

## Relationships between reference lines altered during leg shape correction as requested by the patient

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**Introduction** Patients who want their leg shape changed often identify the O- or X-shaped legs with varus or valgus deformity striving for ideally shaped legs as classified by A. A. Artemiev. The **purpose** of the study was to compare changes in the relationship between reference lines as mechanical axis deviation (MAD), mechanical medial proximal tibial angle (mMPTA), mechanical lateral distal tibial angle (mLDTA) and the associated duration of the correction (CP), fixation (FP) and frame-on periods (FoP) in patients who underwent correction to have the legs shape as requested and those who underwent tibial deformity correction. **Material and methods** There were 43 patients (84 segments operated on) in the cosmesis group and 15 participants (28 segments operated on) in orthopedic group. Preoperative MAD, mMPTA, mLDTA measured  $17.48 \pm 1.14$  mm medially,  $84.90 \pm 0.35^\circ$  and  $90.61 \pm 0.39^\circ$  in the cosmesis patients;  $19.18 \pm 2.86$  mm medially,  $84.04 \pm 0.35^\circ$ ,  $89.09 \pm 0.37^\circ$  in orthopaedic patients with no statistically significant differences observed between the groups. **Results** CP, FP and FoP lasted for  $41.93 \pm 3.96$ ,  $97.67 \pm 7.78$  and  $139.60 \pm 5.15$  days in the cosmesis group, and  $18.22 \pm 3.05$ ,  $134.89 \pm 9.42$  and  $153.00 \pm 8.49$  in controls. FP/CP, CP/FoP, FP/FoP measured  $0.57 \approx 1/2$ ,  $0.31 \approx 1/3$ ,  $0.69 \approx 2/3$  in the cosmesis group and  $0.15 \approx 1/7$ ;  $0.12 \approx 1/8$ ;  $0.88 \approx 7/8$  in controls. MAD, mMPTA, mLDTA measured  $6.08 \pm 0.87$  mm laterally,  $90.80 \pm 0.31^\circ$ ,  $88.62 \pm 0.35^\circ$  in the cosmesis participants, and  $0.61 \pm 0.82$  mm laterally,  $89.46 \pm 0.54^\circ$ ,  $87.68 \pm 0.63^\circ$  in controls. **Discussion** There were no statistically significant differences in FoP with different duration of CP ( $\approx 1/3$  FoP for the cosmesis group and  $\approx 1/8$  FoP for controls). The means of MAD, mMPTA of measured up to tibial valgus in cosmesis patients and were well within acceptable limits of normal in controls. Tibial valgus was caused by too much overcorrection (by  $1/4$  on average).

**Keywords:** tibial deformity, deformity correction, correction of leg shape, O-shaped leg

### INTRODUCTION

Patients who seek advice about leg correction surgery often have a vague idea of tibial varus and valgus deformities and how to treat them surgically. The most common way of getting the information is to use freely available websites on the Internet with thematic categories [1–3]. Most of the sites do not have the official status of assigned medical organizations, therefore, posts containing false information cannot be the subject of violation of the rights of citizens in the field of health protection [4]. Neither the person's identity with the resources nor his/her legal capacity and competence can be established<sup>1</sup>. The lack of expert control over the posted judgments and the reliability of the information misleads leg lengthening candidates [5–8].

The legs can be "ideally" shaped, O-shaped ("true and false curvature") and X-shaped as classified by A.A. Artemyev [5]. Most patients are misguided to identify the O- or X-shaped legs as varus or valgus deformity of the lower limbs [9–12], and ideally aligned legs are deemed those having no signs of lower limb deformity according to the classification of the above author. These views have been refuted by the author of

the classification [5] and other orthopaedic surgeons [6–8, 13]. There are also freely available programs on the internet which are incorrectly presented as "planners" of operations for correcting tibial osteotomies based on photographs of the legs without the use of long leg standing anteroposterior radiographs (for instance, the Legscorrection 1.0 program [14], "Ortho-Cosmetologist" [15] and "Leg Shape Correction" software [11]). The purpose of the deformity correction is to normalize the relationship between the reference lines and simultaneous limb length equalization if needed [9–11]. The leg shape other than "ideal" shows no signs of the deformity [7–12]. Preoperative planning with long leg standing anteroposterior radiographs can be performed using applications or graphic editors [9–12, 16–18], specialized licensed software developed for orthopedic surgeons (for example, TraumaCad, Bone Ninja, OrthoView) [8, 19, 20].

The purpose of the study was to compare changes in the relationship between reference lines and the associated duration of the correction, fixation and frame-on periods in patients who underwent correction to have the legs shape as requested and those who underwent tibial deformity correction.

<sup>1</sup> The text concerning the legal aspects was prepared jointly with the staff lawyer of GBUZ "GB St. Great Martyr George" V.G. Rakhmin.

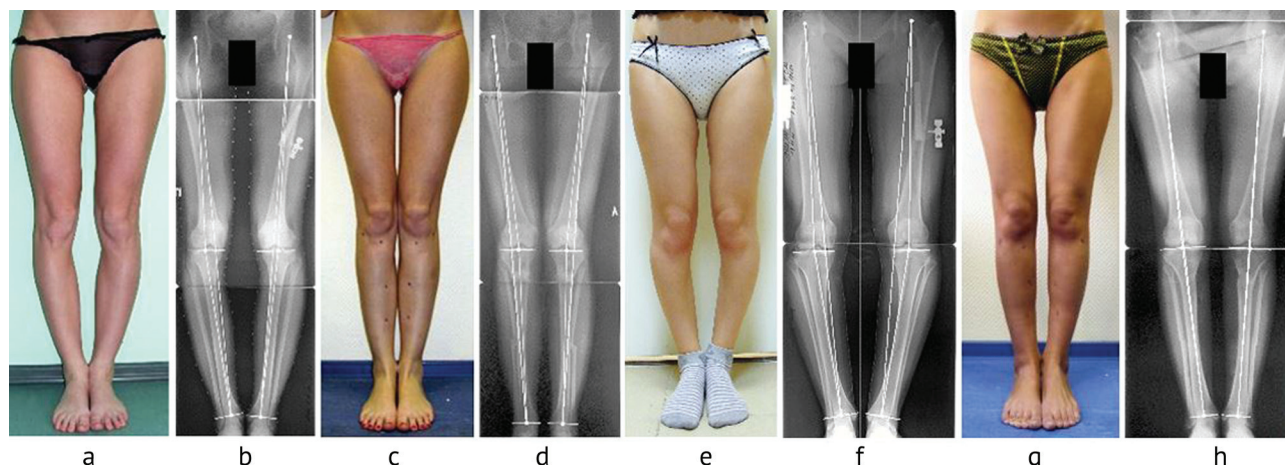
## MATERIAL AND METHODS

The duration of the treatment stages and long leg standing anteroposterior radiographs of patients who underwent tibial deformity correction were reviewed. Tibial deformity was identified in the coronal plane with measurements of the mechanical medial proximal tibial angle (mMPTA) and mechanical lateral distal tibial angle (mLDTA). Preoperative planning was performed with the technique similar to that developed by P. Lobenhoffer [18]. The planning included transverse osteotomy at a distance of 7-9 cm distally from the midnorch of the intercondylar eminence; remodeling of the distal shift (angulation in the frontal plane) to MAD = 0 mm. The level of the tibial osteotomy is determined by the anatomy measuring 1-2 cm distal to the tibial tuberosity to avoid injury. The mMPTA and the mLDTA were measured as predicted values after planning. If the measurements did not correspond to the normal values, preoperative planning of the level and number of osteotomies was performed according to the method offered by D. Paley [9]. Circular external fixation devices with wire and half-pins were used to fix the bone [10, 11]. Postoperative correction was performed gradually using hinges [9-11, 21].

The study did not include patients who developed complications that required additional surgical interventions (category II and III complications as classified by J. Caton (SoFCOT) [22], categories "obstacles" and "complications" as classified by D. Paley [23], categories II, III and IV according to the classification of L.T. Donnan [24]). The classifications

were originally developed to evaluate complications that patients could develop during limb lengthening and could be employed for adverse events that occurred during deformity correction [25]. 43 patients (84 operated segments) who showed no compliance with the recommendations provided by the orthopaedic surgeon, produced correction and completed it after obtaining the leg shape as wanted (Fig. 1 a-d). These patients comprised a "cosmesis" group.

The leg shape achieved was evaluated by patients using a five-point Marker-Sklyar system [6] modified by Kulesh and Solomin [7] with the outcomes scored 5 to 1 ("5" indicated complete satisfaction with surgery; "4" indicated satisfaction of the patient who might plan an additional operation in the indefinite future; "3" indicated dissatisfaction with surgical treatment with no plans for repeat surgery; "2" indicated dissatisfaction with surgical outcome and plans for a repeat operation in the near future or the patient has been re-operated; "1" indicated a re-operation due to impaired supportability of the limb/nonunion/tibial malalignment). The subjective satisfaction score in this group of patients averaged to  $4.51 \pm 0.08$  (scored 5;  $n = 22$ ; scored 4 ( $n = 21$ )). Patients who failed to achieve the leg shape as wanted with satisfaction scored 3 points and below were not included in the study. 15 patients (28 operated segments) demonstrated compliance and could accomplish tibial deformity correction forming an "orthopaedic" control group. The correction terminated as soon as the deformity appeared to be corrected (Fig. 1 e-h).



**Fig. 1** Photographs of patients' legs showing (a) preoperative appearance of the O-shaped legs from cosmesis group as classified by A.A. Artemyev; (b) preoperative long-leg standing AP film of the same patient with reference lines being beyond the acceptable limits of normal measuring MAD (D/S) = +20 mm / +10 mm; mMPTA (D/S) =  $82^\circ / 83^\circ$ ; mLDTA (D/S) =  $94^\circ / 92^\circ$ ; (c) photograph of the same patient with ideally aligned legs as classified by A.A. Artemyev at six-month follow-up; (d) postoperative long-leg standing AP film of the same patient with reference lines being beyond the acceptable limits of normal measuring MAD (D/S) = -16 mm / -14 mm; mMPTA (D/S) =  $89^\circ / 88^\circ$ ; mLDTA (D/S) =  $88^\circ / 89^\circ$ ; (e) preoperative appearance of the O-shaped legs from orthopaedic group as classified by A.A. Artemyev; (f) preoperative long-leg standing AP film of the same patient with reference lines being beyond the acceptable limits of normal measuring MAD (D/S) = +15 mm / +21 mm; mMPTA (D/S) =  $82^\circ / 81^\circ$ ; mLDTA (D/S) =  $92^\circ / 91^\circ$ ; (g) photograph of the same patient with O-shaped legs as classified by A.A. Artemyev at six-month follow-up; (h) postoperative long-leg standing AP radiograph of the same patient with reference lines being well within the acceptable limits of normal measuring MAD (D/S) = +2 mm / +1 mm; mMPTA (D/S) =  $87^\circ / 88^\circ$ ; mLDTA (D/S) =  $90^\circ / 91^\circ$

For each operated segment, the associated duration of the correction (CP) between the day of surgery through the day of accomplished manipulations with the frame, fixation (FP) between the day of accomplished manipulations with the frame through the day of frame removal and frame-on period (FoP) between the day of surgery through the day of frame removal. Therefore,  $FoP = CP + FP$ . The ratios between the CP and FP (CP/FP), the CP and FoP (CP/FoP) and the FP and FoP (FP/FoP) were calculated for each segment measuring  $(CP + FP)/FoP = 1$  for each patient. Long-leg standing AP radiographs were performed preoperatively and after frame removal and reviewed in a standard way [9-12, 26]. Mechanical axis deviation (MAD), mechanical medial proximal tibial angle (mMPTA), mechanical lateral distal tibial angle (mLDTA) were measured. Medial MAD was measured in millimeters and marked with the "-" sign [27]. Measurements of the angles on long-leg standing AP films were produced independently by three orthopaedic surgeons. Further investigations were performed on the averaged measurements. MAD, mMPTA, and mLDTA measured for each patient of both groups were compared with the normal values, calculating the deviation as a scalar value being independent on the direction of deviation and having neither "+" nor "-" sign. Normal range for MAD was -3 mm inclusive to +3 mm inclusive [12], for mMPTA, 85° to 90° [9-12], for mLDTA, 86° to 92° [9-12].

The statistical analysis included calculation of the average measurements of six variables characterizing the duration of treatment periods: CP, FP, FoP and the ratios CP/FP, CP/FoP and FP/FoP in the cosmesis

and orthopaedic groups. Significant differences in the variables were identified between the two groups with Student t tests for normally distributed variables. The data obtained were summarized as  $M \pm SD$ , where M, means ( $M = \bar{x}$ ) and SD, standard deviations ( $SD = \delta/\sqrt{n}$ ) [28]. The values of M and SD were specified up to the second decimal place [29]. The average measurements of six variables including MAD, mMPTA, mLDTA and the standard deviations were calculated for both groups using long-leg standing AP radiographs performed before and after treatment. Significant differences in the variables within the group before and after treatment and significant differences in the corresponding variables between the groups were identified in a similar manner. The data obtained were compared with the literature data.

The mean age of patients was 26 (range, 18-32) years in the 'cosmesis' group and 29 (range, 18-43) years in the 'orthopaedic' group. Surgeries were performed between 2008 and 2018. All patients have accomplished the treatment. Patients of both groups were operated on by one surgeon, P.N. Kulesh, Ph.D. who followed up on them. Long-leg standing AP radiographs were produced using stitch technology. There were no statistically significant differences in the preoperative measurements of MAD, mMPTA, mLDTA and the deviations between the groups, which confirms the consistency. The study received a favourable opinion from the relevant research ethics committee of the Russian Vreden Research Institute of Traumatology and Orthopedics, Ministry of Health and Social Development of the Russian Federation on 04.03.11.

## RESULTS

There were statistically significant differences in the length of CP between cosmesis and orthopaedic groups measuring  $41.93 \pm 3.96$  days and  $18.22 \pm 3.05$  days, respectively, and in the duration of FP measuring  $97.67 \pm 7.78$  days and  $134.89 \pm 9.42$  days, respectively. The differences in the duration of FoP were not significant between cosmesis and orthopaedic groups measuring  $139.60 \pm 5.15$  days and  $153.00 \pm 8.49$  days, respectively. The mean CP/FP ratios in the cosmesis and orthopaedic groups were  $0.57 \pm 0.09$  and  $0.15 \pm 0.04$ , CP/FoP in the groups being  $0.31 \pm 0.03$  and  $0.12 \pm 0.03$ , respectively, FP/FoP being  $0.69 \pm 0.03$  and  $0.88 \pm 0.03$ , respectively. Differences in FP/FoP, CP/FoP and FP/FoP ratios software were statistically significant in both groups. Data on the length of CP, FP, and FoP reported by different authors during tibial deformity correction

in adult patients using transosseous osteosynthesis is presented in Table 1 and Figure 2.

Changes in the MAD measurements from  $+17.48 \pm 1.14$  mm to  $-6.08 \pm 0.87$  mm in the cosmesis group and from  $+19.18 \pm 2.86$  mm to  $-0.61 \pm 0.82$  mm in the orthopaedic group (Fig. 3a) as well as the deviations from the norm before and after treatment (from  $15.93 \pm 0.81$  mm to  $5.63 \pm 0.58$  mm and from  $20.18 \pm 1.46$  mm to  $1.25 \pm 0.38$  mm, respectively) (Fig. 3d) were statistically significant. Changes in mMPTA measurements from  $84.90 \pm 0.35^\circ$  to  $90.80 \pm 0.31^\circ$  and from  $84.04 \pm 0.76^\circ$  to  $89.46 \pm 0.54^\circ$  before and after treatment (Fig. 3b) were statistically significant. Changes in the deviations of the mMPTA from  $1.42 \pm 0.19^\circ$  to  $1.58 \pm 0.20^\circ$  (Fig. 3e) were not statistically significant in the cosmesis group, and from  $2.39 \pm 0.41^\circ$  to  $0.79 \pm 0.24^\circ$  (Fig. 3e)



being statistically significant among orthopaedic patients. Changes in the mLDTA measurements from  $90.61 \pm 0.39^\circ$  to  $88.62 \pm 0.35^\circ$  before and after treatment (Fig. 3c) were statistically significant in the cosmesis group. Changes in the mLDTA measurements from  $89.09 \pm 0.37^\circ$  to  $87.68 \pm 0.63^\circ$  (Fig. 3c) were not statistically significant in the orthopaedic group. Altered deviations in the mLDTA measurements from  $0.98 \pm 0.18^\circ$  to  $0.62 \pm 0.11^\circ$  and from  $0.14 \pm 0.01^\circ$  to  $0.55 \pm 0.12^\circ$  (Fig. 3f) were not statistically significant in both groups. Comparison of the angles after treatment between the groups showed statistically significant differences in MAD measurements, statistically insignificant

differences in mMPTA values and statistically insignificant differences in mLDTA measurements. The differences in deviations in MAD (Fig. 3d) were statistically significant after treatment; the differences in deviations in mMPTA measurements (Fig. 3e) were not statistically significant after treatment; and the differences in deviations in mLDTA (Fig. 3e) were also not statistically significant after treatment.

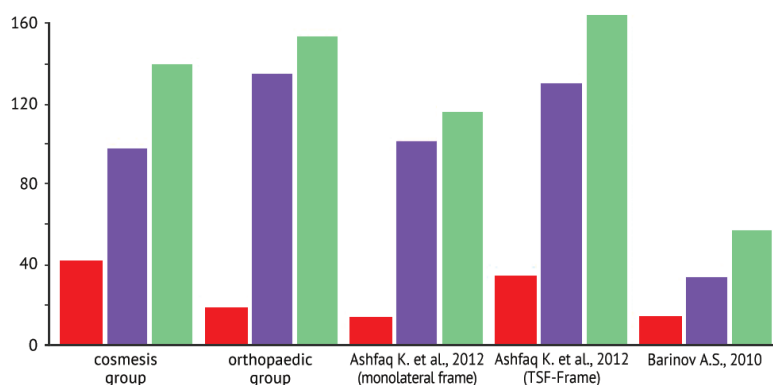
The effect of tibial deformity correction in adult patients performed with transosseous osteosynthesis on the correlation of reference lines (MAD and mMPTA) as reported by different authors is presented in Table 2 (mLDTA measurements and deviations are not presented by the authors).

Table 1

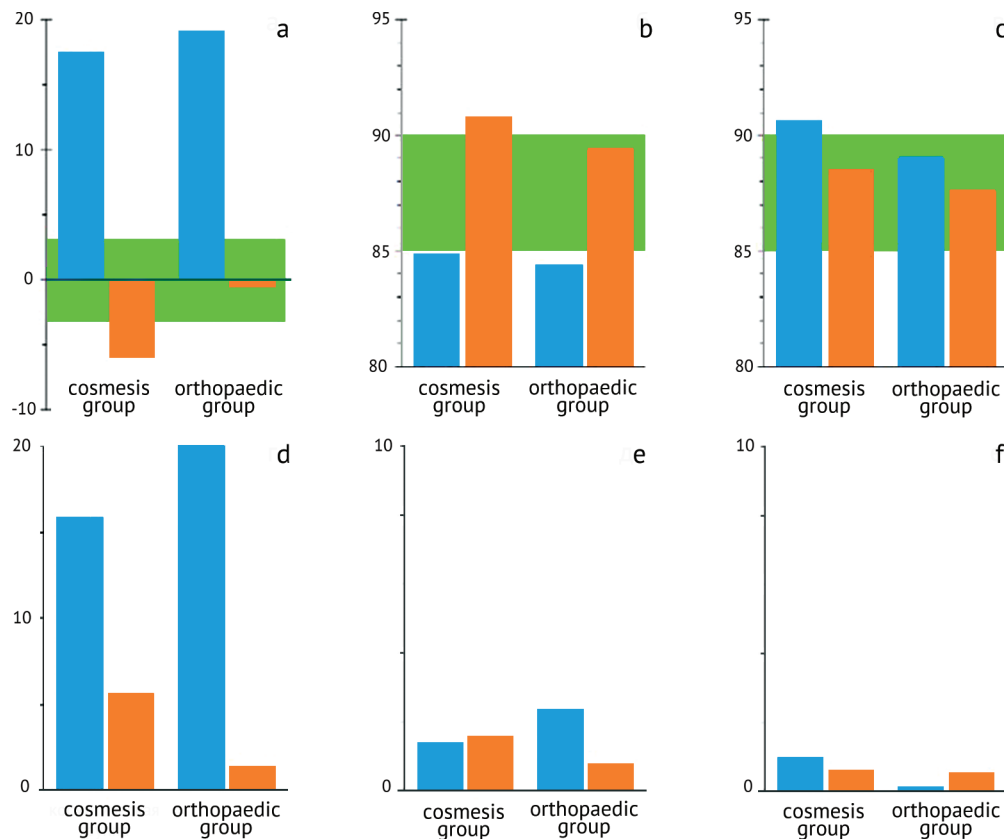
Literature data on the duration of CP, FP, FoP, the ratios and the comparison with the own data

	Authors							
	O.V. Klimov, K.I. Novikov, A.M. Aranovich, 2008 [30]	H.A. Marker, L.V. Sklyar, 2009 [6]	A.S. Barinov et al., 2010 [31]	K. Ashfaq, S.R. Rozbruch et al., 2012 (monolateral frame) [32]	K. Ashfaq, S.R. Rozbruch et al., 2012 (TSF-Frame) [32]	Y.E. Park et al., 2013 [33]	A.A. Artemyev et al., 2015 [34]	R.J. Da Cunha, S.R. Rozbruch et al., 2020 [35]
Number of segments operated on	18	33	246	23	41		434	8
Age of patients	15–37	20–29	27.25	44 (23–73)	39 (21–72)	24.8 (SD 5.3)		53. 37. 53. 29
CP [days]		10–40*	$19.70 \pm 3.53^*$ (14–27)	15 (8–20)	34 (7–99)			
FP [days]		$58.4 \pm 4.4$	$33.70^*$ (19–53)	101 (81–133)	130 (95–177)			
FoP [days]	$68.2 \pm 12.7$		$57.00 \pm 11.54$ (47–93)	116*	164*	173	107.14*	97
CP/FP			$0.58^* \approx 3/5$	$0.15^* \approx 1/7$	$0.26^* \approx 1/4$			
CP/FoP			$0.35^* \approx 3/8$	$0.13^* \approx 1/8$	$0.21^* \approx 1/5$			
FP/FoP			$0.59^* \approx 5/8$	$0.87^* \approx 7/8$	$0.79^* \approx 4/5$			
$CP_{auth}/CP_{cosm}$			0.35*	0.36*	0.81*			
$CP_{auth}/CP_{orth}$			0.81*	0.82*	1.87*			
$FP_{auth}/FP_{cosm}$		0.60*	0.35*	1.03*	1.33*			
$FP_{auth}/FP_{orth}$		0.43*	0.25*	0.75*	0.96*			
$FoP_{auth}/FoP_{cosm}$	0.49*		0.41*	0.83*	1.17*	1.77*	0.77*	0.69*
$FoP_{auth}/FoP_{orth}$	0.45*		0.37*	0.76*	1.07*	1.28*	0.70*	0.63*

**Note**  $CP_{auth}$ , length of the correction period as reported by the author;  $CP_{cosm}$ , length of the correction period in the cosmesis group;  $CP_{orth}$ , length of the correction period in the orthopaedic group. Mean values (M) were used for calculations. Adjustments for FP and FoP were specified in a similar manner; \* values calculated based on the data provided by the authors.



**Fig. 2** Correlations in the length of the periods explored (CP, FP, FoP) in the study groups as compared to the data reported by different authors (CP marked as red, FP marked as violet, FoP marked as green)



**Fig. 3** Changes in the angles measured on long-standing AP radiographs in both groups represented in (a) diagram showing changes in the mean measurements of MAD (hereafter: preoperative angles marked with blue, measurements performed after treatment marked with orange, normal range marked with green); (b) diagram showing changes in the mean measurements of mMPTA; (c) diagram showing changes in the mean measurements of mLDTA; (d) deviation in MAD measurements; (e) deviation in mMPTA measurements; (f) deviation in mLDTA measurements

Table 2

MAD, mMPTA and the deviations measured before and after tibial deformity correction in the upper third of adult patients using transosseous osteosynthesis as reported by different authors (the optimal mMPTA of 85°-90° reported by all authors [9])

		Authors				
		D. Saragaglia et al., 2007 [36]	K. Ashfaq, S.R. Rozbruch et al., 2012 [32] (monolateral frame)	K. Ashfaq, S.R. Rozbruch et al., 2012 [32] (TSF-Frame)	B. Özkul et al., 2017 [37]	R.J. Da Cunha, S.R. Rozbruch et al., 2020 [35]
Number of segments operated on		16	15 / 8	35 / 6	50	8
Patients' age		51.19 ± 11.15	44 (23–73)	39 (21–72)	19.4 ± 6.9 (14–39)	53. 37. 53. 29
MAD [mm]	Preoperatively		+22 ± 8 (10–44)	+40 ± 35 (5–155)	+37.6 ± 21.6 (9–98)	+31.1 ± 11.8 (16–42)
	Optimal value		0 / -10 [38]	0 / -10 [38]	+9.7 ± 6.8 [9]	+8 ± 7 [39]
	After treatment		+3 ± 3 (0–7) -5 ± 3 (-2 – -10)	+5 ± 7 (0–30) -4 ± 3 (0–7)	+8.4 ± 12.1 (3–44)	+5.5 ± 5.6 (0–11)
mMPTA [degrees]	Preoperatively	84.5 ± 2.19 80 (40–87)	85 ± 3 (79–89)	80 (40–87)	76 ± 7.2	82.4 ± 1.3 (81–84)
	After treatment	90.31 ± 1.20 (88–92)	90 ± 3 (85–96)	88 (83–96)	89 ± 2.5	88.3 ± 1.9 (86–90)
Deviations	MAD (M) [mm]				5.4	0.5
	mMPTA (M) [degrees]	0.31	0	0	0	0

## DISCUSSION

Average CP/FP ratio in the orthopaedic group was 3.8 times less than that in the cosmesis group. The average CP length duration of PC was ≈ 1/2 of the FP length in the cosmesis group and ≈ 1/7 of the FP in the orthopaedic group. Average CP/FoP ratio was 2.6 times less in the orthopaedic group than

that in the cosmesis group. The average duration of CP was ≈ 1/3 of the FoP in the cosmesis group and ≈ 1/8 of the FoP in the orthopaedic group. The average FP/FoP ratio was 1.3 times greater in the orthopaedic group than that in the cosmesis group. The average duration of FP was ≈ 2/3 of the FoP

in the cosmesis group and  $\approx 7/8$  of the FoP in the orthopaedic group.

Our own data on CP were comparable with the data of two authors who reported [32] a group of patients treated with monolateral devices with CP being less than that in the cosmesis and orthopaedic groups, and CP [31] being less than that in the cosmesis group and greater than that in the orthopaedic group. Data on FP were reported by 3 authors with FP [6, 31] being less than that in the cosmesis and the orthopaedic groups, and one [32] had FP being less than in a group of patients treated with a monolateral device than that in the cosmesis group and greater than that in the orthopaedic group. Data on FoP were provided by 6 authors: in five [30, 31, 32, 34, 35] – had less FoP than the “cosmetic” and “orthopedic” groups ([32] – the group of patients who received treatment with a monolateral device), in two [32, 33] – FoP is longer than in both groups ([32] – the group of patients receiving TSF-Frame).

Two authors [30, 31] reported the data that would allow us to calculate the CP/FP, CP/FoP and FP/FoP ratios. Four series [30, 33–35] reported FoP only, one [6] reported the CP and FP in a form that does not allow calculating the FoP. Calculations of the ratios using the data presented by A.S. Barinov et al. [31] were similar to those detected in the cosmesis group of our series. The ratios calculated in a group of patients treated with a monolateral device presented by K. Ashfaq et al. [32] are on par with the ratios calculated in the orthopaedic group.

MAD measured after treatment were comparable to those reported by two of the four authors [35, 37]. The values being well within acceptable limits of normal [12] were observed in orthopaedic patients of our series. The reported value being closer to the norm was  $9.02 \approx 9$  times greater [35]. The optimal MAD value and the range were reported to be different [9, 12, 38]. This can be ascribed to a change in orthopaedic views over time with new studies on the tibial deformity correction relying on updated recommendations for the normal correlations between reference lines. The normal mean of mMPTA after correction was reported by four of the five authors. MMPTA was not within acceptable limits of normal in the cosmesis group of our series and in the reported series [36]. We could not find any information in the medical literature reporting analysis of long standing films of lower limbs that were surgically corrected to change the leg shape for cosmesis. The mean MAD was well within acceptable limits of normal in orthopaedic patients [12] and was closer

to the mid range as compared to the reported data; the mean MAD of cosmesis patients was closer to the norm as compared to the one reported [37]. The mean mMPTA was well within acceptable limits of normal in orthopaedic patients as reported in three of the four publications (75 %) [32, 35, 37]. The mean mMPTA of cosmesis patients was further away from the normal values. There were statistically significant deviations in MAD measured after treatment in the cosmesis and orthopaedic groups ( $t_{\text{emp}} = 4.20$  with  $t_{\text{kr}} = 1.97$  and  $2.61$ ). The mean MAD of cosmesis patients was considered as valgus alignment of the lower limb after treatment.

Similar findings were obtained earlier in a smaller group of patients with MAD measuring  $+20.85 \pm 9.08$  mm preoperatively and  $8.55 \pm 9.94$  mm after treatment; with mMPTA measuring  $86.45 \pm 1.85^\circ$  preoperatively and  $89.65 \pm 2.30^\circ$  after treatment; with mLDTA measuring  $89.35 \pm 3.50^\circ$  preoperatively and  $87.25 \pm 1.63^\circ$  after treatment. Statistical data were presented as  $M \pm \delta$ , where M was the mean and  $\delta$ , the standard deviation [39]. This cannot be explained by an error in performing the correction, because the mean MAD was well within acceptable limits of normal in orthopaedic patients. The mean preoperative mMPTA was less than normal value in both groups and was considered as varus alignment of the tibia. The mean mMPTA measured valgus alignment of the tibia in the cosmesis patients and was well within acceptable limits of normal in orthopaedic patients. Consequently, the valgization performed for cosmesis patients to achieve the leg shape wanted was excessive and finally resulted in valgus alignment of the tibia. The proportion of excessive valgization in cosmesis patients was 1/4 on average of that performed. The average change in MAD in the group was  $|17.48 \text{ mm} - (-6.08 \text{ mm})| = 23.56 \text{ mm} \approx 24 \text{ mm}$ . The average valgization that would normalize MAD is supposed to change it by an average of  $|17.48 \text{ mm} - 0 \text{ mm}| = 17.48 \text{ mm} \approx 18 \text{ mm}$  (3/4 of 24 mm). This statement cannot be refuted by the review of changes in mMPTA occurred in the group. The mean change in mMPTA was  $|84.90^\circ - 90.80^\circ| = 5.90^\circ \approx 6^\circ$ . Three quarters of the valgization performed would alter the parameter by an average of  $4.43^\circ \approx 4.5^\circ$  (3/4 of  $6^\circ$ ), that is, to  $89.33^\circ$ . The parameter was within acceptable limits of normal. Similarly, if we conditionally assume a normal MAD value of 0 mm, the proportion of "excessive" valgization in orthopaedic patients group would proportion to a 1/17 of that performed (the mean MAD deviation decreased 16 times from resultant correction).

The limitation of the retrospective comparative study performed was the review of treatment period and long leg standing AP radiographs of patients who were operated on and supervised by a single orthopaedic surgeon. More reliable information can be obtained by conducting a similar multicenter study. The cases of tibial deformity correction were reviewed

solely in the coronal plane. Patients who could not achieve the leg shape as wanted were excluded from the cosmesis group with the leg shape scored 3 and below on the five-score Marker-Sklyar grading system [6] modified by Kulesh and Solomin [7]. The study did not include patients who developed complications that required additional surgical interventions.

## CONCLUSIONS

1. The ratio of the average duration of the correction period and the fixation period was 1:2 in the cosmesis group and 1:7 in the orthopaedic group. The difference in the length of frame-on periods in both groups was statistically insignificant (Fig. 2).

2. The mean MAD, mMPTA measured to tibial valgus in cosmesis patients who achieved the leg shape as wanted (Fig. 3 a, b; Table 2) and in controls. The mean MAD, mMPTA, mLDTA achieved after the tibial deformity correction were well within acceptable limits of normal in control orthopaedic group (Fig. 3 a–c; Table 2). Therefore, the correction aimed at achieving the leg shape wanted was different from the correction aimed at eliminating tibial malalignment and provided no absence of a deformity.

3. There was a statistically significant decrease in the deviation of MAD by 3 times on average in cosmesis group after treatment, and by 16 times in controls (Fig. 3d). There was no statistically significant decrease in the deviation of the mMPTA in the cosmesis group, and there was a statistically significant decrease in the deviation of the mMPTA in the orthopaedic group, by 3 times on average (Fig. 3e).

4. Since the preoperative mean MAD and mMPTA measured to tibial varus in both groups with normal mLDTA, tibial valgus was caused by too much overcorrection/valgization (by  $\frac{1}{4}$  on average) in cosmesis patients. Consequently, the correction performed facilitated the leg shape for the patient as wanted due to the development of another orthopaedic pathology of tibial valgus.

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