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Konstantin Ukhanov, Viktor Vilensky, Konstantin Korchagin,
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Reference Lines and Angles

http://ortho-suv.org

St.Petersburg, 2018

For each of bones reference lines are offered. The angles at which these lines are crossed indicate if there is deformation or not. These standard referent lines are named as follows:

- anatomic axes
- mechanical axes
- joint orientation lines

All these referent lines are drawn both in frontal and sagittal planes. Therefore accurate following recommendations on x-ray examination (the chapter 2.10.1) is an obligatory requirement at planning of long bones deformity correction.

The anatomic axis of a long bone is the mid-diaphyseal line. The term “a longitudinal axis” (of bone, of bone fragment) can be used as a synonym of "an anatomic axis”.

It is necessary to take into account, that the term "axis" in this case is conventional. Long bones are not rectilinear. However, physiological curvature of some of them, being applied to clinical criteria, can be approximated to a straight line. For other bones the anatomic axis is accepted, as the curved line. It can by a straight line in frontal plane and curved line – in sagittal plane, as it is in femur.

The mechanical axis of the bone is a straight line connecting the centers of proximal and distal joints of the limb.

The mechanical axis of the lower limb is a straight line connecting the centers of hip joint and ankle joint.

The mechanical axis of the upper limb is a straight line connecting the center of the humeral bone head and the center of the ulna head.

Joint orientation lines are drawn using special anatomic and radiological reference points.

At crossing an anatomic axis with joint orientation lines "anatomic", or “epidiaphyseal”, angles are formed: proximal and distal for each of bones.

At crossing a mechanical axis with joint orientation lines the angles called “mechanical" are formed (according D. Paley, 2005) (Tabl. 1).

Tabl. 1.

Nomenclature of main reference angles

abbreviation	title
Mechanical angles of femur	
LPFA	lateral proximal femoral angle
mLDFA	mechanical lateral distal femoral angle
mPPFA	mechanical posterior proximal femoral angle
mPDFA	mechanical posterior distal femoral angle
Mechanical angles of tibia	
MPTA	medial proximal tibial angle
LDTA	lateral distal tibial angle
mPPTA	mechanical posterior proximal tibial angle
mADTA	mechanical anterior distal tibial angle
Anatomic angles of femur	

MNSA	medial neck shaft angle
MPFA	medial proximal femoral angle
aLDFA	anatomic lateral distal femoral
ANSA	anterior neck shaft angle
PPFA	posterior proximal femoral angle
PDFA	posterior distal femoral angle
Anatomic angles of tibia	
MPTA	medial proximal tibial angle
LDTA	lateral distal tibial angle
PPTA	posterior proximal tibial angle
ADTA	anterior distal tibial angle
Other reference lines	
JLCA	joint line convergence angle
MAD	mechanical axis deviation

m – mechanical, **a** – anatomical, **M** – medial, **L** – lateral, **A** – anterior, **P** – posterior, **Pr** – proximal, **D** – distal, **F** – femoral, **T** – tibial, **A** – angle

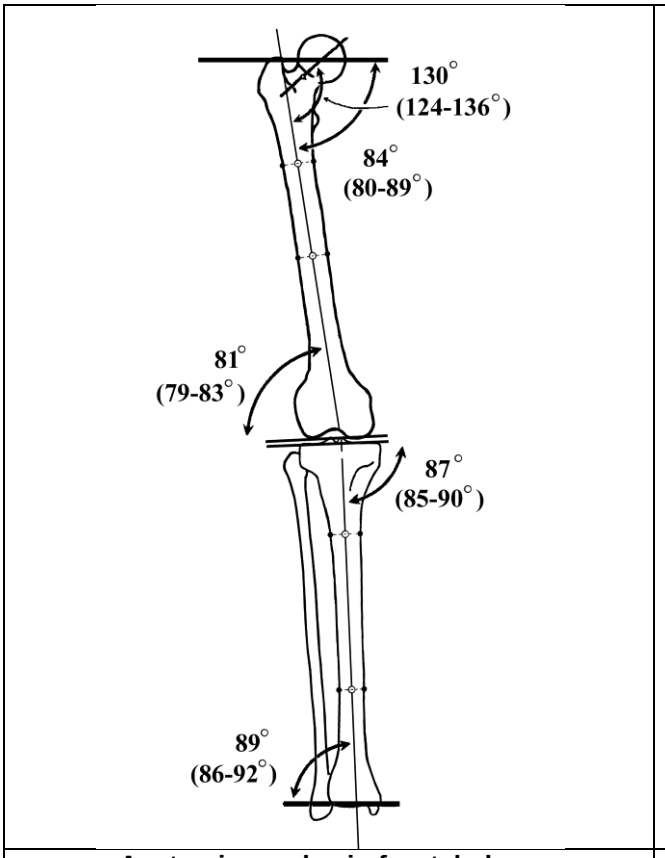
It is necessary to note that top of anatomic angle as well as top of mechanical angle should be at definite point of joint orientation line. These points along with anatomic and mechanical angles are specific for each of bones.

Thus, reference lines and angles (RLA) include:

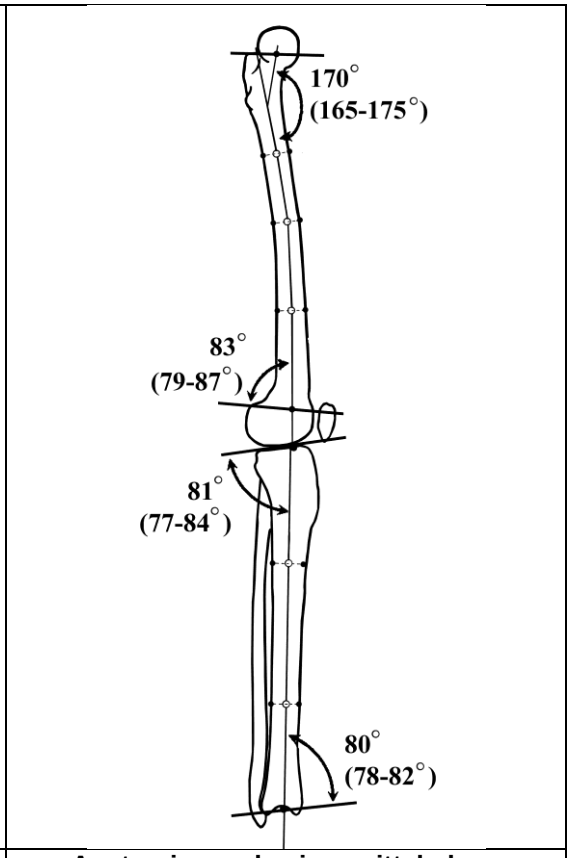
- Anatomic axes
- Mechanical axes
- Joint lines
- Anatomic angles
- Mechanical angles

Each of them defines for frontal and sagittal planes.

Reference Lines and Angles of the Upper Limb

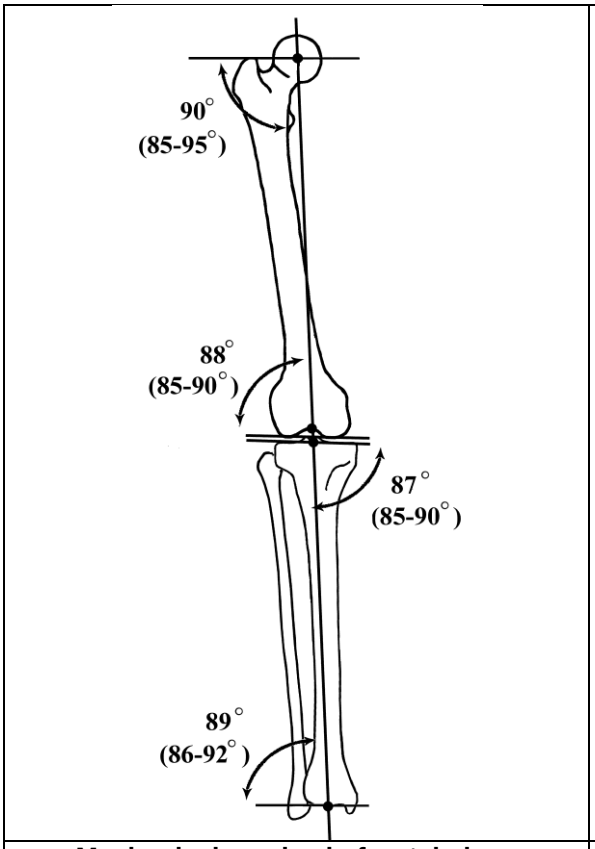


Anatomic angles in frontal plane



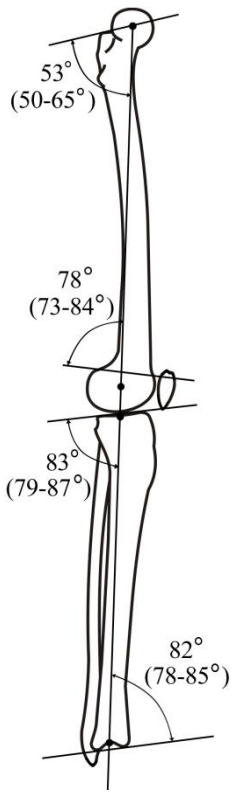
Anatomic angles in sagittal plane

Similarlyy to D.Paley, 2005

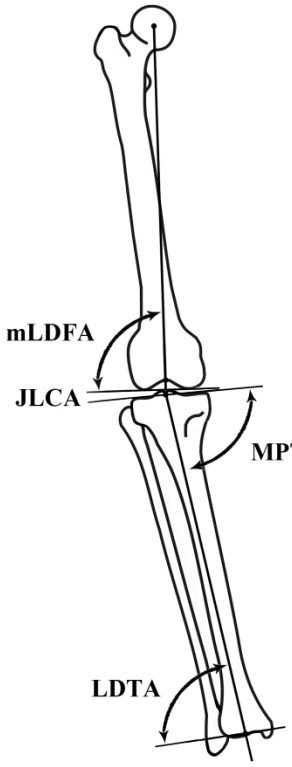


Mechanical angles in frontal plane

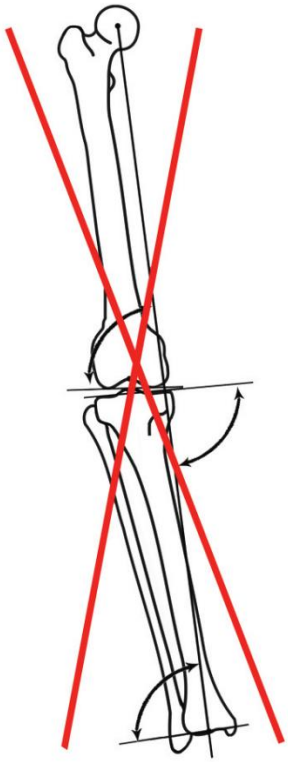
Similarlyy to D.Paley, 2005



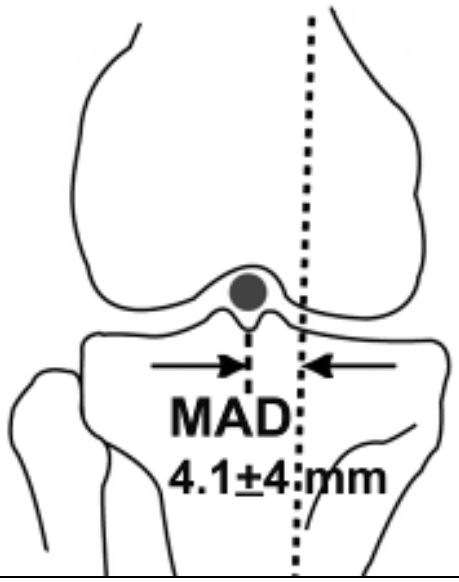
Mechanical angles in sagittal plane



Correct measuring angles when MAD ≠ 0

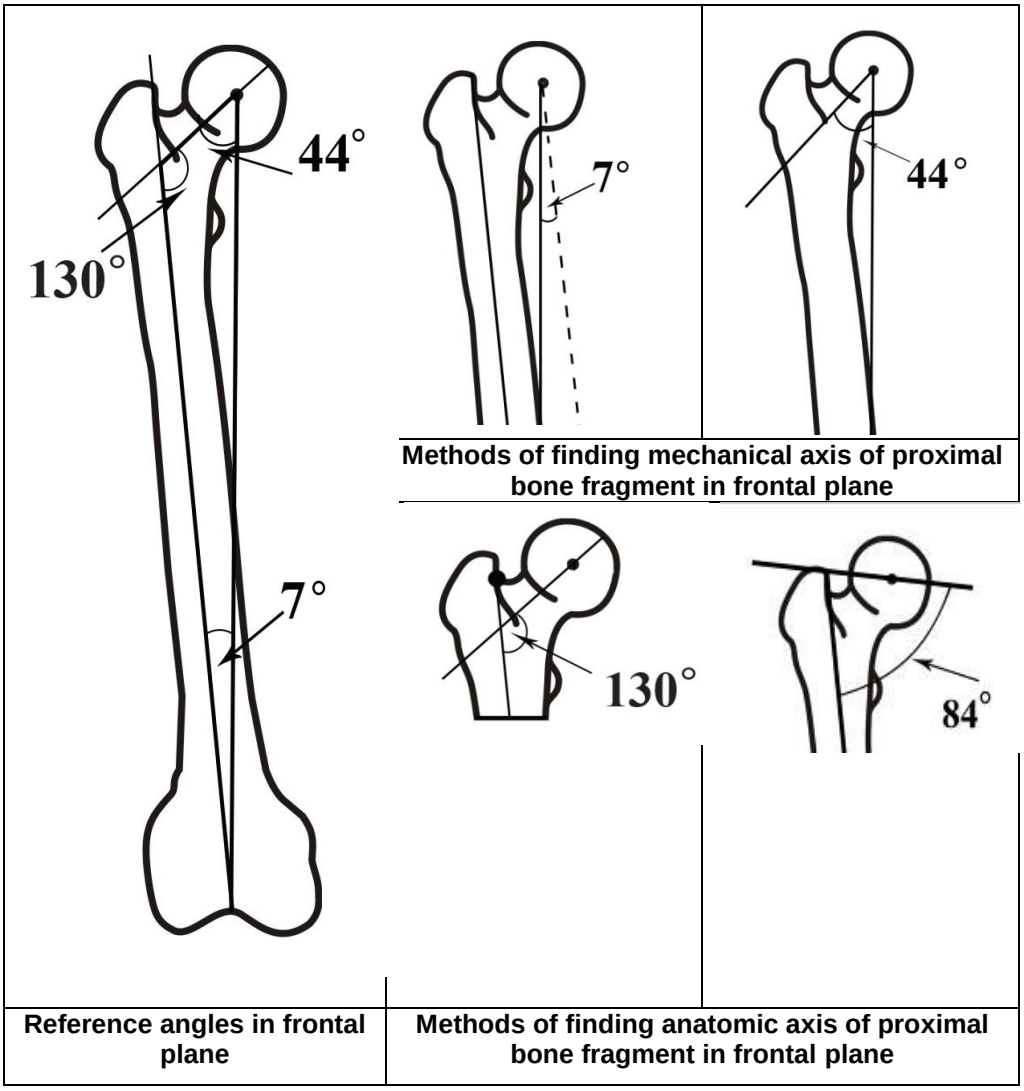


Incorrect measuring angles when MAD ≠ 0



Mechanical Axis Deviation

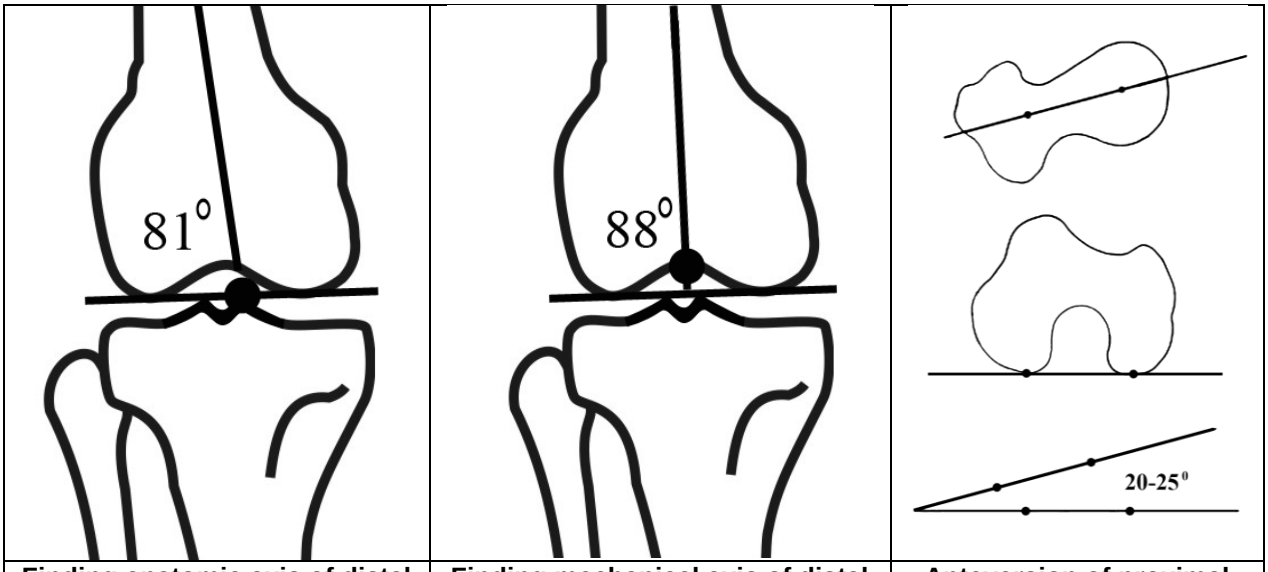
Similarlyy to D.Paley, 2005



Reference angles in frontal plane

Methods of finding mechanical axis of proximal bone fragment in frontal plane

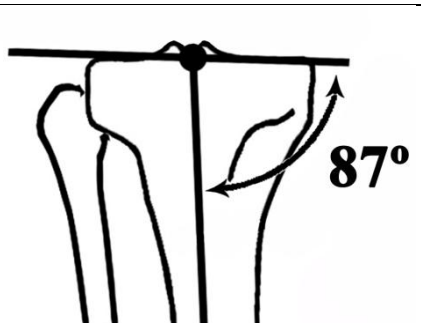
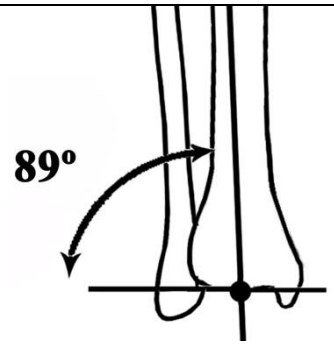
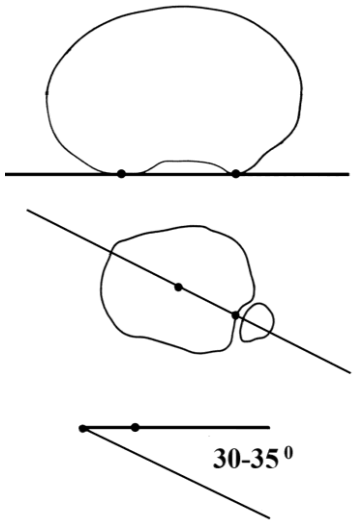
Methods of finding anatomic axis of proximal bone fragment in frontal plane

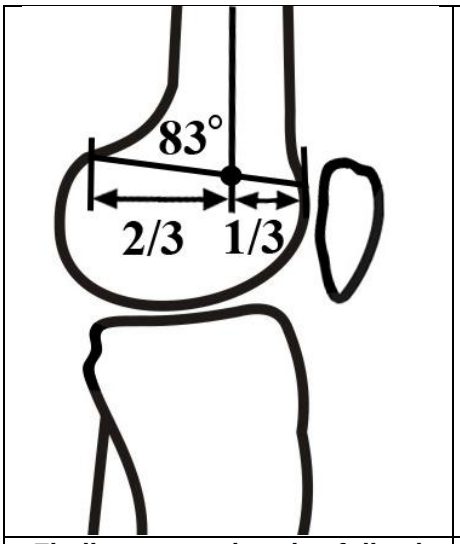
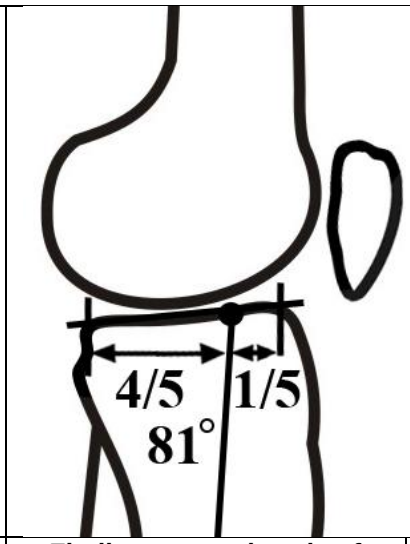
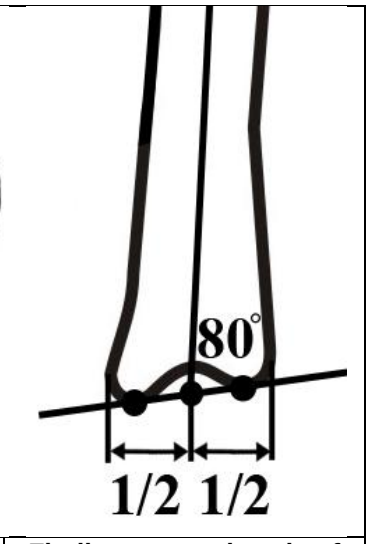


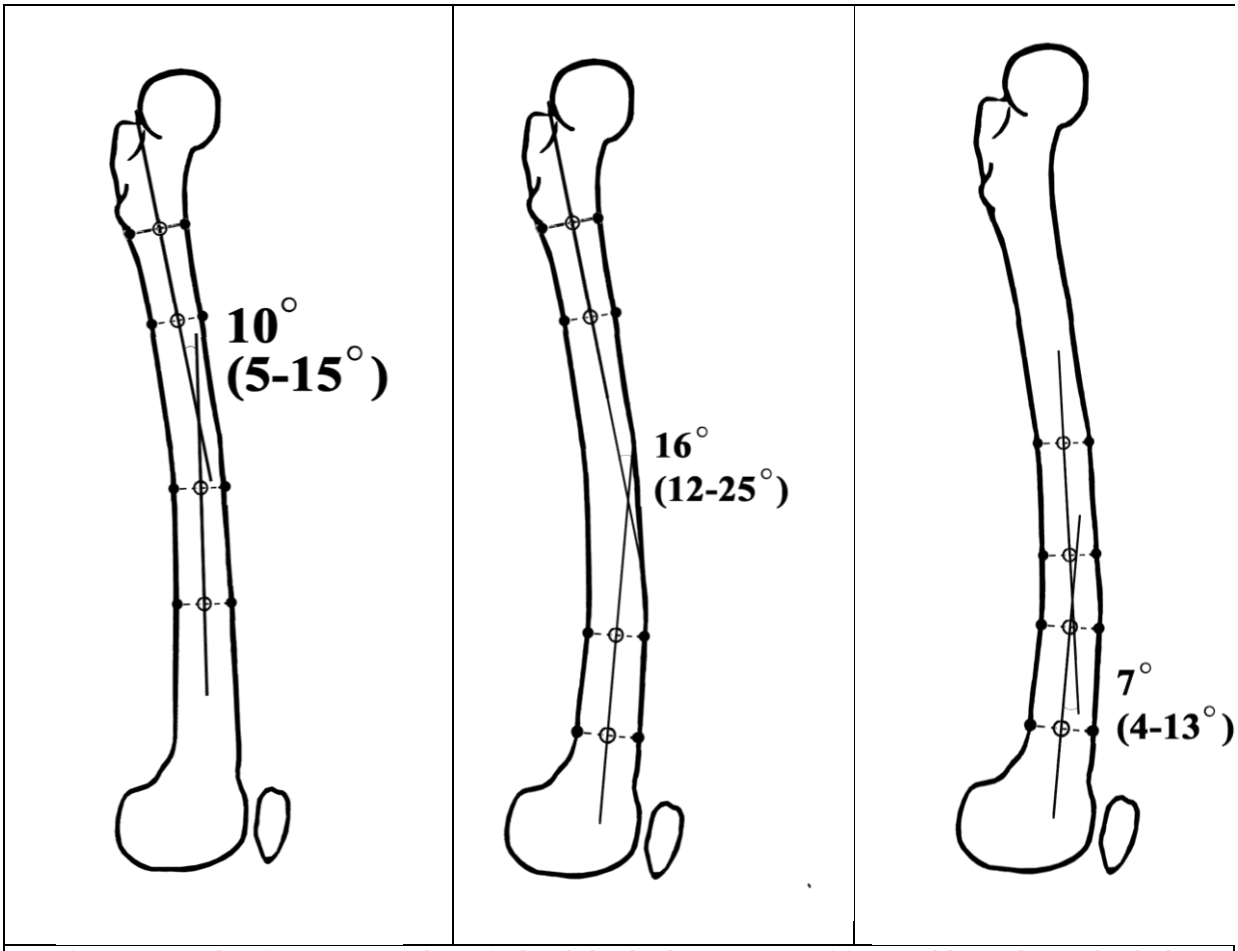
Finding anatomic axis of distal bone fragment in frontal plane

Finding mechanical axis of distal bone fragment in frontal plane

Anteversion of proximal part of femoral bone
(Strecker W. et al., 1994, 1997; Prokop M. et al., 2003)

		
Finding mechanical axis of proximal bone fragment in frontal plane	**Finding mechanical axis of distal bone fragment in frontal plane**	**Torsion of distal part of tibia (Strecker W. et al., 1994, 1997; Prokop M. et al., 2003)**

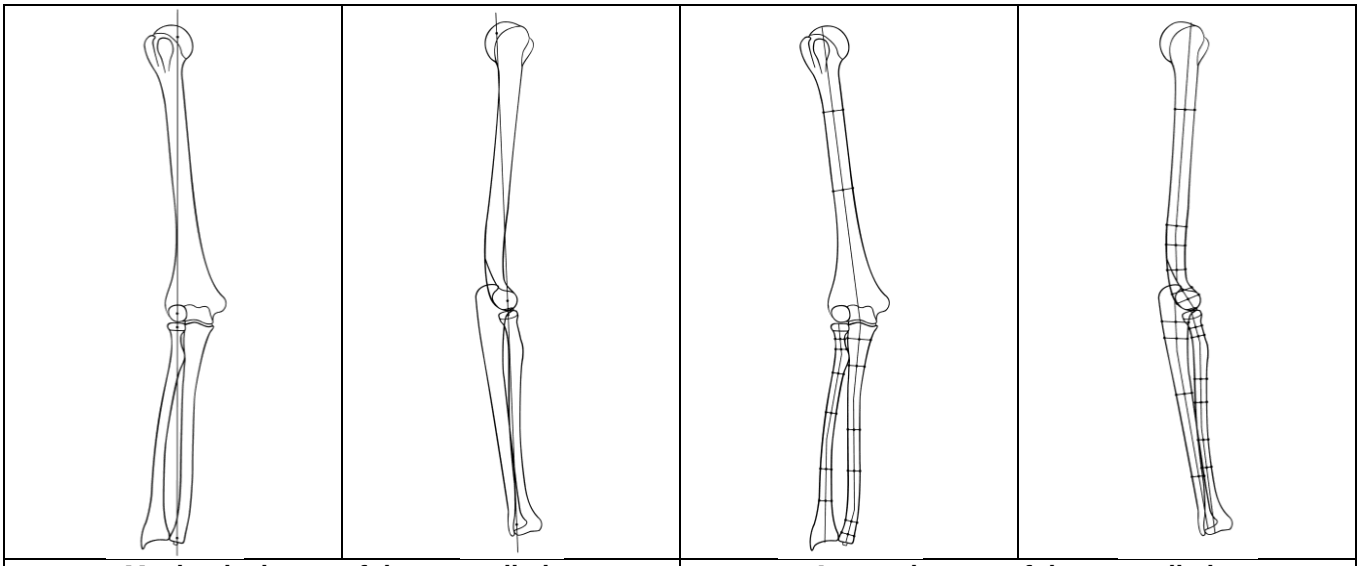
		
Finding anatomic axis of distal femoral bone fragment in sagittal plane	**Finding anatomic axis of proximal tibial bone fragment in sagittal plane**	**Finding anatomic axis of distal tibial bone fragment in sagittal plane**



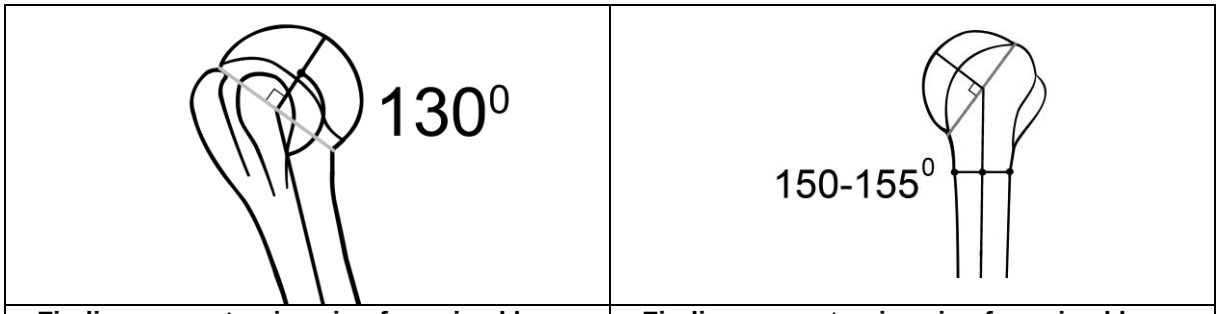
Reference angles for preservation of physiological curvature of femoral bone in sagittal plane
Solomin L., Skomoroshko P., unpublished results

Reference Lines and Angles of the Upper Limb

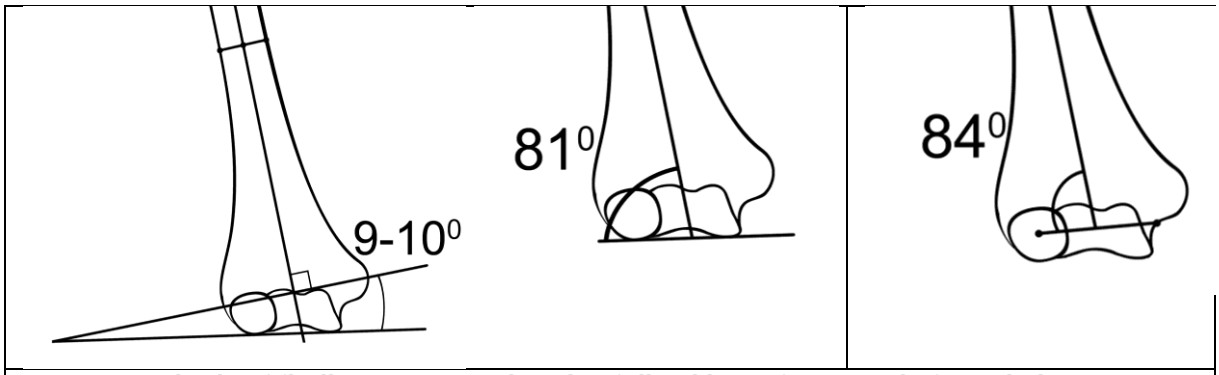
(Solomin L., Kulesh P., unpublished results)



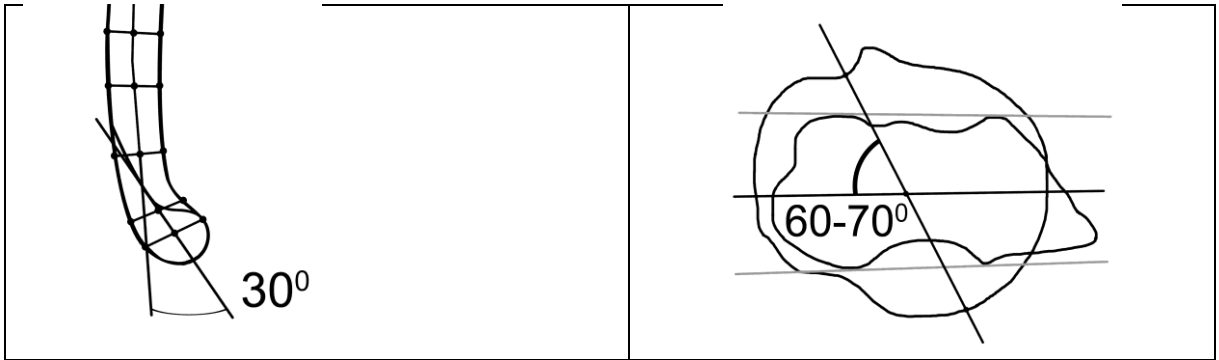
Mechanical axes of the upper limb | **Anatomic axes of the upper limb**



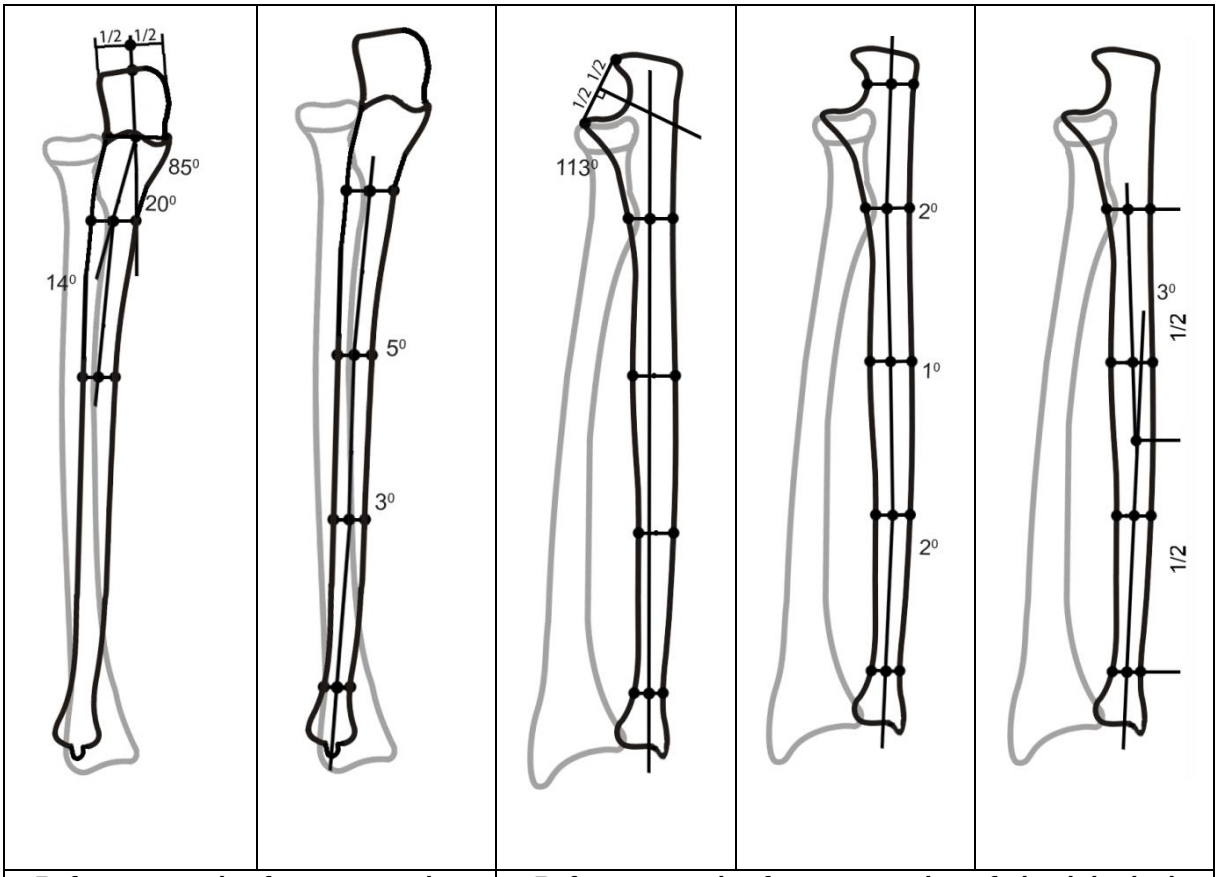
Finding an anatomic axis of proximal bone fragment in frontal plane | **Finding an anatomic axis of proximal bone fragment in sagittal plane**



Methods of finding an anatomic axis of distal bone fragment in frontal plane

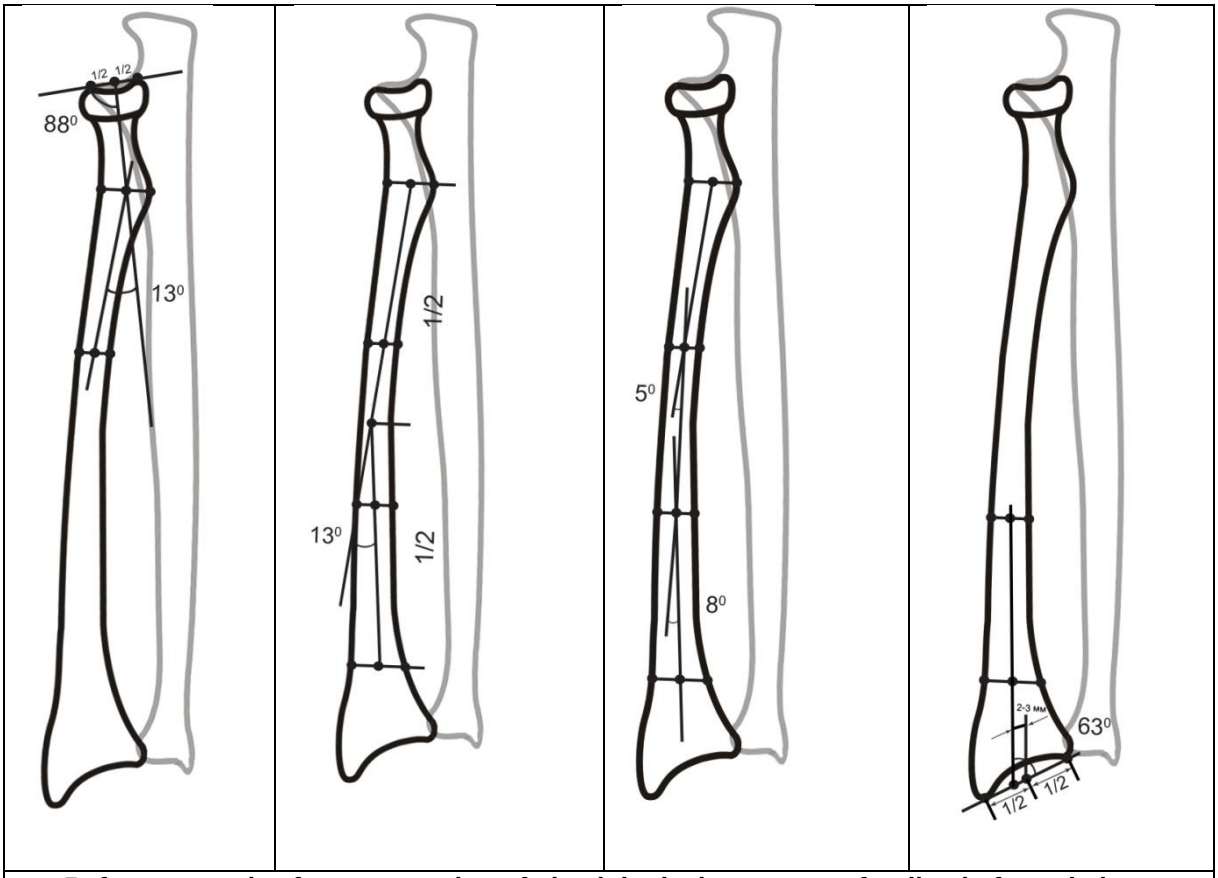


Finding an anatomic axis of distal bone fragment in sagittal plane | **Retroversion of distal part of humeral bone** (Prokop M. et al., 2003)

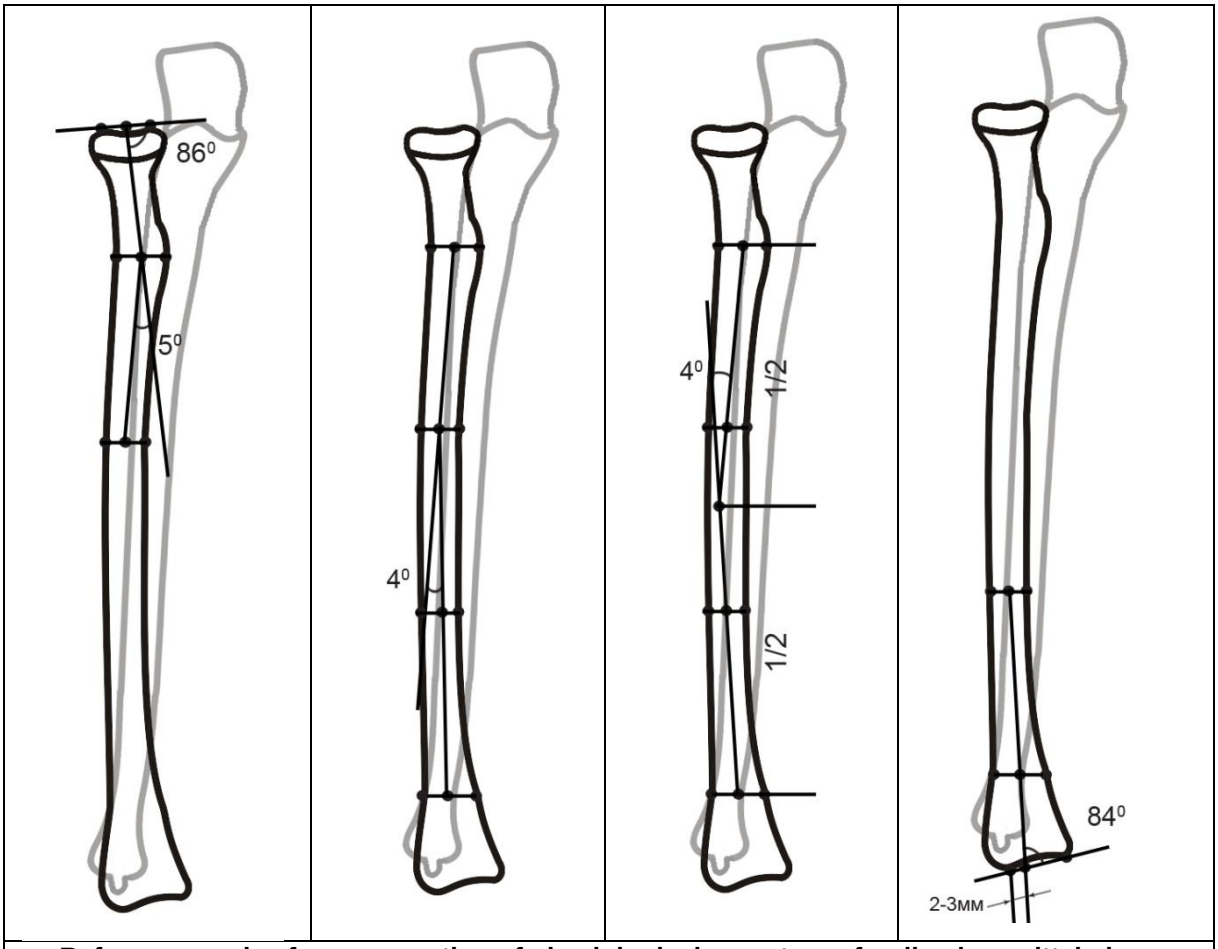


Reference angles for preservation of physiological curvature of ulna in frontal plane

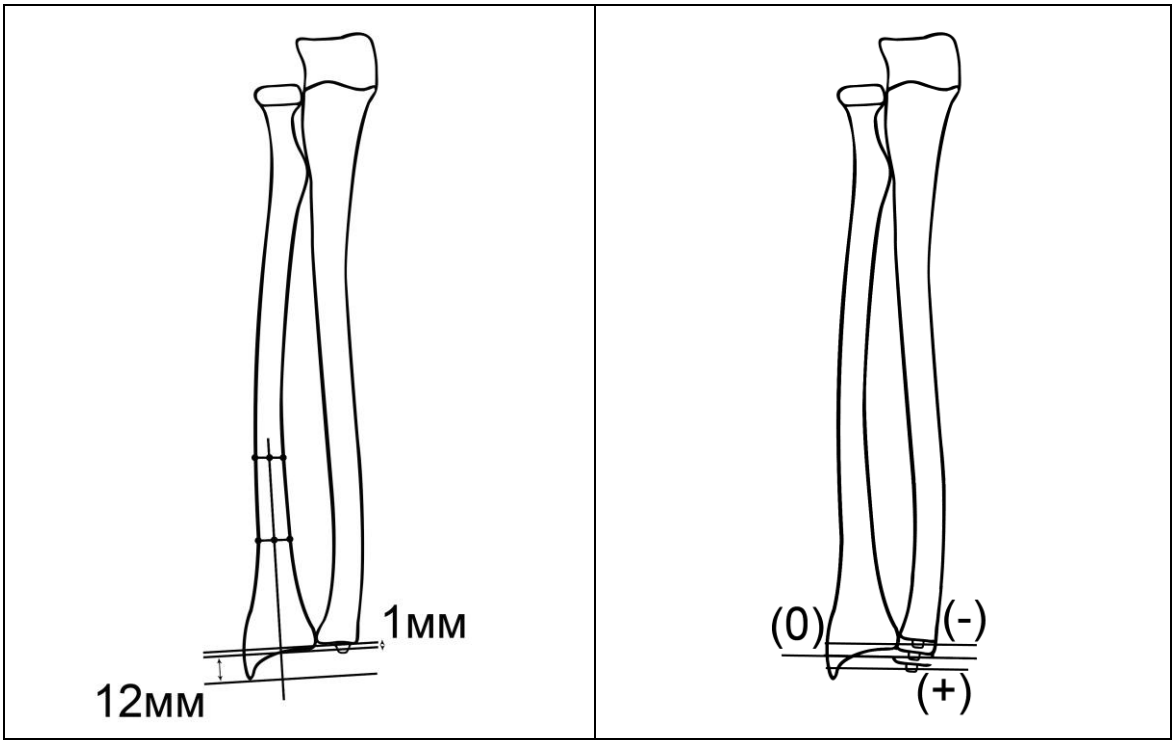
Reference angles for preservation of physiological curvature of ulna in sagittal plane



Reference angles for preservation of physiological curvature of radius in frontal plane



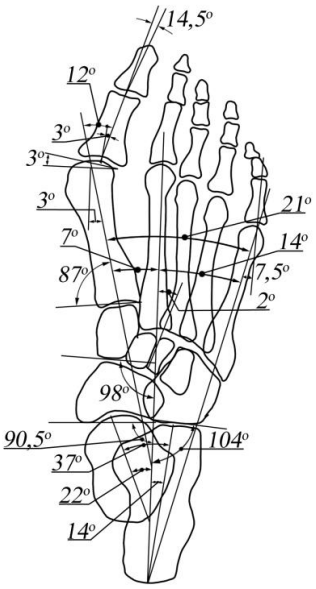
Reference angles for preservation of physiological curvature of radius in sagittal plane

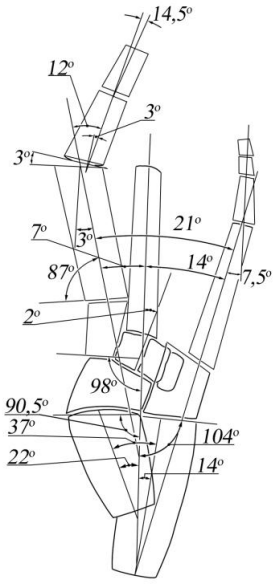


Variants of levels of joints of radial and elbow bones location
(Ashkenazi A.I., 1990)

Reference Lines and Angles of the Foot

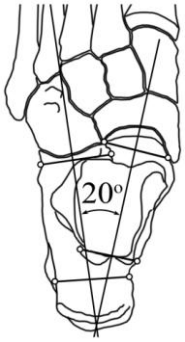
Frontal Plane





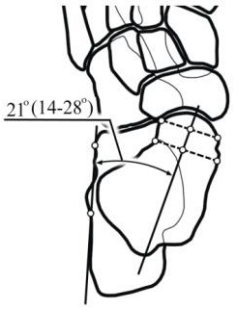
Basic reference lines and the angle of the foot in frontal plane

Kirienko A., unpublished results



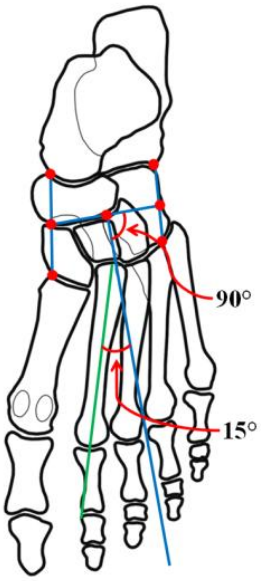
The angle between two axes of the talus and calcaneus

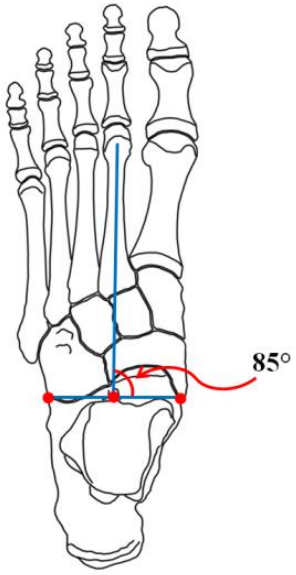
Marx V.O., 1978



The angle between the axis of the talar body and the line along the lateral surface of the calcaneus

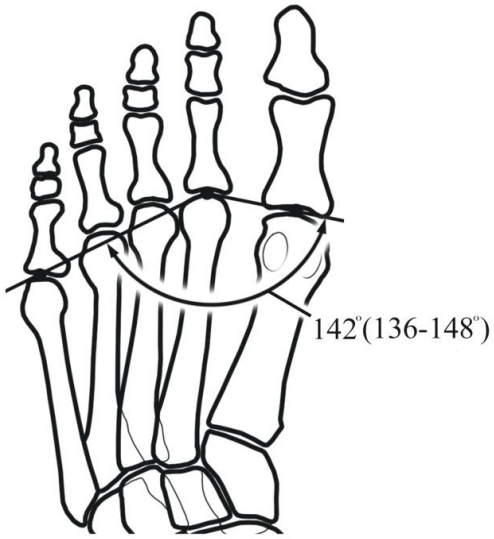
similarly to Sinai Hospital of Baltimore, 2010



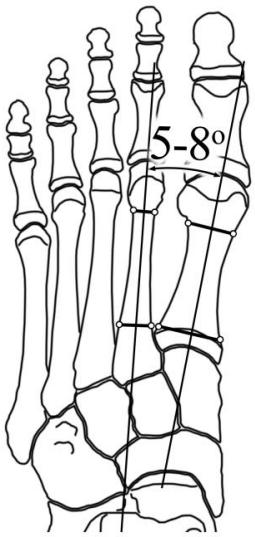


The relationship between the midfoot and hindfoot

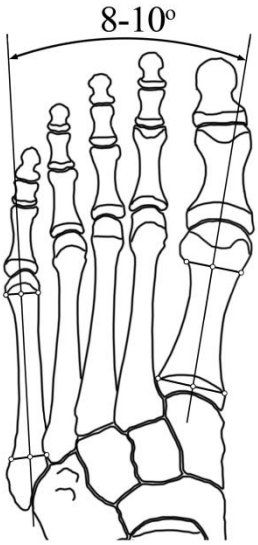
similarly to Lamm B. et al., 2016



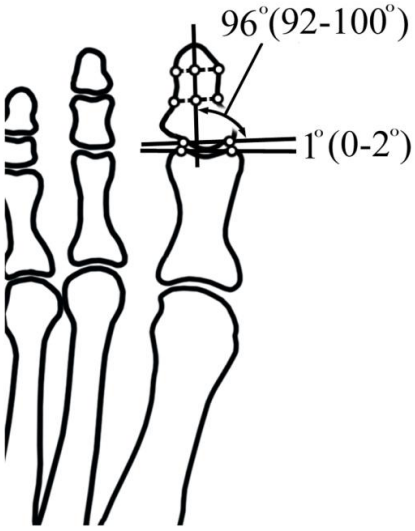
Metatarsal parabola angle
similarly to Sinai Hospital of Baltimore, 2010



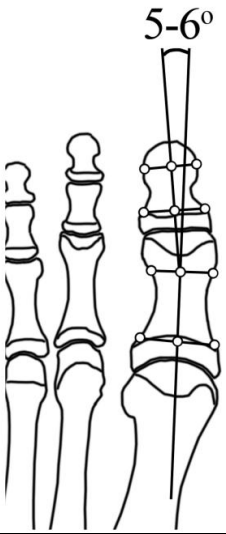
The angle between the first and the second metatarsal bones Kardanov A.A., et al., 2007



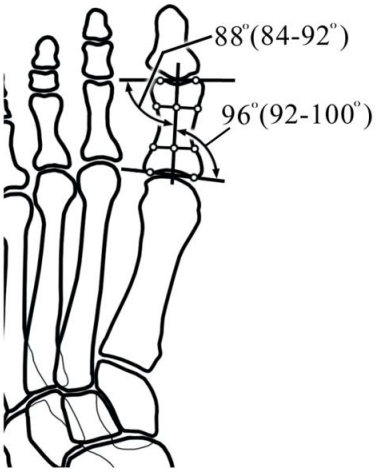
The angle between the axes of the first and the fifth metatarsal bones
Kardanov A.A., et al., 2007



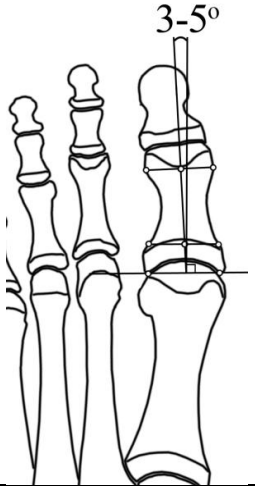
Joint line convergence angle of the first proximal interphalangeal angle. Anatomical proximal medial angle of the first phalanx
similarly to Sinai Hospital of Baltimore, 2010



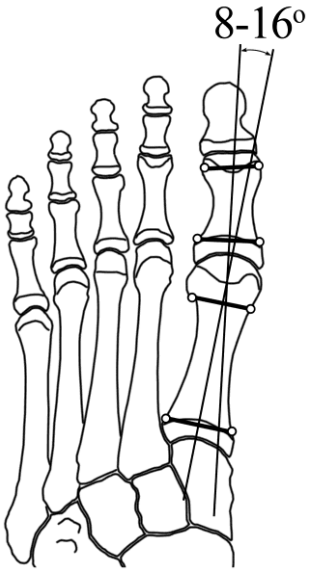
The firtst interphalangeal valgus angle
Kardanov A.A., et al., 2007



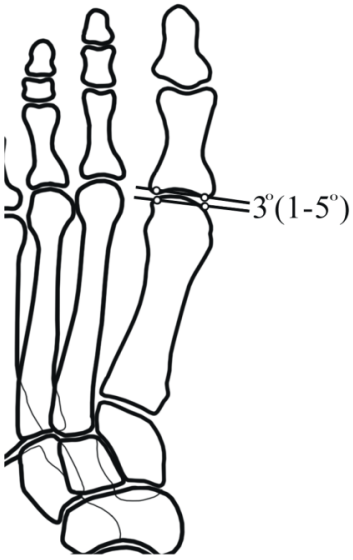
Anatomical proximal medial angle of the first phalanx. Anatomical distal lateral angle
similarly to Sinai Hospital of Baltimore, 2010



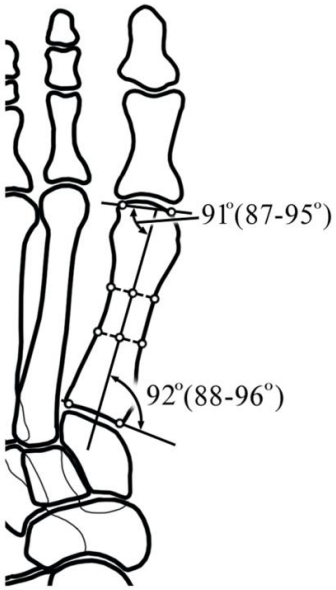
The angle between the anatomical axis of the first proximal phalanx and the line which is perpendicular to the first metatarsophalangeal articular surface Kardanov A.A., et al., 2007



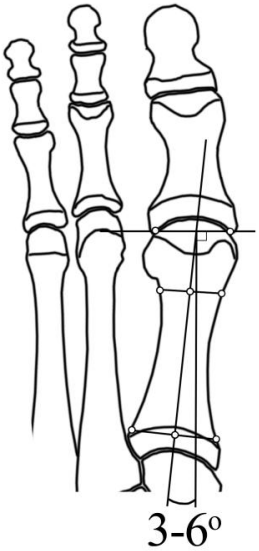
The first metatarsophalangeal valgus angle
Kardanov A.A. et al., 2007



Joint line convergence angle of the first metatarsophalangeal joint
Kardanov A.A., et al., 2007

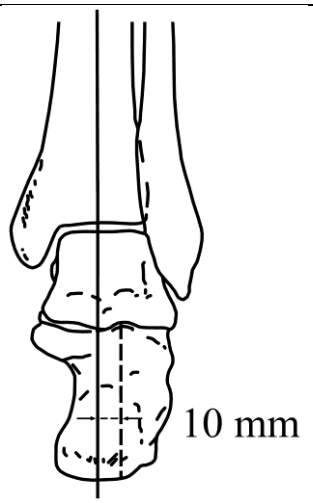


Anatomic proximal medial angle of the first metatarsal bone
similarly to Sinai Hospital of Baltimore, 2010

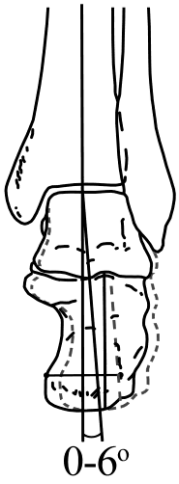


The angle between the anatomical axis of metatarsal bone and the line which is perpendicular to the first metatarsophalangeal articular surface

Kardanov AA, et al, 2007

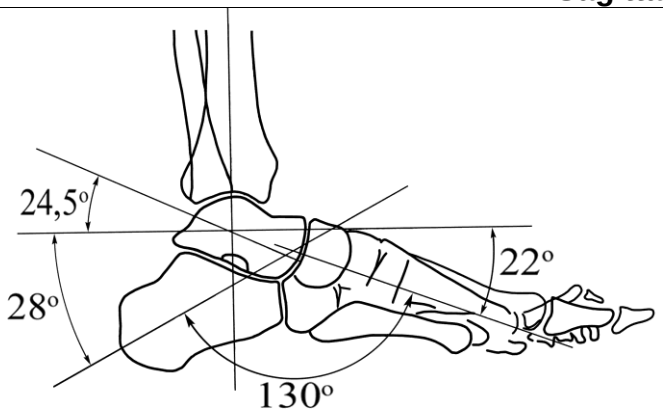


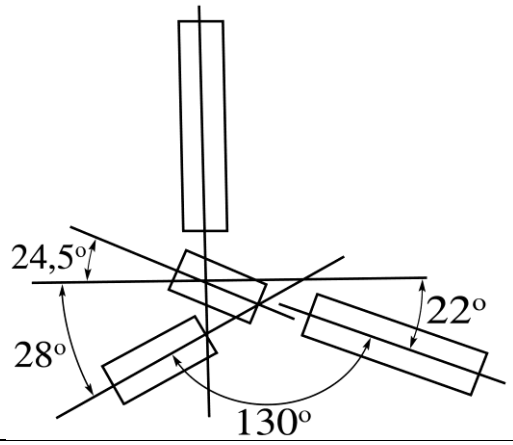
The anatomic axis of the calcaneus
D. Paley, 2002; A. Kirienko et al., 2004



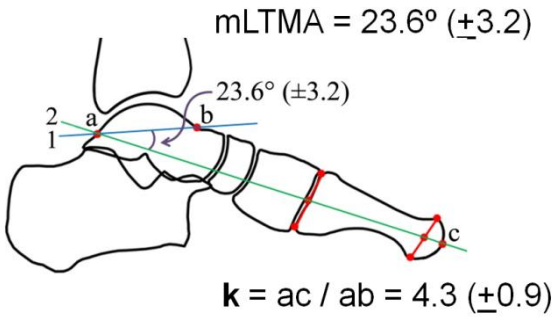
Valgus angle between the two axes of tibia and calcaneus
Marx V.O., 1978

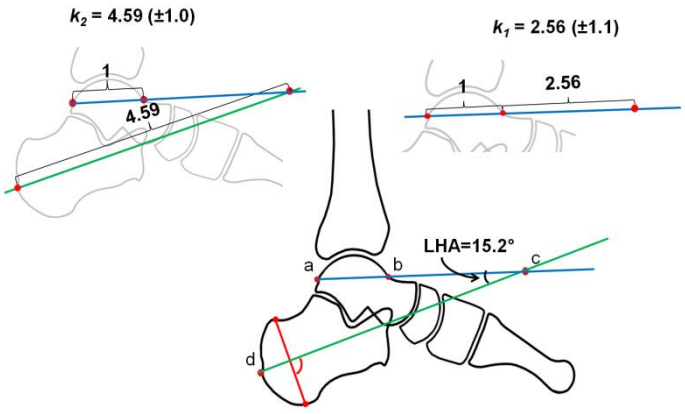
Sagittal Plane



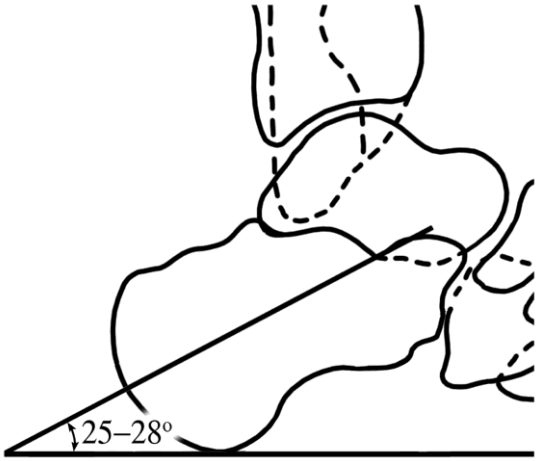


The angle between the longitudinal axis of the calcaneus and the forefoot; the angle between the horizontal plane and the metatarsal/forefoot axis; the hindfoot angle between the horizontal plane and the axis of the heel; the angle between the talar axis and the horizontal plane
Kirienko A. et al., 2004

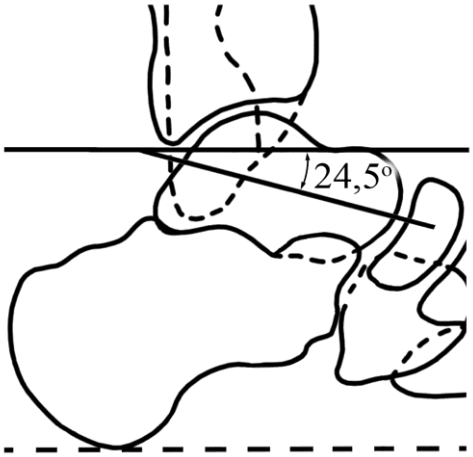




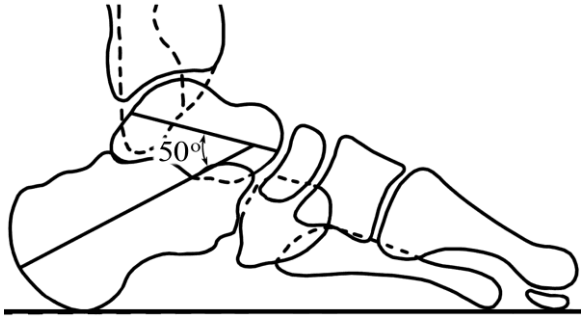
"Integral" RLA of hindfoot and midfoot
Solomin L et al., 2017



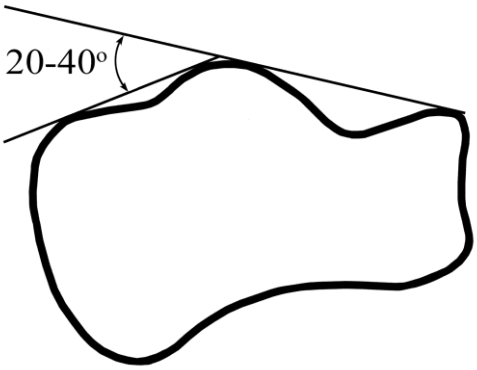
Calcaneal-bearing angle
Marx V.O., 1978; Yaremenko D.A. et al., 2004



The angle between the talar axis and the horizontal plane
Kirienko A. et al., 2004



Talo-calcaneal angle
Yaremenko D.A. et al., 2004



Böhler angle (tuber-joint angle)
Marx V.O., 1978

Recommended literature

1. Горячев, А.Н. Ротационная контрактура у больных с переломами костей предплечья / А.Н. Горячев, А.А. Фоминых, А.Г. Игнатьев // Гений ортопедии. – 2001. – № 2. – С. 97–98.

2. Королюк, И.П. Рентгенанатомический атлас скелета (норма, варианты, ошибки интерпретации) / И.П. Королюк. – М. : Видар, 1996. – 191 с.

3. Котельников, Г.П. Травматология и ортопедия / Г.П. Котельников, С.П. Миронов, В.Ф. Мирошниченко. – М., 2006. – 400 с.

4. Маркс, В.О. Ортопедическая диагностика : руководство для врачей / В.О. Маркс. – Минск : Наука и техника, 1978. – 512 с.

5. Орнштейн, Э.Г. О физико-механических свойствах костей предплечья / Э.Г. Орнштейн, И.Н. Фиглер // Ортопедия, травматология и протезирование. – 1975. – № 10. – С. 45–47.

6. Полилокальный дистракционный остеосинтез при исправлении деформаций нижних конечностей : учебн.-метод. рекомендации / МЗ РФ, РНЦ «ВТО» ; сост. : А.В. Попков, Л.В. Скляр. – Курган, 1997. – 30 с.

7. Скляр, Л.В. Оперативное лечение детей с деформациями нижних конечностей, вызванными рахитом и рахитоподобными заболеваниями : автореф. дис. … д-ра мед. наук / Скляр Л.В. – Курган, 2001. – 22 с.

8. Соломин, Л.Н. Основы чрескостного остеосинтеза аппаратом Г.А. Илизарова / Л.Н. Соломин. – СПб. : МОРСАР АВ, 2005. – 544 с.

9. Ставрев, В. Биомеханические исследования ротационных движений костей предплечья / В. Ставрев, П. Ставрев // VI съезд травматологов и ортопедов России, 9–12 сентября 1997 г. – Нижний Новгород, 1997. – С. 452.

10. Шевцов, В.И. Аппарат Илизарова. Биомеханика / В.И. Шевцов, В.А. Немков, Л.В. Скляр. – Курган : Периодика, 1995. – 165 с.

11.Шевцов, В.И. Лечение больных с переломами плечевой кости и их последствиями методом чрескостного остеосинтеза / В.И. Шевцов [и др.]. – Курган, 1995. – 224 с.

12.Юмашев, Г.С. Травматология и ортопедия / Г.С. Юмашев. – М. : Медицина, 1983. – 576 с.

13. Chao, E.Y. Biomechanics of malalignment / E.Y. Chao, E.V. Neluheni, R.W. Hsu, B. Paley. – Orthop. Clin. Noth. Am. – 1994. – Vol. 25. – P. 379–386.

14. Cook, T.D. Radiographic assessment of bony contributions to knee deformity / T.D. Cook, J. Li, R.A. Scudamore // Orthop. Clin. North. Am. – 1994. – Vol. 25. – P. 387–393.

15. Jung, J. Changes in ulnar variance in relation to forearm rotation and grip / J. Jung [et al.] // J. Bone Joint Surg. – 2001. – Vol. 83-B. – P. 1029–1033.

16.Kapanji, A. Upper limb / A. Kapanji // The physiology of the joints. – Edinburgh : Churchill Livingstone, 1982. – Vol. 1. – 283 p.

17.Kasten, P. Computer simulation of forearm rotation in angular deformities: a new therapeutic approach / P. Kasten, M. Krefft, J. Hesselbach, A.M. Weinberg // Injury. – 2002. – N 33. – P. 807–813.

18. Morrey, B. Instructional course lectures, the American Academy of Orthopaedic Surgeons – complex instability of the elbow / B. Morrey // J. Bone Joint Surg. – 1997. – N 79-A. – P. 460–469.

19.Morrey, B. The elbow and its disorders / B. Morrey. – Philadelphia, 2000. – 880 p.

20. Paley, D. Principles of deformity correction / D. Paley. – N.-Y. : Springer-Verlag, 2005. – 806 p.

21. Palmer, A.K. Biomechanics of the distal radioulnar joint / A.K. Palmer, F.W. Werner // Clin. Orthop. – 1984. – N 187. – P. 26–35.

22. Prokop, M. Spiral and multislice computed tomography of the body / M. Prokop, M. Galanski. – N.-Y. : Georg Thieme Verlag, 2003. – 710 p.

23. Schuind, F.A. A normal data base of posteroanterior roentgenographic measurements of the wrist / F.A. Schuind, R.L. Linscheid, K.N. An, E.Y. Chao // J. Bone Joint Surg. – 1992. – Vol. 74-A. – P. 1418–1429.

24. Solomin, L. The basic principles of external fixation using the Ilizarov device. / L. Solomin. – Milan : Springer-Verlag, 2008. – 358 p.

25. Solomin L.N, Ukhanov K.A, Boychenko A.V, Herzenberg J.E. Midfoot sagittal plane deformity analysis and correction planning. Vestnik Khirurgii after I.I.Grekov. 2017; Vol 176 (5): 59-63. (in Russ.)

26. Solomin L.N., Ukhanov K.A., Sorokin E.P., Herzenberg J.E. Analysis and Planning of Hindfoot Deformity Correction in Sagittal Plane. Traumatology and Orthopedics of Russia. 2017;23 (1):23-32. (in Russ.) DOI:10.21823/2311-2905-2017-23-1-23-32

27. Strecker, W. Computerised tomography measurement of torsion angle of the lower extremities / W. Strecker, M. Franzreb, T. Pfeifer // Unfallchirurg. – 1994. – Vol. 97. – P. 609–613.

28. Strecker, W. Length and torsion of the lower limb / W. Strecker, P. Leppler, F. Gebhard, L. Kinzl. // J. Bone Joint Surg. – 1997. – Vol. 79-B. – P. 1019–1023.

29. Yasutomi, T. Mechanism of limitation of pronation/supination of the forearm in geometric models of deformities of the forearm bones / T. Yasutomi, Y. Nakatsuchi, H. Koike, S. Uchiyama // Clin. Biomechanics. – 2002. – Vol. 17. – P. 456–463.