The 21th Prague-Lublin-Sydney Symposium, Humpolec, September 3-5, 2019

Orthopaedic anthropology

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J. Hyánek, M. Kuklík, K. Kozlowski

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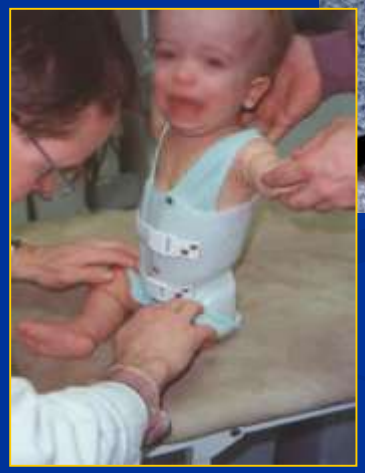
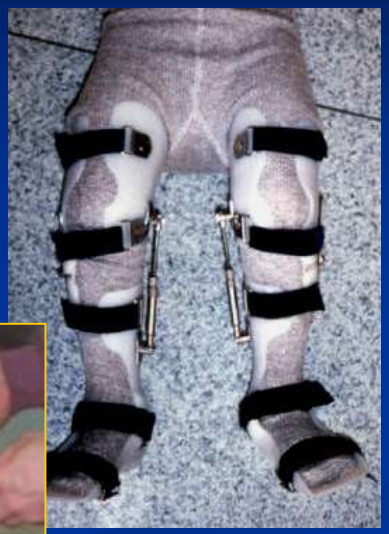
Prague, Czech Republic
Faculty of Health Care Studies, West Bohemia University, Pilsen,
Czech Republic
etc.

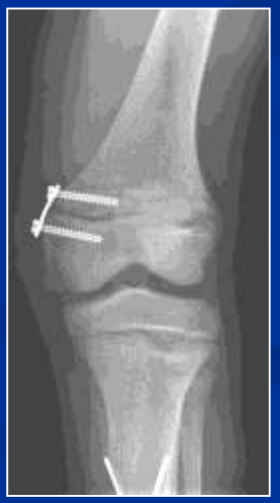
ORTHOPAEDICS AND ANTHROPOLOGY?

- After certification in paediatrics in 1980 …
- Orthopaedic treatment of children with GSD is different from common orthopaedic practice.

From the left Associate Professor Karel Mayer+, professor Stanislav Popelka+, Professor Rudolf Kubát +







ORTHOPAEDICS AND ANTHROPOLOGY?

- I realized that deeper knowledge of **genetic diagnosis**, **biomechanics** and **auxology** is indispensable.
- cooperation with clinical geneticist – M. Kuklík (from 1980)
- anthropologists - J. Brůžek (from 1983), H. Krásničanová, D. Zemková
- pathologist - C. Povýšil
- biomechanics – Z. Sobotka (+ 1995), M. Petrtýl, J. Čulík, F. Maršík
- students of anthropology Š. Petrášová … T. Anýžová, Z. Morvová and students of physiotherapy and biomechanics
- From the start of my orthopaedic praxis I collaborated with hand surgeons - R. Vrabec (+ 1996), V. Smrčka orthopaedic orthotist I. Hadraba (+ 2018) –experienced in paediatric orthopaedics and technical orthotist P. Černý (braces, limb orthoses).

Assoc. Prof. Ivan Hadraba, MD, PhD (+2018)

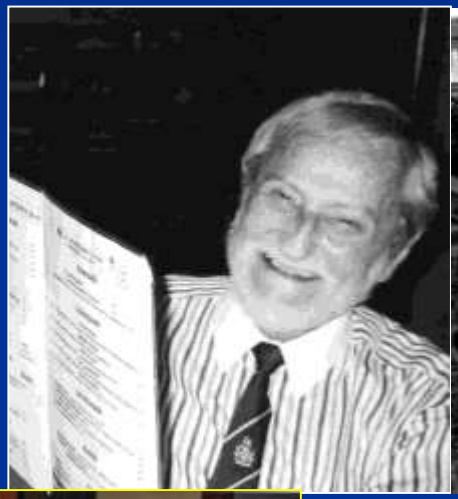
ORTHOPAEDIC ANTHROPOLOGY?

International anthropological congresses of Aleš Hrdlička 1999 and 2003

Professor Tobias (Johannesburg, South Africa) president of „International Anthropological Congress – Anthropology and Society“ (Prague-Humpolec, May 22-24, 2003) assessed the session of the Congress „Comprehensive approach to congenital and acquired deformities of locomotor system” as ORTHOPAEDIC ANTHROPOLOGY

Philip V. Tobias
1925 - 2012

The evolution of Man´s Upright Posture. An essay in Orthopaedic Anthropology. PÚ 10, 2003. No. 1+2, p.7-28



Tobias and
Eugen Strouhal

Tobias and
Kazimierz Kozlowski

BONE / SKELETAL DYSPLASIAS / OSTEOCHONDRODYSPLASIAS (BD, SD, OCHD)

- SKELETAL DYSPLASIAS (SD) are developmental disorders of chondro-osseous tissue.
- Primary SD result from mutated genes that are expressed in chondroosseous tissue.
- Secondary SD are caused by abnormalities of extraosseous factors with secondary effects on skeletal system – metabolic, enzymatic and hormonal disorders.
- Incidence: 0.30 – 0.45 : 1000 live birth

BONE DYSPLASIAS (BD, SD, OCHD)

- symmetrical abnormalities of the whole skeleton
- short disproportional stature
- abnormalities of shape of skull, thorax, vertebral column and extremities
- variously serious malfunction of joints

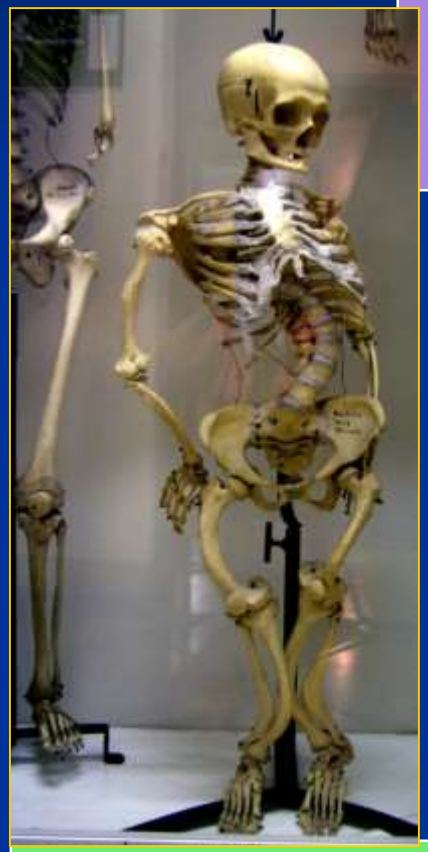
BD, SD, OCHD + DYS

=

GENETIC SKELETAL DISORDERS (GSD)

molecular genetic causes

Abnormal biochemical characteristics of essential bone components: collagen, glykosaminoglycans, hydroxyapatite



CHANGES IN SHAPE AND STRUCTURE OF SKELETON

Functional adaptation of bones (Frost 1995: Utah paradigma of bone physiology)

Hormonal, metabolic & enzymatic disorders

Teratogenic influence in critical sensitive periods of ontogenesis

AIMS of GSD diagnostics

- categorization into nosologic units (genetic diagnosis)
- determination of etiopathogenesis
- investigation of associated congenital developmental defects of remaining systems
- choice of appropriate therapy
- prenatal and presymptomatic diagnostics in affected families

9th version of NOSOLOGY AND CLASSIFICATION OF GENETIC SKELETAL DISORDERS: 2015 REVISION

Bonafe L, Cormier-Daire V, Hall C, Lachman R, Mortier G, Mundlos S, Nishimura G, Sangiorgi L, Savarirayan R, Sillence D, Spranger J, Superti-Furga A, Warman M, Unger

Med Genet Part A 9999A:1–24.

436 conditions were included in 42 groups

defined by molecular, biochemical and/or radiographic criteria.

Nosology is still a hybrid between a list of clinically defined disorders, waiting for molecular clarification, and an annotated data base documenting the phenotypic spectrum produced by mutations in a given gene.

GENETIC SKELETAL DISORDERS

- **Clinical experience** contributes to understanding of mechanisms of growth and to creation of a comprehensive view to skeletal growth focused on chondrocyte.

- **PATHOBIOMECHANICS** is focused on changes of geometric and mechanical properties of the skeleton and structural configuration of bone tissue due to **functional adaptation** and abnormal biochemical characteristics of basic components **of connective tissues** on the basis of molecular genetic influences. Deformities of the skeleton develop along with general growth and development of the organism - prevailingly in a way which is specific to given diagnosis.

DIAGNOSTICS of GSD

Cooperation with Professor Kazimierz Kozlowski, M.R.A.C.R. (Westmead NSW 2145, Sydney) from beginning of 90th yrs. of 20th

- During 25 years of existence of the Centre for Defects of Locomotor Apparatus in Prague we diagnosed about

  120 nosologic units in a group of more than 700 patients.

- For most of these patients **comprehensive treatment** was and is carried out.

Diagnostic achievements

- Spondyloepiphyseal dysplasia (SED) with metatarsal shortening (formerly Czech dysplasia)

HOORNAERT KP, MARIK I, KOZLOWSKI K, COLE T, LE MERRER M, LEROY JG, COUCKE P, SILLENCE D, MORTIER GR. (2007). Czech dysplasia metatarsal type: another type II collagen disorder. Eur J Hum Genet, 15, 12, p. 1269-1275**.**

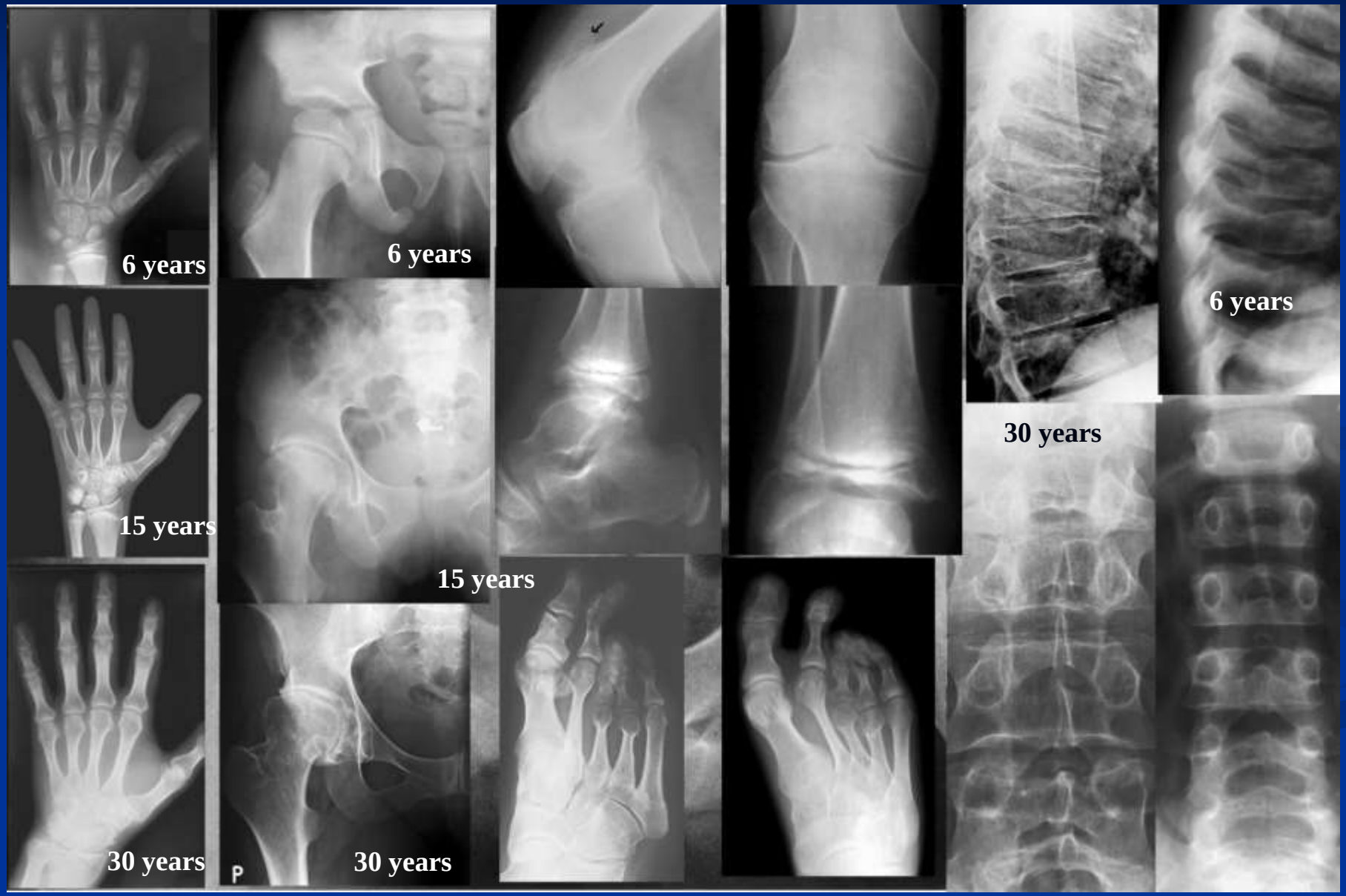
- Severe mesomelic dysplasia with inreased neck translucency and tetralogy of Fallot in one and cystic hygroma in the other

VSETIČKA J, GATTNAROVA Z, MARIK I, KOZLOWSKI K. (2010). Am J Med Genet – Part A, 152A, 4, p. 815-818.

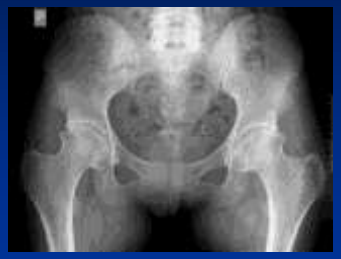
- Spondylometaphyseal dysplasia type A4 - a new form or a variant

MARIK I, HUDAKOVA O, PETRASOVA S, KUSZEL L, CZARNY-RATAJCZAK M, KOZLOWSKI K. (2012). J Appl Genetics 53: p.289–294.

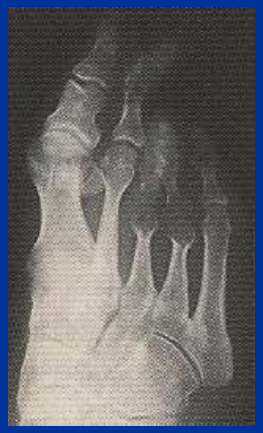
2. Type 2 collagen group: SED with metatarsal shortening (formerly Czech Dysplasia)

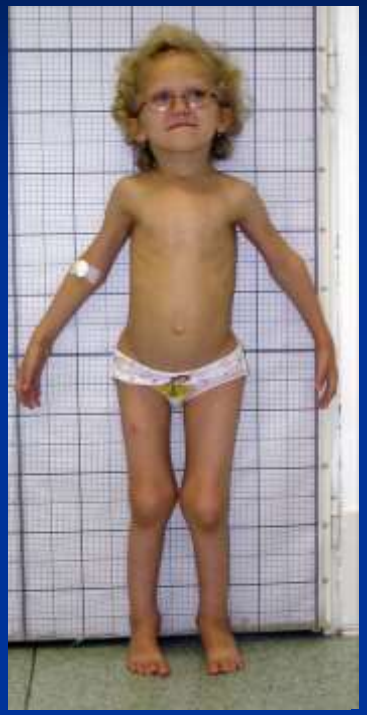


Broad spectrum of clinical manifestation of mutations *in Col2 A1* gene

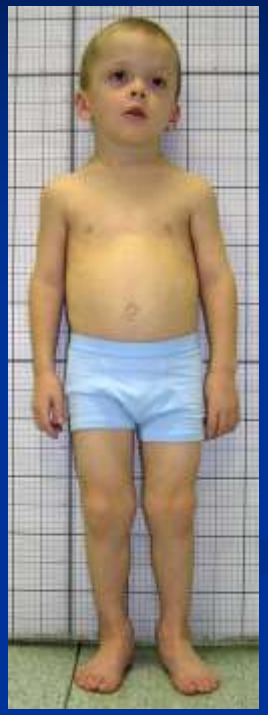


Arg275Cys





Kniest dysplasia



Stickler syndrome
(also *Col 9 a Col 11)*

SED congenita

Achondroge-
nesis - lethal

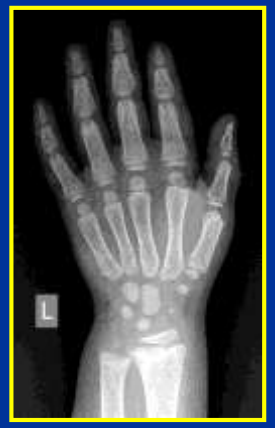
Spondyloepiphyseal dysplasia with short metatarsals („Czech dysplasia“)

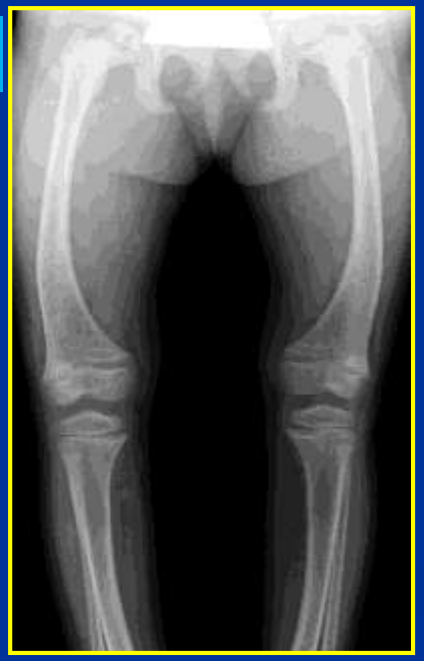
Familial short stature with/without joint envolvement

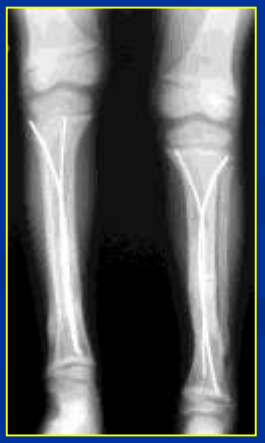
TREATMENT

- ✓ **Accent on COMPREHENSIVE TREATMENT**
- **Orthotic** treatment & Physiotherapy
- **Medicamentous** & Physiotherapy
- Follow-up of biochemical markers
- **Surgical** & Orthotic treatment & Physiotherapy

Hypophosphatemic Rickets



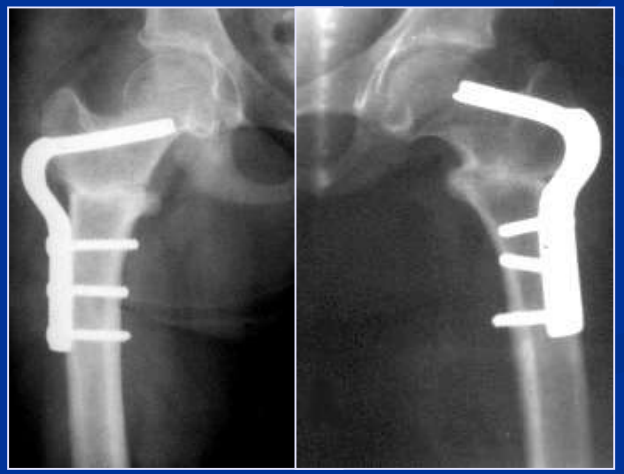
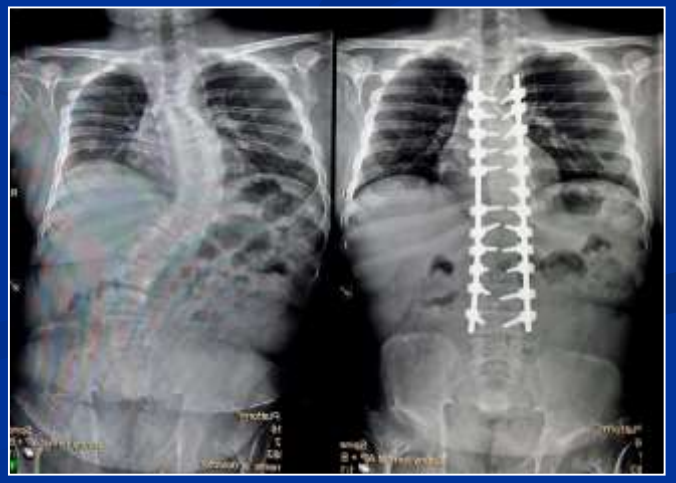




AIMS of SURGICAL TREATMENT

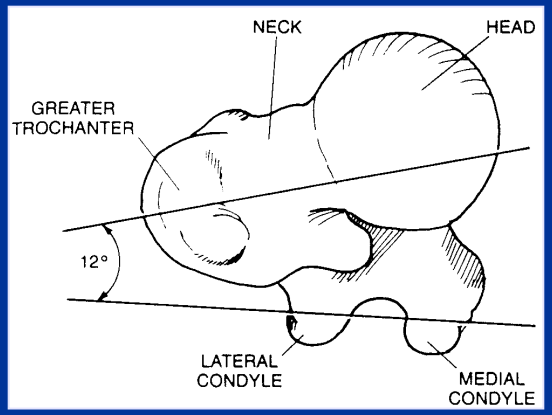
- 3D correction of long bone deformities and shortenings (corrective and multiple osteotomies, epiphysiodesis – total or partial)
- prolongation of long bones
- surgery of hip and knee joints
- reconstruction of hand and foot defects
- correction of spine deformities

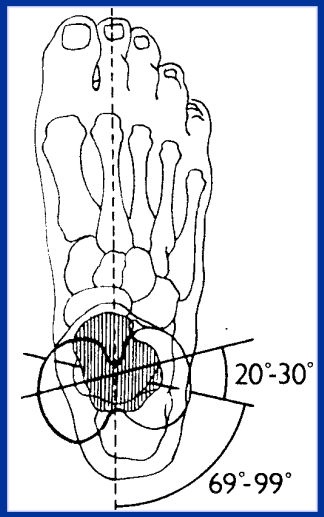


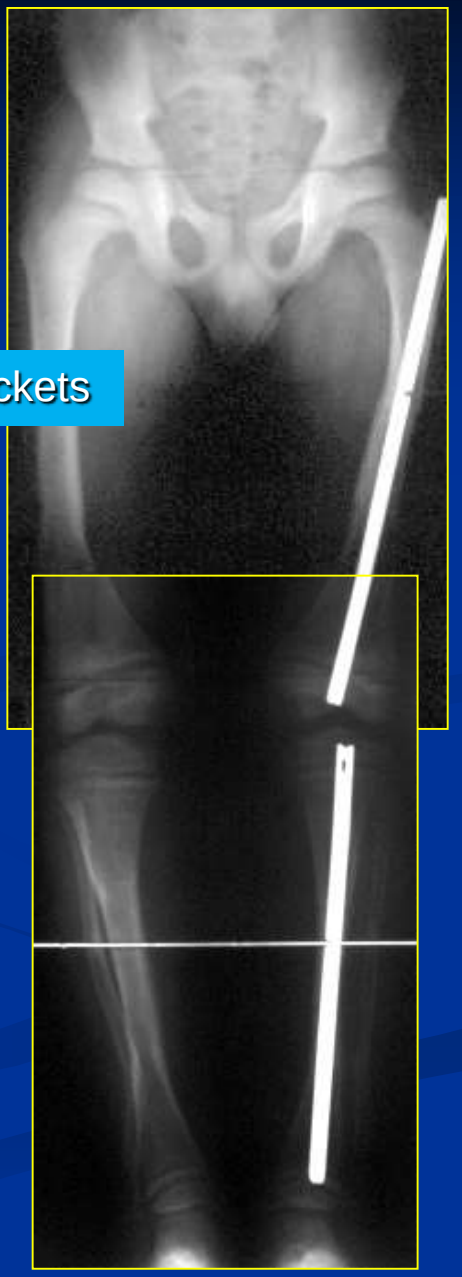
TREATMENT

- **Surgical 3D correction** of leg deformities in one session because of malposion of big leg joints: **Hypophosphatemic rickets** (HR), Osteogenesis imperfecta (OI), bone dysplasias (BD)



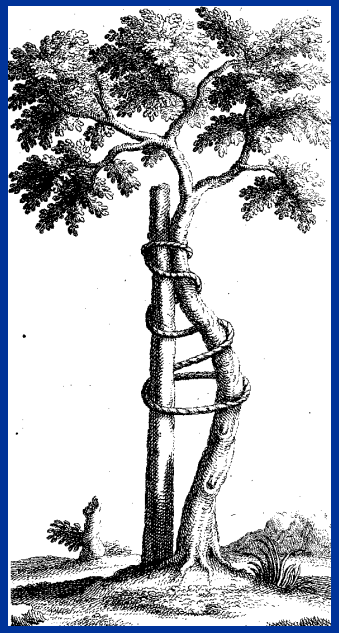


Hypophosphatemic Rickets



AIMS of ORTHOTIC FITTINGS & PHYSIOTHERAPY

- 2D correction of long bone deformities
- 2D correction of joint contractures
- 3D correction of spine deformities
- 3 points principle acting on growth plates (extremities, spine)
- Delpech-Wolf (1828) and/or Hutter-Volkmann law (1973)



orthosis
N. Andry 1658 - 1742

brace
Jacques Cheneau

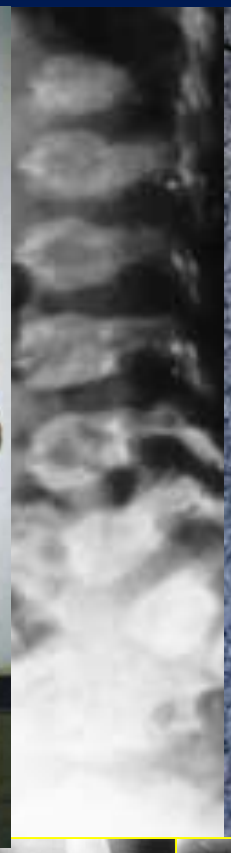
Functional adaptation of bones

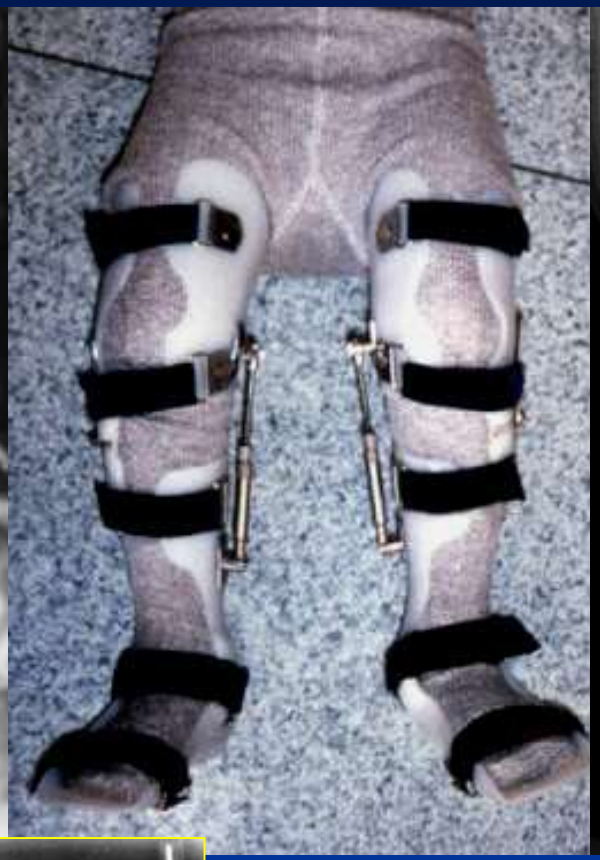
Assoc. Professor
Eng. Zdeněk Sobotka, DSc
1926 – 1998

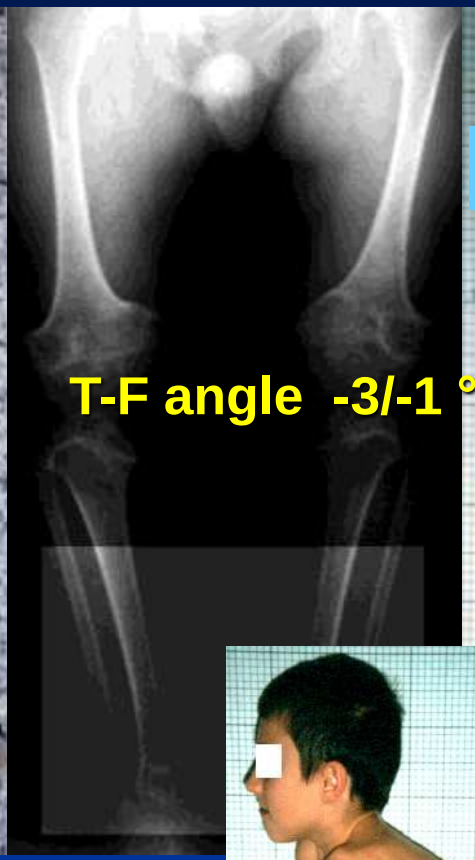
Sobotka and Mařík (Pohybové ústrojí 2, 1995, No.1, p. 15-24) arrived to **Deformational-rheological theory of bone remodelling**.

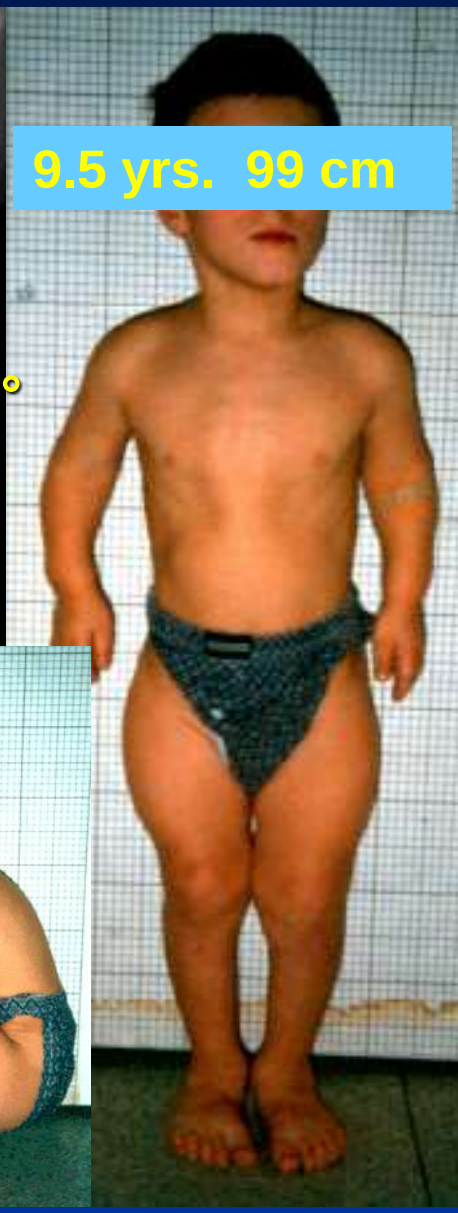
- According to this theory, the remodelling of bone tissue depends on its time-varying straining represented by extensions and shortenings. Because of the viscoelastic properties of bones (bone tissue contains collagen fibres, proteoglycans and fluids in skeleton), the strains vary not only at varying loading but the **strain changes continue and fade** as elastic after-effects at constant loads and after unloading – in rest, in sleep. The intensity of remodelling is then time-dependent and depends on the amount, changes and duration of straining.
- **By this theory we can explain and understand efficiency of orthotic treatment in the night regime or effectiveness of physiotherapy on remodelling of locomotion system.**

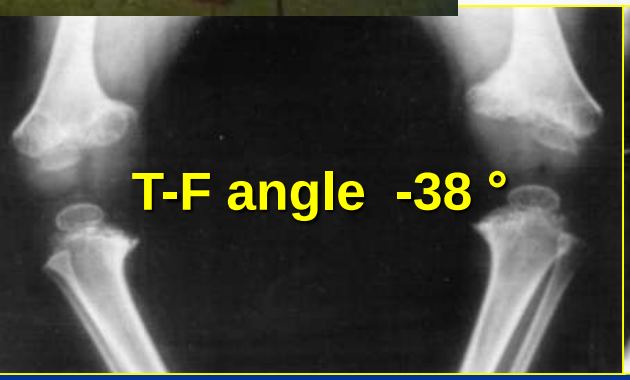
8. MED & PSACH group: PSEUDOACHONDROPLASIA

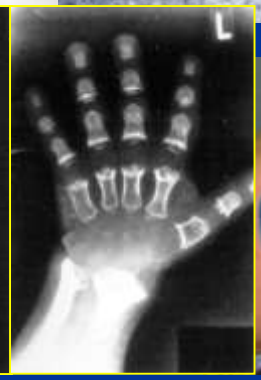


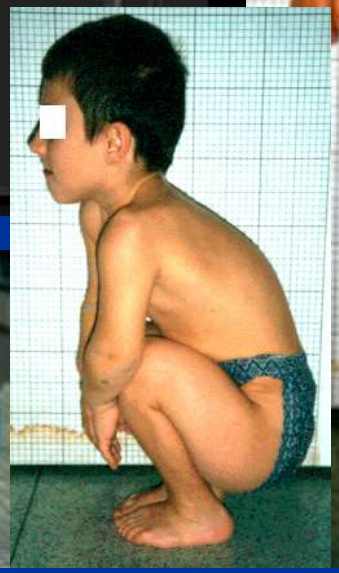










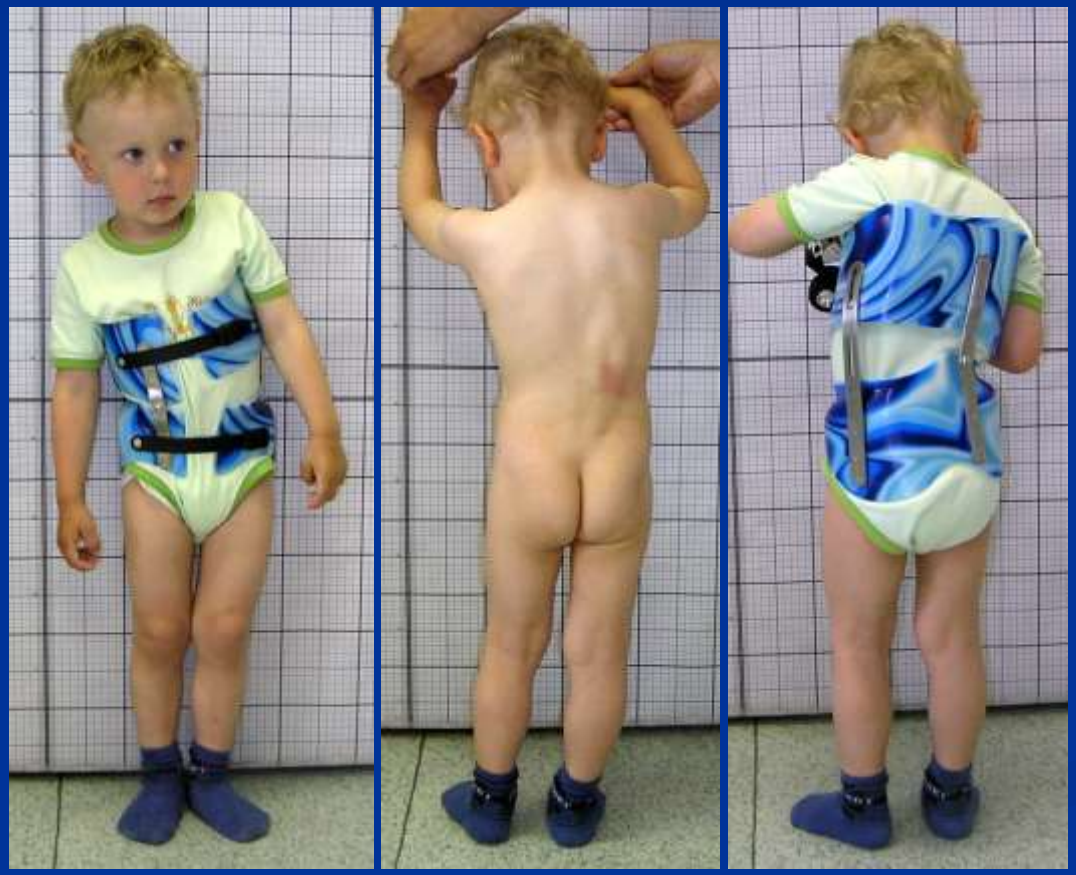


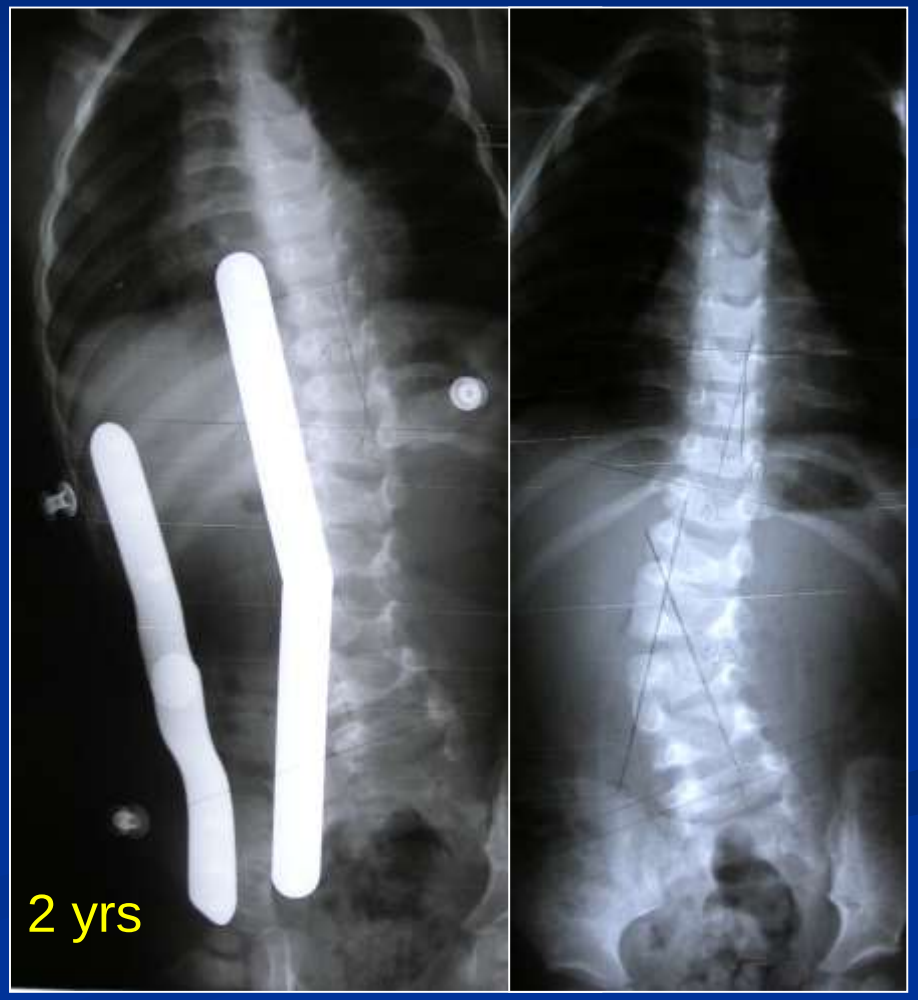
HEMIVERTEBRA L1 & L3 ON THE RIGHT SIDE

The special brace with regulated bending (prestressing)

After 12 months of bracing correction of Cobb´s angle on 12 °

2 yrs





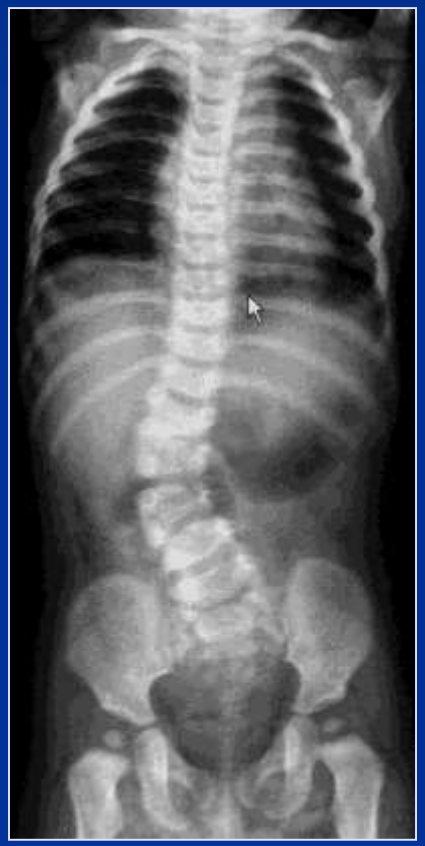
1 year T12 - 33°dx - L7

HEMIVERTEBRA L1 & L3 ON THE RIGHT SIDE

Two special braces with bending effect (prestressing)

After 10yrs. of bracing 15°correction of Cobb´s angle

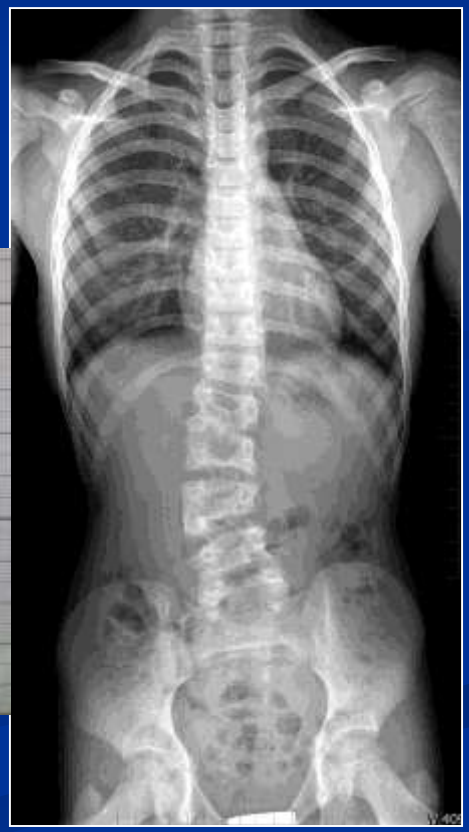
Bone remodeling laws are true for physeal growth of congenital wedge and hemiwedge vertebrae, too.



1 year T12 - **33°dx** - L7

11 yrs. T12 - 8°dx - L7

11 yrs.



11 yrs. T12 - **18°dx** - L7

25. OSTEOGENEIS IMPERFECTA

- one of the most severe disorders of connective tissue

On the basis of genetic origin are distinguished ***collagenous forms*** – mutations of *COL1A1* or *COL1A2* genes which encode collagen type I protein
and ***non-collagenous forms*** - result from mutations of genes which affect the collagen processing and production

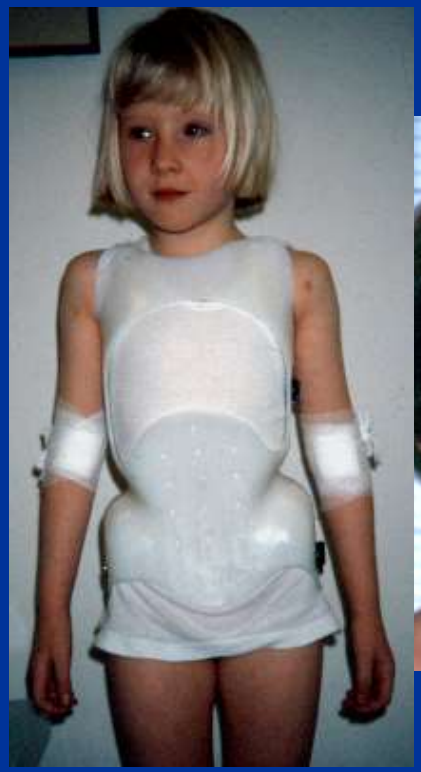
From clinical point of view there are distinguished
- non-deforming types - lower amount of collagen I
- deforming types - altered structure of collagen I

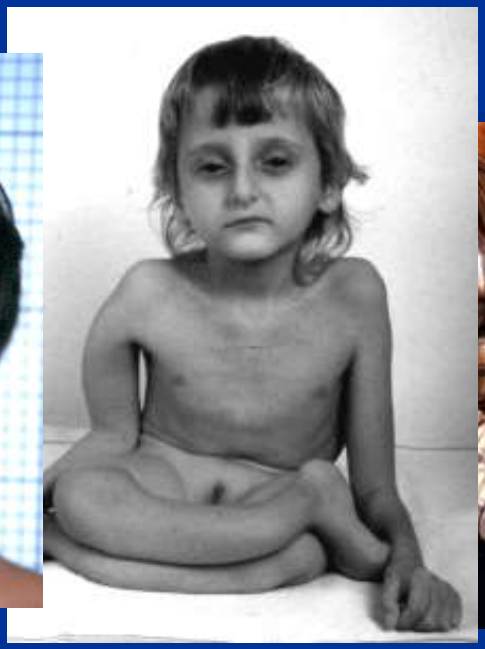
- Similar approach to surgery of long bones deformities as in HR
- Medicamentous therapy: Calcitonine (1980) bisphosphonates (1990), calcium, vitamine D, etc.

25. OSTEOGENESIS IMPERFECTA

Clinical picture:

Variable; repeated fractures and deformities of long bones, thorax, spine
Hypermobility of joints, hyperlaxicity
Blue sclerae, dentinogenesis imperfecta (DI), hearing loss
Cardiovascular and hematologic defects etc.

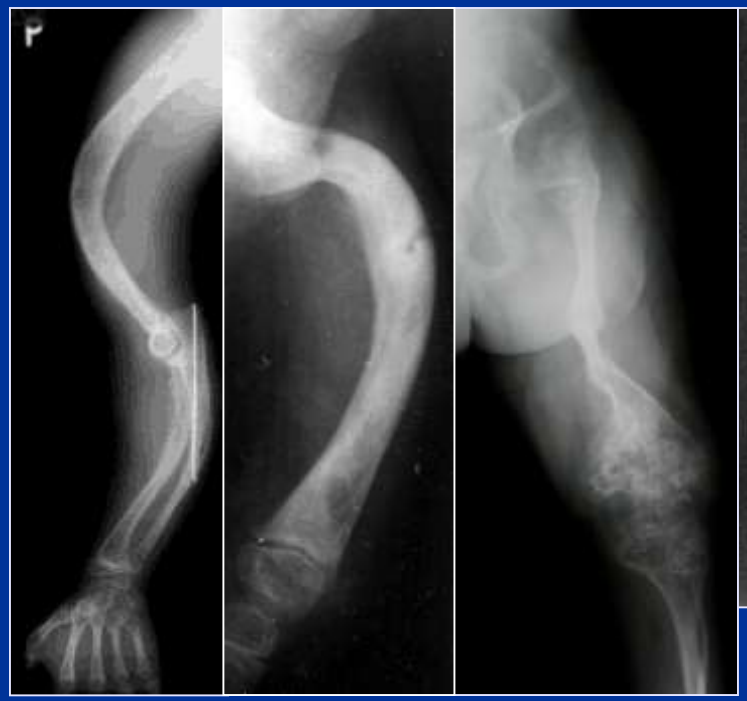


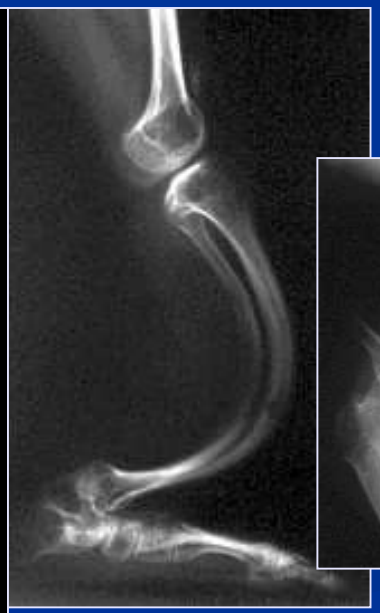


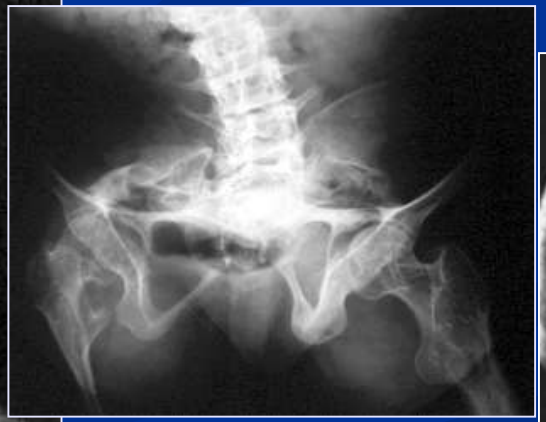
25. OSTEOGENESIS IMPERFECTA

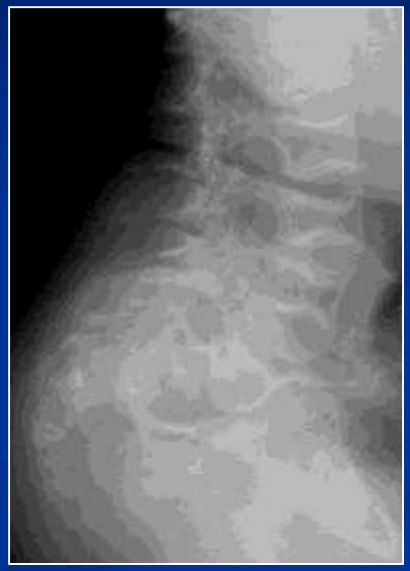
Radiological picture:

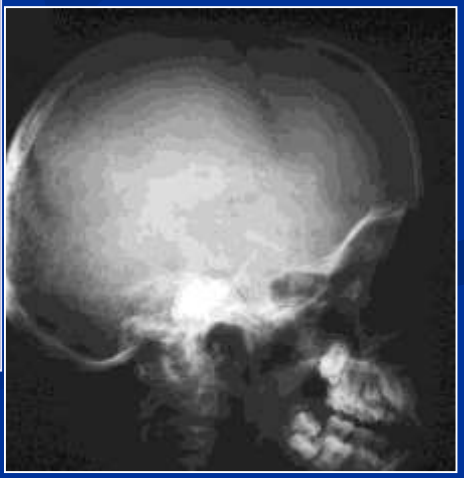
Fractures and deformities of skeleton, narrowing, shifting and disappearing of intramedullary canal of long bones, pseudoarthroses, platyspodyly and "codfish" vertebrae, Wormian bones, protrusio acetabuli – heart shaped pelvis, osteopenia, caput membranaceum, antero-postrior widening of the trunk









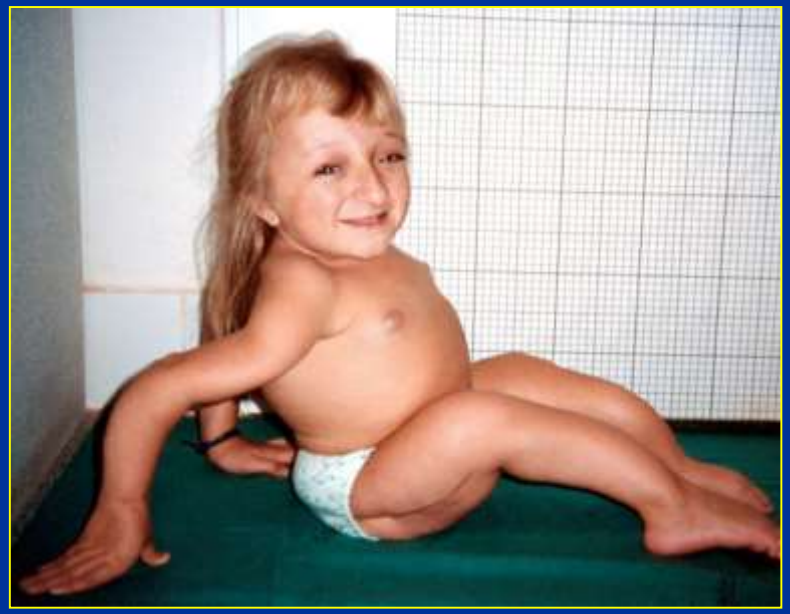


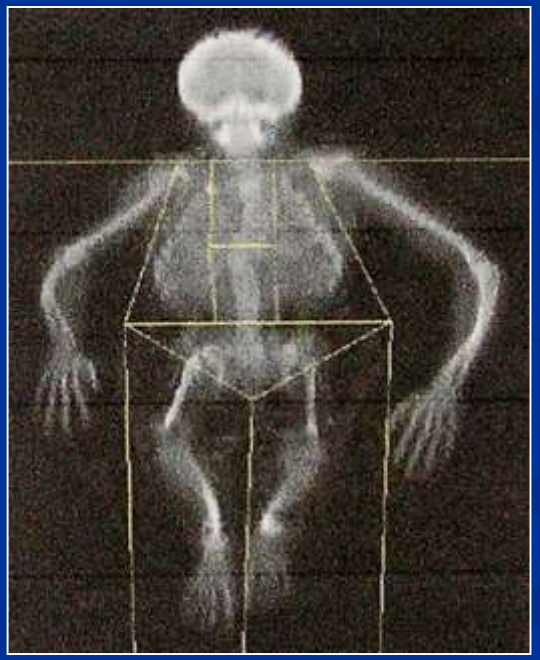
25. OSTEOGENESIS IMPERFECTA

Genotype – phenotype correlation

Hrušková L, Mařík I, Mazurová S, Martásek P, Mazura I. COL1A2 gene analysis in a Czech osteogenesis imperfecta patient: a candidate novel mutation in a patient affected by osteogenesis imperfecta type 3. Advances in Genomics and Genetics. 2015: 5, p. 175-281. ISSN 1179-9870. IF 2,4

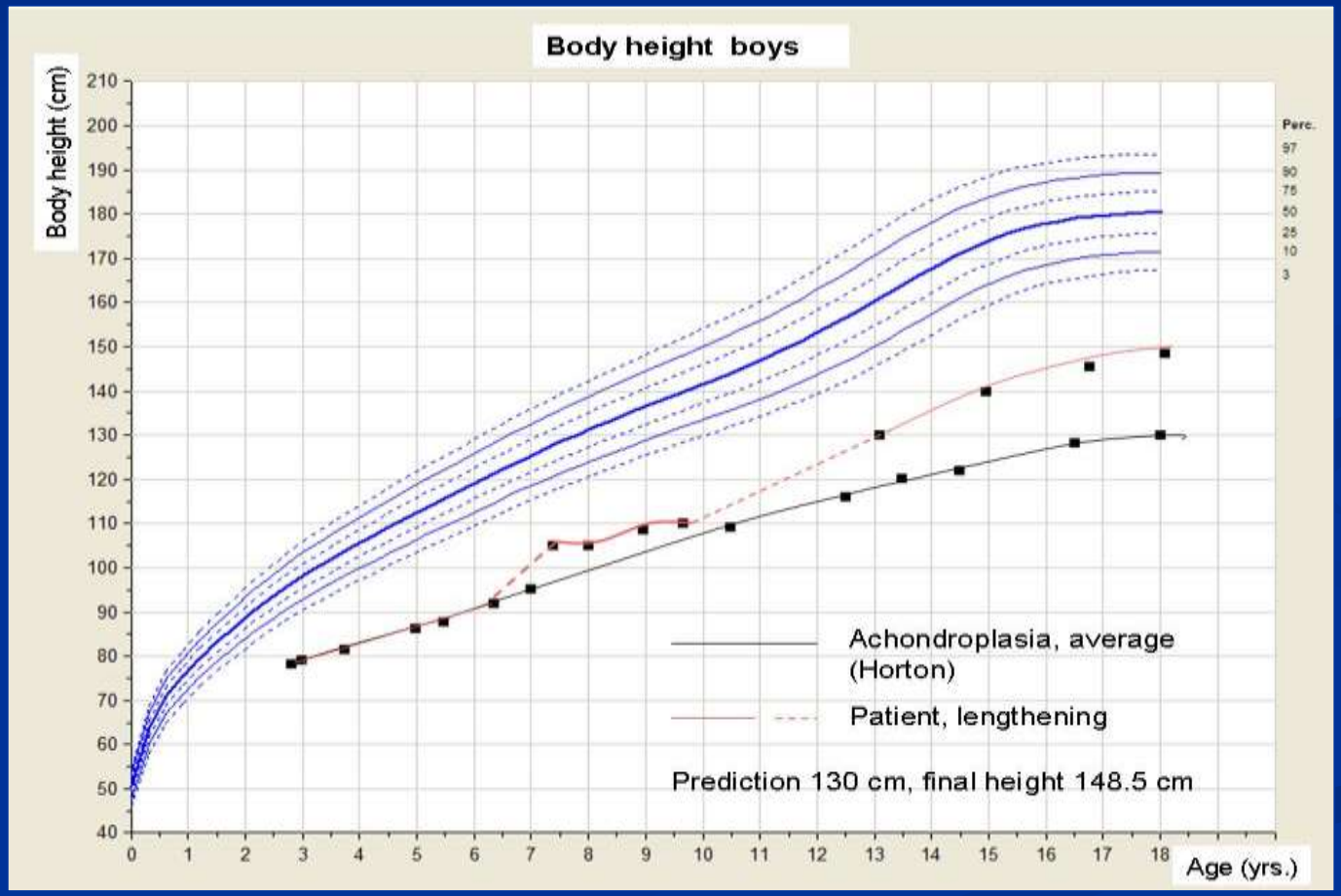
The identified **Gly814Trp mutation** results in functional alteration of the protein.



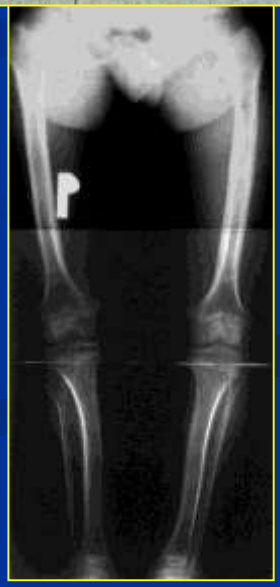


1. FGFR3 group: ACHONDROPLASIA

Most frequent bone dysplasia caused by defect of endochondral ossification due to FGFR3 gene mutation



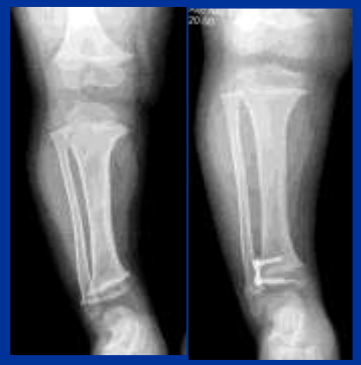
Result of legs prolongation -**18.5 cm**



1. FGFR3 group: ACHONDROPLASIA

Last years we indicate mainly osteotomies or hemi-epiphysiodesis to correct deformities of legs because the **lengthening procedures** are accompanied by many **obstacles** and **complications**.

10 y 7 m



15 y 7 m

Result of tibial corrective OT, drilling epifysiodesis of both distal fibula and 8-plates lateral hemi-epifysiodesis of both distal tibia

Result of heel varus deformity by drilling epifysiodesis of both distal fibula and drilling lateral hemi-epifysiodesis of both distal tibia

11 y 9 m

-8°

-15°

15 y 9 m

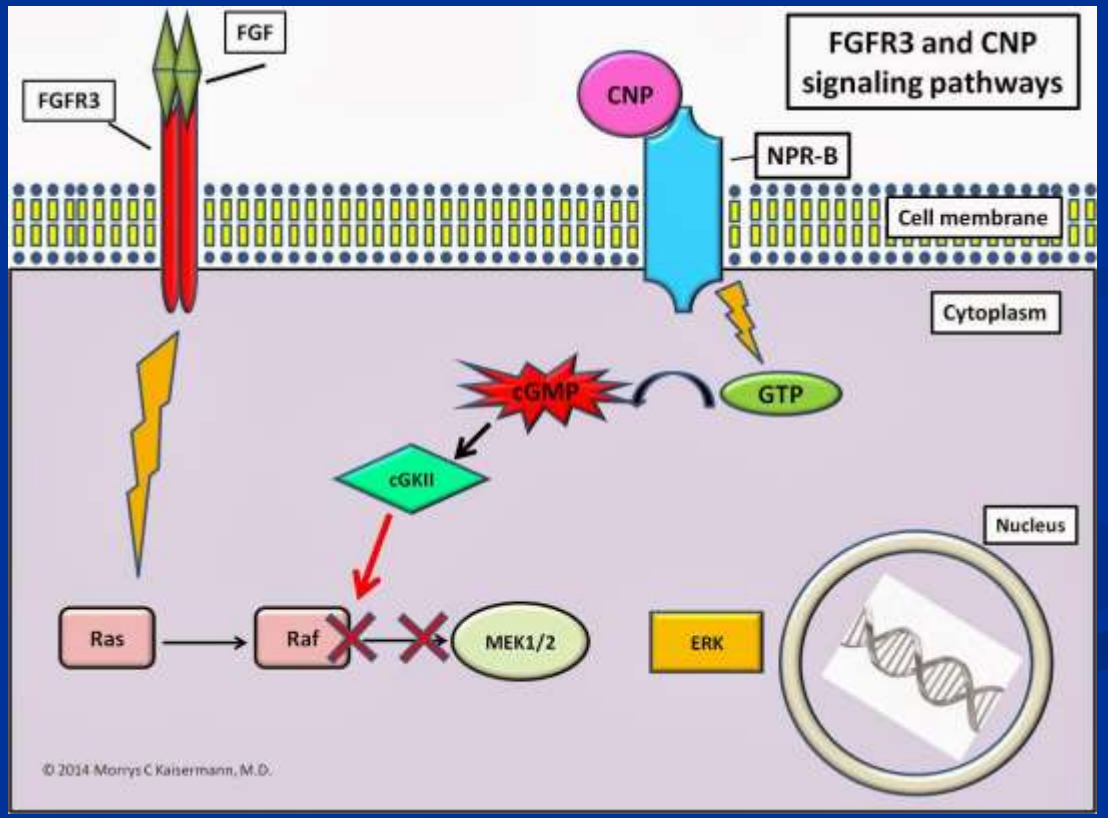
-2°

-2°

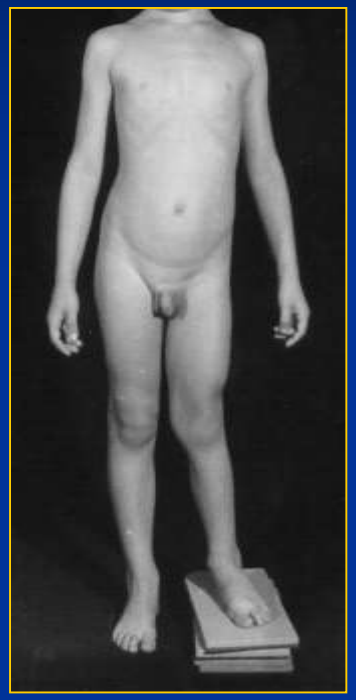
1. FGFR3 group: ACHONDROPLASIA

Molecular research led to understanding of signaling pathways influencing skeletal growth.
New studies suggest that **C-type natriuretic peptide (CNP) analogues** may provide a novel therapeutic approach to growth disorders

FGFR3 mutation slow down endochondral growth. **CNP analogues** brakes consequence of this mutation.



Lower extremity length discrepancies and desaxation



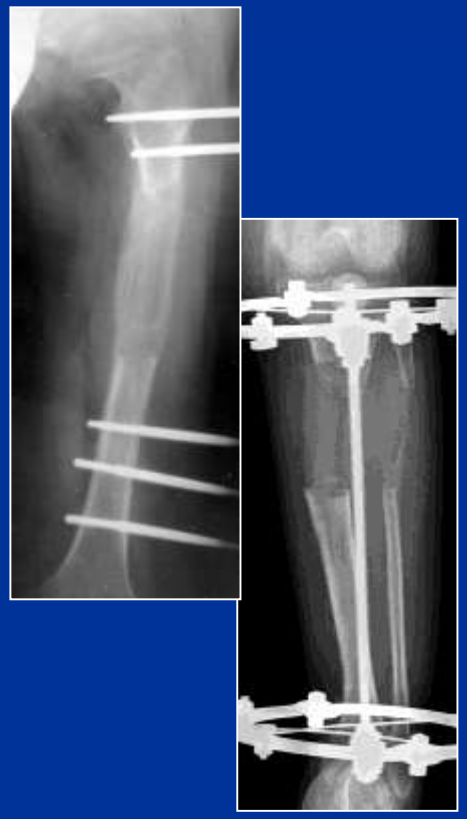
Biomechanical consequences:
Asymmetrical forces at ankle, knee, hip, SI and vertebral joints cause **„chain formation of disorder underneath”**

Leg length discrepancy and **knee desaxation** belongs to most frequent problems solved by paediatric orthopaedic surgeons. Their causes can be as **congenital** limb defects as **acquired** growth defects due to injury of physis, inflammation, thermal burn, frostbitten, irradiation, neurological diseases or iatrogenic (after surgery). etc.

In both congenital and acquired defects, there is effort of physicians to use most effective but minimally invasive intervention.

Lower extremity length discrepancies

On the basis of **leg growth prediction** is possible to indicate the most appropriate orthopaedic treatment



- 1 - 2 cm ? - orthopaedic shoes
- 2 – 6 cm - corrective osteotomy after the completion of the growth
- **2 – 6 cm - epiphysiodesis in the knee region in the final stage of the growth period**
- **5 – 20 cm – lengthening by Ilizarov technique**
- > lengthening combined with epiphysiodesis
- **> 20 cm –** ortho-prosthetic fitting

Lower extremity length discrepancies and desaxation

- **Auxology** is indispensable for **planning**, **timing** of surgical procedrues and **evaluation** of results of comprehensive treatment
- Growth of the skeleton and its parts in relation to **bone age** and **sexual maturation**
- **Remaining growth graphs**

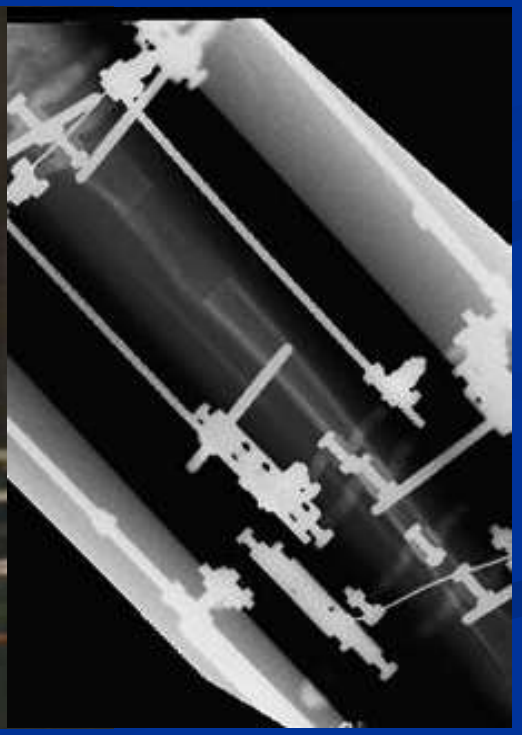
- **Disease specific charts**

Lower extremity length discrepancies and desaxation

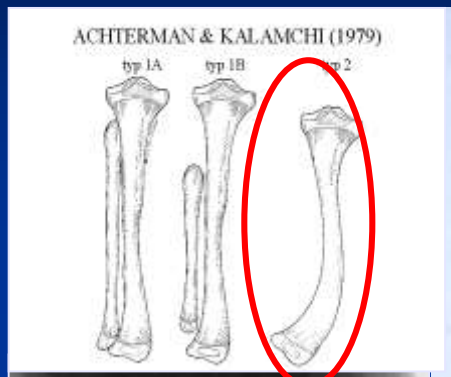
Lengthening procedures spread to western countries of Europe and USA in 80st yrs of last century due to merit of Gavriil Ilizarov from Kurgan, Siberia.

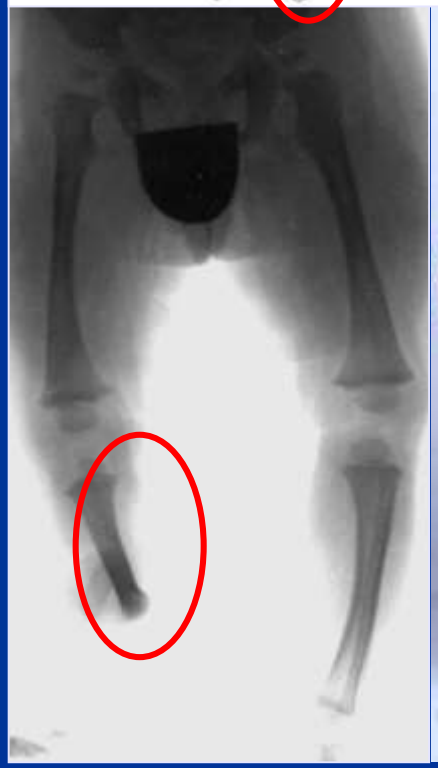
1951 Ilizarov ring fixator

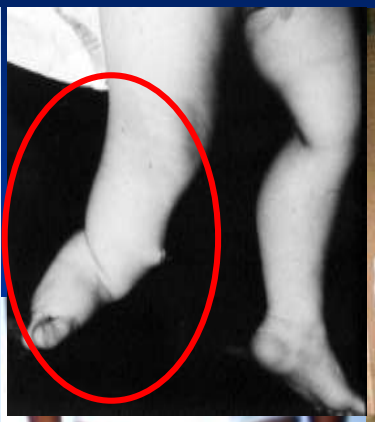
1984 Ilizarov ring fixation frame



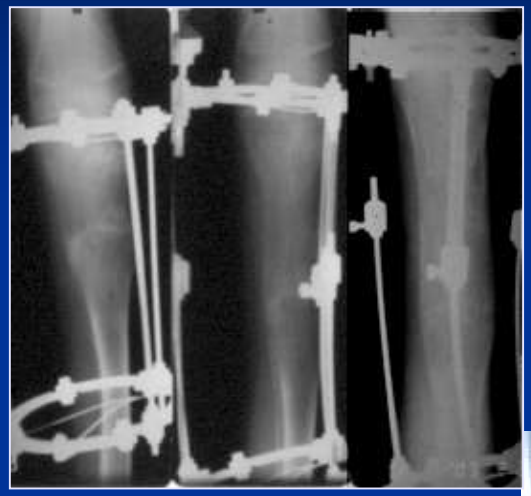
38. Limb hypoplasia-reduction defects group:
FIBULAR HYPOPLASIA SYNDROME

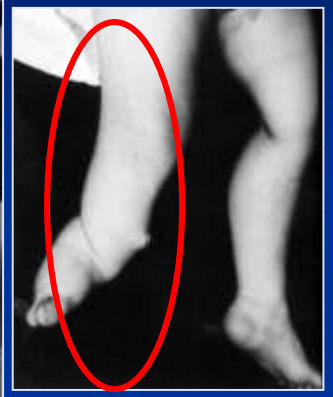


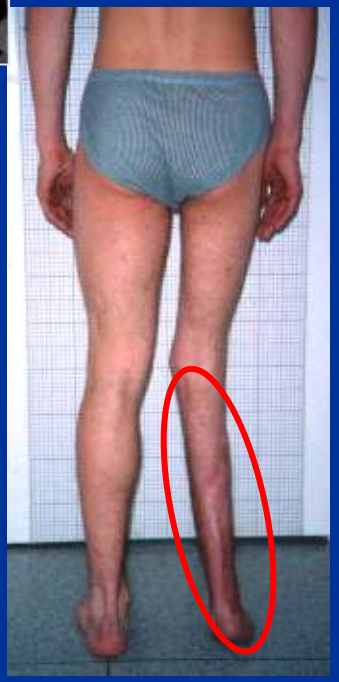


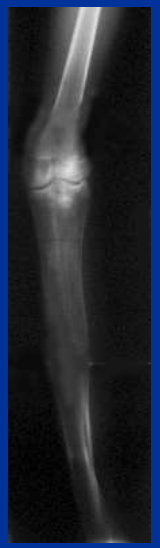


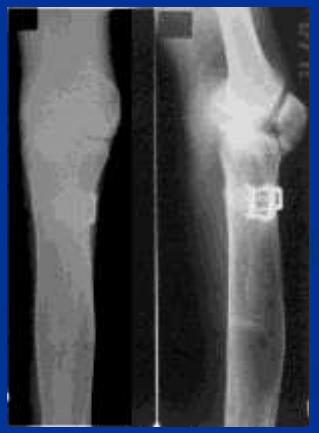
38. Limb hypoplasia-reduction defects group:
FIBULAR HYPOPLASIA SYNDROME



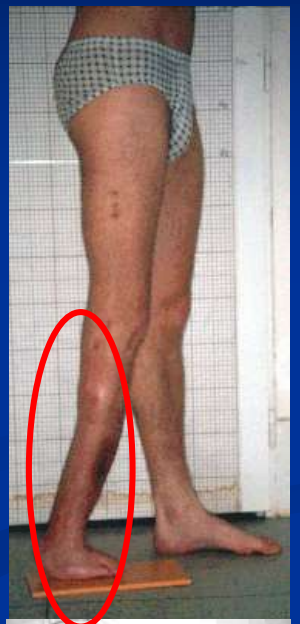


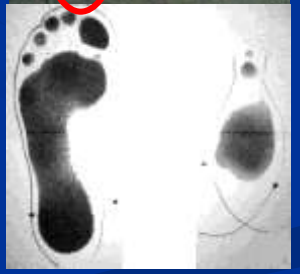






+ 18 cm

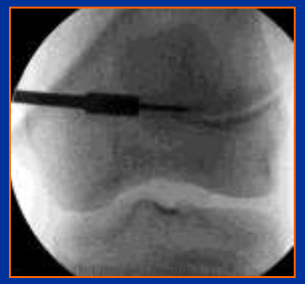




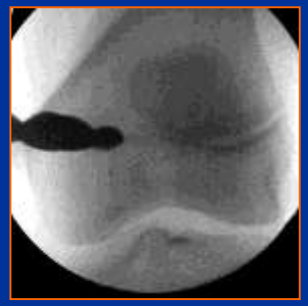
Lower extremity length discrepancies and desaxation

EPIPHYSIODESIS – partial and total (technique of Macnicol, 1992)

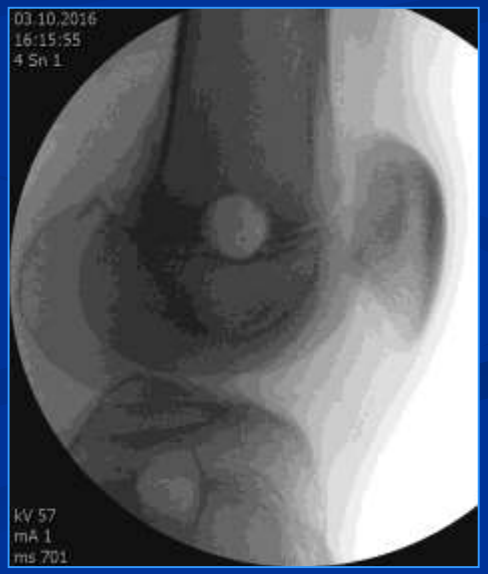
- Drilling permanent epiphysiodesis is carried out by drilling of growth plate with canulated tube saw in frontal plane.
- Usage of X-ray intensifier for identification of the physis centre in both projections are necessary



partial



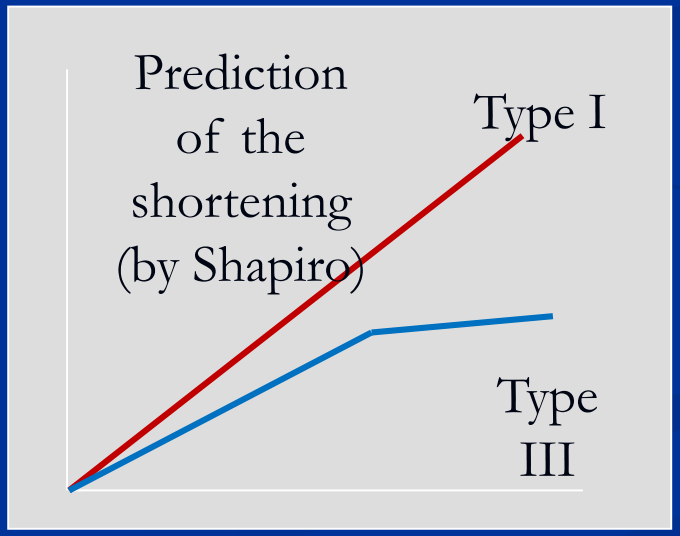
total

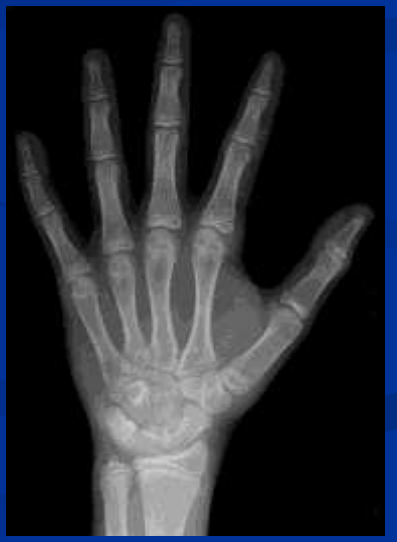


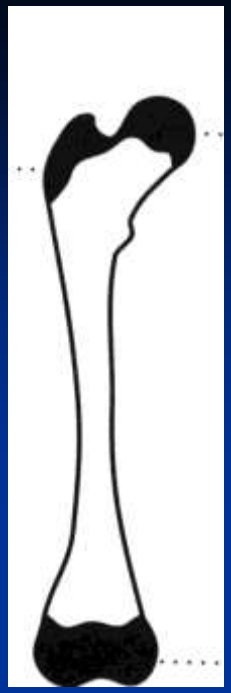
Lower extremity length discrepancies and desaxation

- **Prediction methods** of leg length discrepancies combine auxology, anthropometry and radiology using **remaining growth prediction** of the lower extremities by Anderson, Green, Messner (1963) and **bone age** by Greulich Pyle and Tanner Whitehouse 3 (2001).

- **Shapiro type I „upward slope pattern“ or type III „upward slope - plateau pattern“** of the growth of affected leg



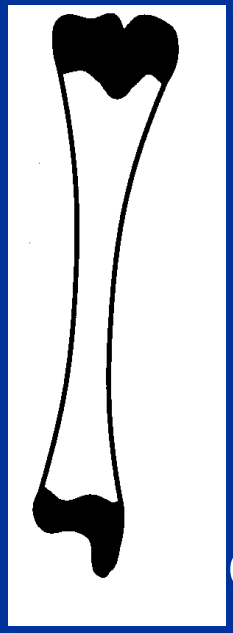




30 %
Closure g./b.- 13/15 yrs

70 %
Closure g./b. -15/17 yrs

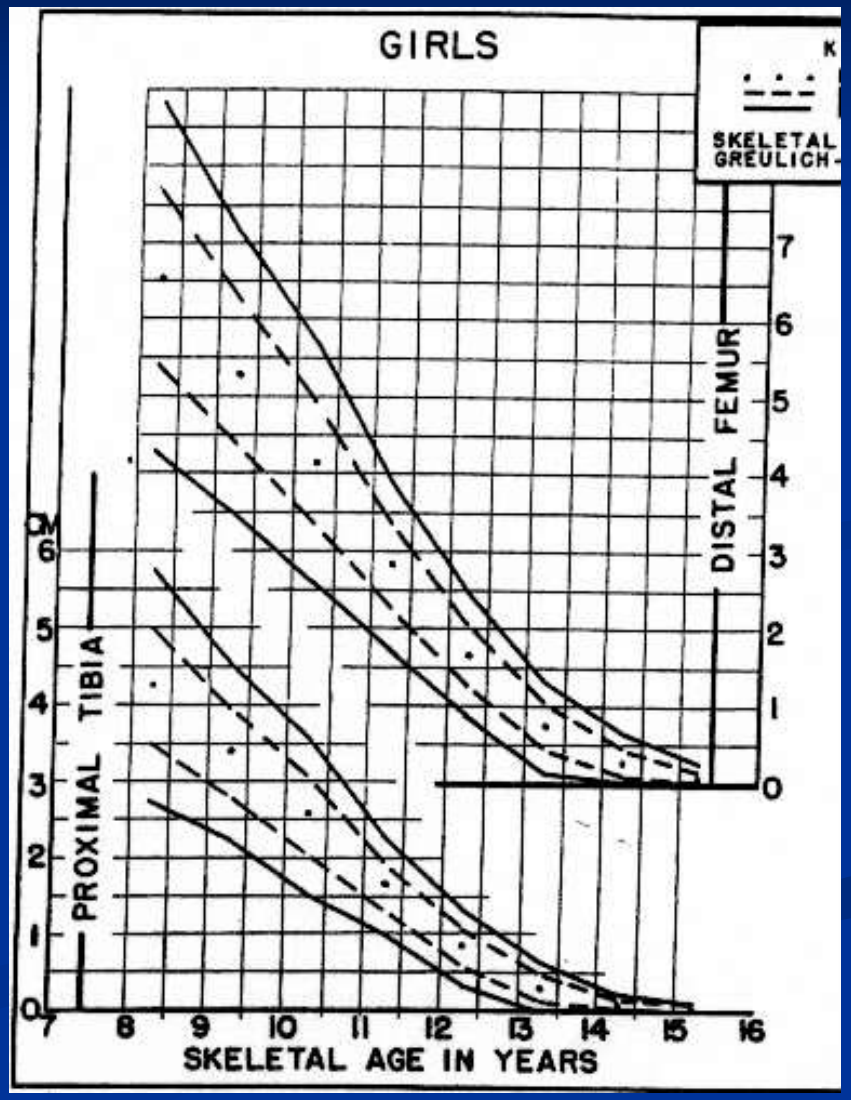
57 %
Closure g./b.- 15/17 yrs



43%
Closure g./b.- 13/15 yrs

Remaining growth charts

Anderson, Green, Messner (1963)

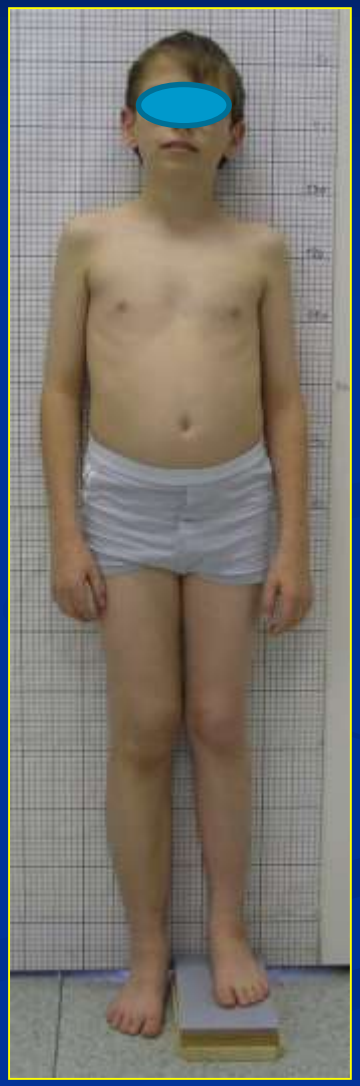


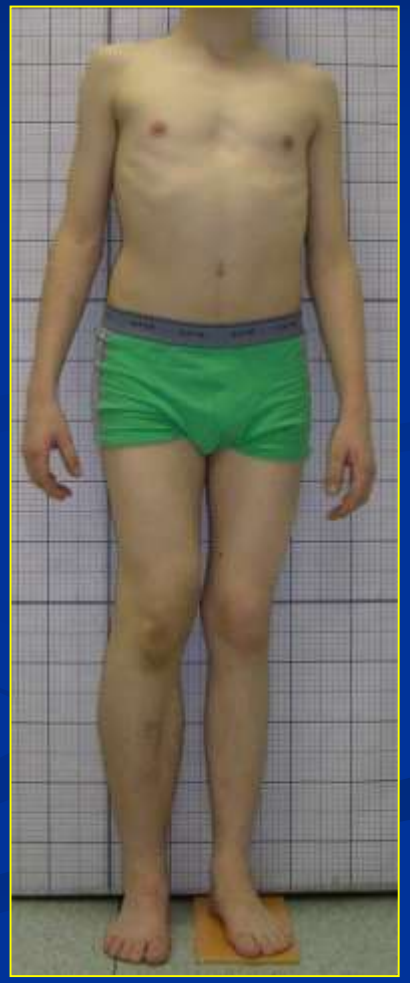
Lower extremity length discrepancies
drilling epiphysiodesis

- **Results of treatment** (unpublished)
- 48 patients (2004 – 2016)
- Predicted abbreviation was **2.5 cm (1.5 – 7 cm)**
- Final shortening was **0.5 +/- 0.6 cm (0 – 2.4 cm)**

Case: boy with angiodysplasia Klippel Treunanay, type 1 „upward slope pattern“ (by Shapiro)

- BA TW3 RUS 13y x 15.4 y calendar age
- prediction of overgrowth 5.0 cm
- remaining growth: distal femur 3.2 cm proximal tibia 1.8 cm
- **final overgrowth 1.0 cm**





1.0 cm

Lower extremity knee desaxation
drilling hemi-epiphysiodesis

- Research of children in kindergartens and basic schools focused on physiological development of the axis of lower extremities - students.

- **Results of surgery** (drilling hemi-epiphysiodesis) of a cohort 50 children (unpublished)

T-F angle before surgery **10.9 ± 2.8°**

after surgery **4.63 ± 1.36°**

T-F 13.5°/13.0° photo.
T-F 13.3° anthropo.

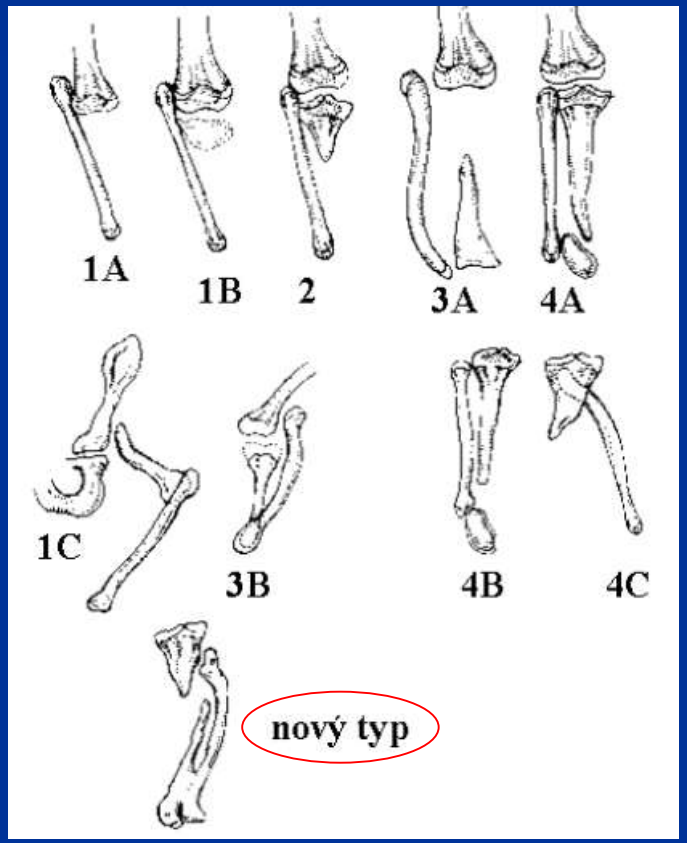
T-F 4.2°

OTHER PROJECTS

- Electronically controlled distraction fixator stimulating the new bone formation in callus (M. Petrtýl)
- Characteristics of the tibiofemoral angle, rear foot angle and plantar arch in healthy children (students)
- Measurement of spinal and postural deformities from radiographs and reading from photographs (P. Černý)
- Kinematic analysis of walking in patients with different weight of prosthesis (P. Krawczyk)
- Growth data of Czech achondroplasia patients (students)
- Growth data of Czech patients with hypophosphatemic rickets

What ORTHOPAEDIC ANTHROPOLOGY can offer to anthropologists engaded in historical or evolutionary anthropology ?

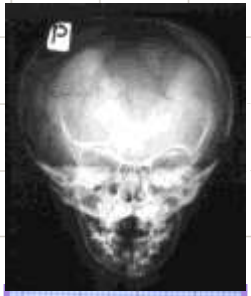
Smrčka V, Mařík I, Dočkalová M, Svensonová M. (1998). Congenital deficiency of the tibia at a medieval monastic cemetry in Olomouc (Czech Republic). Journal of Paleopathology, 10, No. 3, pp. 111 - 120.

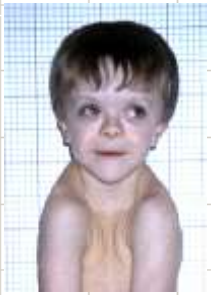


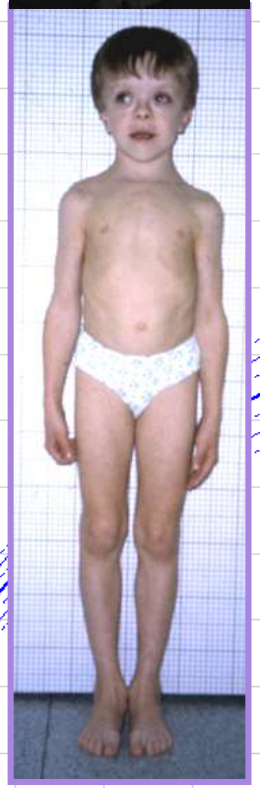
Smrcka V, Marik I, Svenssonova M, Likovsky J. (2008). Legg-Calvé-Perthes Disease in Czech Archaeological Material. Clin Orthop Rel Res, 467, 1, p. 293-297.

Cleidocranial dysplasia

haploinsuficiency of ***RUNX2 (CBFA1)*** **gene**







Disorder of membranous ossification & partial defect of endochondral ossification

CONCLUSIONS

RUNX2 (CBFA1)

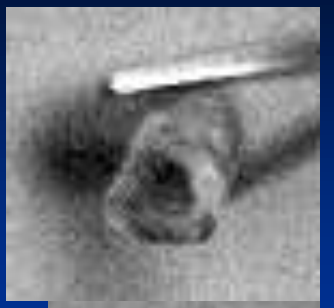
is one of the genes which Homo sapiens differs from Homo (sapiens) neanderthalensis (Middle Paleolith)

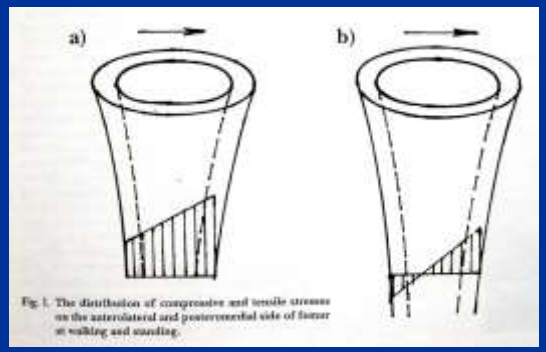
This gene is involved in development of skeleton: clavicles, scapulae, thorax, shape of skull, closure of fontanelles

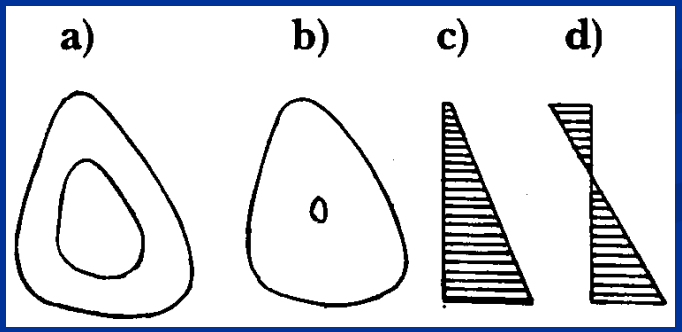
Knowledge and experience with bone dysplasias, radioclinical findigs and recent discoveries of molecular genetic defects significantly contribute to explain skeletal changes during human evolution

CONCLUSIONS

- **Clinical anthropometry** is important for both **confirmation** of **genetic diagnosis** and **comparison** of **genotype and phenotype**
- **Auxology** is indispensable for **indication**, **timing**, **monitoring** and **evaluation** of comprehensive treatment of GSD in growth period
- **Knowledge of GSD** contribute to understanding of **growth processes** at molecular level
- **Pathobiomechanics** explains causes of **disturbed functional adaptation of skeleton at some bone dysplasia**, e.g. phenomenon of narrowing, vanishing and displacement of medullary canal of the long bones of children with OI







CONCLUSIONS

- The branch ORTHOPAEDIC ANTHROPOLOGY covers pieces of knowledge on skeleton development and its functional adaptation in orthopaedic profession, mainly in period of growth.
- It engages in precise verification of body and skeleton abnormalities, deformities and disproportions and their development is verified by anthropometric, X-ray, densitometric, CT, MRI, microscopic, histological, histochemical, electronmicroscopic, biochemical, biomechanical, photograhic and 3D scanning methods, and the like. It means exact description of deformities at macro-, meso-, micro- and nanolevels.
- Etiopathogenetic causes of skeleton abnormalities, growth diseases and genetic skeletal disorders are included in the topic.

- **The new discoveries arise just at interface of scientific branches!**

AMBULANT CENTRE
for defects of locomotor apparatus
limited liability company

Thanks for your kind attention

SOCIETY FOR CONNECTIVE TISSUES
J.E.Purkyně
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