁰ or in both sexes.³¹ In children, CCT is reported to decrease rapidly during the neonatal period,^{32,33} and then to increase slowly and reach the adult level at 3³⁴ or 5 years of age.²⁹ Sawa³⁵ studied the Japanese population and found that the mean CCT of 1-month-old infants ($534 \pm 36 \mu\text{m}$) is thicker than that of 3-month-old infants ($508 \pm 22 \mu\text{m}$), but they found no difference between the 3-month-old infants and the 20- to 29-year-old adults ($516 \pm 17 \mu\text{m}$). Muir et al.³⁶ suggested that CCT slowly increases in children up to the age of 5 and then decreases at around age 10–14 years. Hussein et al.²⁹ reported that CCT increases in children until age 9 years and then decreases between ages 10 and 14.²⁹ In our study, CCT was significantly less in group 1 than in groups 3 or 4, suggesting that adult CCT values are reached by 5 years of age.

Earlier studies have reported racial differences in CCT, not only in adults but also in children. Table 2 summarizes results from other countries for CCTs in pediatric populations from 0 to 18 years of age, measured with ultrasound pachymetry. We understand that it is not ideal to compare our data directly with those of previous reports, but as long as all the measurements were obtained with ultrasound pachymetry, it is reasonable to do so. Compared with the readings obtained from two different institutions,^{17,29} the CCT of Japanese children still appears to be thicker than that of African American children and thinner than that of Caucasian or Hispanic children.

Studies focusing on the relationship between CCT and IOP have reported a significant correlation between IOP and CCT in children,³⁶ as in adults. Suzuki et al.³¹ studied Japanese adults and found that IOP measured with the

Goldmann applanation tonometer was positively correlated with CCT. We found a positive correlation between CCT and IOP measured by Tono-Pen in children, but the correlation coefficient was low.

The Tono-Pen is generally used in children whose IOP is neither very high (>21 mmHg) nor very low (<9 mmHg).³⁷ IOPs obtained with Tono-Pen are significantly correlated with those obtained using the Goldmann tonometer.^{38,39} IOPs measured with the Goldmann tonometer, the noncontact tonometer, and the Tono-Pen are known to be influenced by CCT, but IOPs measured by Tono-Pen are less affected by CCT than the other tonometers.^{40,41}

We are aware that measured IOP differs significantly with the type and state of anesthesia; for example, succinylcholine can increase IOP, whereas halothane can reduce it.⁴² In addition, IOP in the human infant depends strongly on the level of relaxation.⁴²

In conclusion, the CCT of Japanese children increases up to age 5 years, when it does not differ significantly from that of adults. The CCT of Japanese children is thinner than that of Caucasian children but thicker than that of African American children. Knowing the average CCT value in the Japanese pediatric population will be useful when caring for not only congenital anomalies involving the cornea but also pediatric glaucoma.

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