3D sagittal plane examination of the spino-pelvic complex in adolescent idiopathic scoliosis

Theses of PhD dissertation

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Pécs

2018

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List of abbreviations

2D – two dimensional

3D – three dimensional

AIS – adolescent idiopathic scoliosis

AP – anteroposterior

C7 – seventh cervical vertebra

L1 – first lumbar vertebra

L2 – second lumbar vertebra

L5 – fifth lumbar vertebra

LAT – lateral

PI – pelvic incidence

PT – pelvic tilt = PV – pelvic version

S1 – first sacral segment

SS – sacral slope

T1 – first thoracic vertebra

T10 – tenth thoracic vertebra

T12 – twelfth thoracic vertebra

T5 – fifth thoracic vertebra

1 Introduction

The spine is a harmonic system of vertebrae joint together like a column, forming a stable but sufficiently mobile frame whose main function is the protection of the spinal cord, bearing of the body's burdens and enabling the adequate mobility of the trunk, respectively.

Due to rapid development in recent past regarding both the field of orthopaedics and diagnostic possibilities, a significant change has occurred also in the assessment and treatment strategy of spinal deformities. Thus an increased demand has risen for the exact mapping of the relation of the joint pelvis and spine and for the evaluation of these anatomic structures as a complex biomechanical unit.

A "spine without deformities" or "normal" spine has a relatively straight and regular appearance in the frontal plane, while it takes the shape of a harmonic wave in the sagittal plane, which can be divided into the following four parts: cervical lordosis, thoracic kyphosis, lumbar lordosis and sacral kyphosis. Three pelvic parameters are used for defining the pelvis in the sagittal plane: pelvic tilt (PT), sacral slope (SS) and pelvic incidence (PI). The first two parameters depend on the position of the pelvis, while pelvic incidence is an idiosyncratic and anatomic parameter by definition.

The sagittal description of the spine is various in medical literature, thus several terms are applied, such as T1–T12, T4–T12 or T5–T12 for thoracic lordosis and L1–L5 or L1–S1 for lumbar lordosis.

The spine and the pelvis form a closely – and also dynamically - attached unit in all three dimensions with the pelvis as a solid base. As a result, the harmonically "curved" spine is approximately ten times more resilient to mechanical impacts than a completely straight spine would be.

1.1 Possibilities for change in the sagittal spino-pelvic profile

The sagittal appearance of the human spino-pelvic complex is not constant throughout our lives. A change occurs in its appearance and hence in its descriptive parameters during ontogenesis, as shown in comparison between children and adults. There are differences among various ethnic groups as well, both in those without spinal deformity and in those with scoliosis. In addition, the sagittal spino-pelvic appearance has a well-documented difference in case of certain deformities of the spine and pelvis, compared to a population without spinal deformities. However, results notably vary in medical literature regarding patients with scoliosis. Although some authors noted significant difference in pelvic parameters between patients with scoliosis and a control group, other studies have shown none.

1.2 Scoliosis

Scoliosis is the most common structural deformity of the spine in childhood and adolescence, affecting all three dimensions of the spine. Beyond the characteristic frontal appearance, scoliosis changes the sagittal profile as well (mainly toward lordosis). Moreover, vertebrae are horizontally rotated, or even deformed. Patients with adolescent idiopathic scoliosis (AIS), the most frequent type of the deformity, were the subjects of our research. The aetiology of the deformity includes multiple factors. According to several studies, the prevalence is 1-4%.

1.3 Our purpose

Adolescent idiopathic scoliosis, the most common juvenile structural spinal deformity, has a remarkable physical and psychical effect on patients. Examining the exact and detailed appearance of the deformity may help its thorough understanding and treatment, therefore we have set the objective of our research as the following:

- precise and detailed 3D assessment of the sagittal spino-pelvic profile of a large patient population with adolescent idiopathic scoliosis;
- comparison of our results to an “asymptomatic” control group without spinal deformity;
- detailed parameter determination based on 3D reconstruction and analysis of our results in comparison with other studies;
- assessment and comparison of sagittal profiles in case of different frontal curves, complex evaluation of the connection between frontal and sagittal images;
- assessment of sagittal pelvic parameters depending on position and evaluation of their connection to scoliosis.

2 Patients and methods

2.1 EOS 2D/3D device and technology

Radiological imaging, on which our scientific research was based, was performed with the EOS 2D/3D X-ray imaging system. Multiwire proportional chambers, invented by the Nobel prize-winning Polish-French physicist, Georges Charpak, are the core of this device. EOS examination takes place in a half-open booth, in standing position using slot scanning in a calibrated space. This process results in simultaneous full-body X-ray images in two planes (AP and LAT) which are then used by a computer software system to construct 3D surface images of certain parts of the skeleton, based on previously input data.

Apart from the standard upright position, it is possible to use various body positions, including sitting – the method is highly accurate and reliable in these cases as well regarding the spino-pelvic complex. 3D reconstruction can be realized following pre-set steps with the program using 12 thoracic and 5 lumbar vertebrae by default (other variants cannot be managed yet). The models are unable to visualise mild structural deformities, such as exostosis or slight superficial roughness, however, they are perfectly appropriate for the 3D visualization of the main elements.

Excessively low radiation exposure is a high-priority characteristic of EOS imaging (an ordinary full-body scan in two planes means only 0.30 mGy dose for an adult) which is of great significance in case of children, adolescents and patients requiring regular check-up, who would otherwise suffer considerable radiation exposure. Superficial 3D imaging provided by EOS has allowed the evaluation of new clinical parameters which could not have been achieved with 2D imaging before.

2.2 Patients

The EOS 2D/3D diagnostic device has been available at the Department of Orthopaedics, Medical School, University of Pécs since 2007 for routine clinical use. Cases included in our research were retrospectively processed from the thousands of EOS images between 2007 and 2012, focusing mainly on adolescent patients with scoliosis. Subsequently, more than 750 full-length spine images were reconstructed in 3D using the sterEOS 3D software, serving as the basis of the present research. Of the 3D reconstructions, more than 650 showed some form of spinal deformity, while almost a hundred were without spinal abnormality. Revising our database, we excluded all non-AIS cases, thus 458 patients (82 men and 376 women) were involved. The control group without spinal deformity consisted of 69 cases (28 men and 41 women) after revision.

The 48 patients (15 men and 33 women) involved in the position-dependent examination of pelvic parameters were treated separately. The characteristic features of these cases were lower back pain and the fact that the possibility of sacroiliac joint mobility was raised during physical examination. Incidentally, these 48 cases showed rather heterogeneous distribution. There were 21 patients with scoliosis, 3 patients with Scheuermann's disease and 24 patients without any abnormalities detectable by EOS imaging.

2.3 Analysed parameters

- T1–T12 and T4–T12 kyphosis (measured automatically by EOS);
- T5–T12 and T10–L2 kyphosis (determined manually on EOS 2D working station);
- L1–L5 and L1–S1 lordosis (measured automatically by EOS);
- pelvic parameters – PI; PV; SS (determined by EOS);
- Cobb angle; to determine Cobb angle, two lines are drawn parallel to the superior endplate of the highest affected vertebra and to the inferior endplate of the lowest affected vertebra. Then perpendiculars are drawn on these lines, and Cobb angle is the complementary angle of the angle included by the perpendiculars (based on the high accuracy determination by sterEOS using 3D reconstruction)

2.4 Classification of scoliotic cases

The 458 patients with AIS were categorised for further analysis according to the Lenke classification system, which consists of three main steps:

1. Identification of the primary curve. Depending on the frontal profile, cases are divided in 6 main groups.
2. Assignation of lumbar modifier. Depending on the frontal profile of the lumbar spine, there are A, B and C categories.
3. Sagittal modifier of the classification which is based on the T5–T12 kyphosis: “negative”, “normal” and “positive” categories exist.

2.5 Connection between upper body position and changes in pelvic parameters

Analysing the position-dependent change in pelvic incidence, part of the cases showed a decrease, while others showed an increase in pelvic incidence, comparing the values of EOS images taken in standing and sitting position. As we examined the cause of this duality, a connection was found with the sitting position, which could be quantified with the position of the sagittal C7 median compared to the pelvis.

2.6 Statistical methods

Winer criteria was used to evaluate the accuracy of measurements.

Data obtained from our measurements were statistically analysed using SPSS v22 (IBM Corp., Armonk, NY, USA) and Microsoft Office Professional Plus v14.0.6112.5000 (Microsoft Corp., Redmond, WA, USA). Distribution of values was calculated using Kolmogorov- Smirnov test. Random selection was generated with Microsoft Excel VÉLETLEN.KÖZÖTT formula.

Independent samples t-test was used to evaluate correlation between control and AIS groups plus subgroups regarding spino-pelvic parameters. Linear regression analysis was used to evaluate the correlation of parameters.

Independent and paired sample t-tests were used to analyse the connection between position-dependent pelvic parameters of sitting and standing groups. Differences in pelvic incidence and sitting position was evaluated using cluster analysis.

The significance threshold was set at 0.05.

3 Results

3.1 Accuracy of the EOS device and parameter distribution

Intraobserver reliability calculations of our measurements resulted in a correlation coefficient above 0.9 in all cases, thus proving them excellent through our research.

According to Kolmogorov-Smirnov test, all analysed parameters showed normal distribution.

3.2 Results regarding sagittal spino-pelvic profile

Independent samples T test was used to evaluate the sagittal parameters of the AIS and control group. A significant difference between the two groups was found only in the values of thoracic kyphosis (T1–T12 kyphosis, T4–T12 kyphosis, T5–T12 kyphosis). Other spinal and pelvic parameters showed no significant difference.

3.3 Sagittal parameters of scoliotic patients due to Lenke classification

Sagittal spinal parameters for certain Lenke groups versus the control group were analysed using independent samples t-test. The results showed a regressing tendency in all kyphotic parameters in scoliotic cases, except for T10-L2 kyphosis which showed a discrete, but nonsignificant increase. The regressing tendency was statistically significant for all Lenke groups in case of T4–T12 kyphosis, while in T1–T12 and T5–T12 kyphosis, Lenke 2 and Lenke 4 groups it showed no significant difference. As for lumbar curves, namely L1–L5 and L1–S1 lumbar lordosis, the values of Lenke groups and the control group were remarkably similar with no statistically significant difference. Sagittal pelvic parameters showed no significant difference either.

3.4 Correlation between sagittal spino-pelvic parameters

The correlation between pelvic and sagittal spinal parameters was evaluated using linear regression analysis, resulting in a significant correlation between pelvic incidence and lumbar lordosis in the control group, and both lumbar lordosis and thoracic kyphosis in the AIS group. Sacral slope showed statistically significant connection with lumbar lordosis in both groups, while thoracic kyphosis was proven independent. On the contrary, pelvic tilt had no connection with the lumbar curve but curiously, it was significantly connected with the thoracic kyphosis. Analysing the different severity groups separately, the results were similar.

3.5 Ethnic differences in sagittal spino-pelvic parameters

The results of our Central European cases of Caucasian race (both control and AIS group) were compared to cases with different ethnic background of other studies in medical literature.

Pelvic incidences of Caucasian "asymptomatic" cases analysed by other authors (49.1-52.7°) were clearly higher than our results (46.2° for control and 47.3° for AIS). Central American – Mexican patients showed values higher than any Caucasian groups (56.7°), while Asian patients had similar or slightly lower values than the patients included in our study (44.6-47.8°).

If we consider AIS cases separately, the tendency is similar to "asymptomatic" patients. Asian race is associated with remarkably lower values (43.1-44.2°), however, Caucasian (but not Central European) patients showed higher values than our patients (52.5-57.3°vs. 47.3°). Similarly, the Afro-American population has higher values (56°).

3.6 Position-dependent results of pelvic parameters

For the whole studied population, pelvic parameter values in different body positions (standing and sitting) differed significantly regarding pelvic tilt and sacral slope ($p<0.001$), while average pelvic incidence showed no significant difference in different positions. However, analysing pelvic incidence individually, we found clear and remarkable differences in some of the cases which included both increase and decrease with an average deviation of ± 2.8°.

The detected position-dependent change in pelvic incidence could be associated with the C7 median's position compared to the pelvis. This connection was measured, then the data was evaluated using cluster analysis which showed four different groups:

Cluster 1 included cases with decreased pelvic incidence and a backward tilt of the upper body after sitting down;

Cluster 4 involved cases with increased pelvic incidence and a forward tilt of the upper body in sitting position;

Cluster 2 and 3 included those cases that showed no significant difference in changes of pelvic incidence, regardless body position. These two clusters were considered as one group.

Paired sample t-test was used to analyse these groups and proved significant difference of parameters in different positions in Cluster 1 and 4 ($p<0.001$, difference of averages 4.83°and 6.95°, respectively) while there was no statistical difference ($p=0.785$, difference 0.09°) in the stable group (Cluster 2 and 3).

Altogether, scoliosis was present in 21 (44%) of 48 cases as primary disease. Evaluating the correlation between scoliosis and sacroiliac joint mobility, 8 (57%) of 14 cases showing change and 13 (38%) of 34 stable cases showed the abnormality. This difference was proven nonsignificant.

4 Discussion

4.1 Analysis of sagittal spinal parameters

The complex research conducted in this study showed a significant change (decrease) in thoracic curves (T1–T12 kyphosis, T4–T12 kyphosis and T5–T12 kyphosis) from the sagittal spinal parameters in both the integrated (AIS) group and different Lenke groups. Our results confirm that only the thoracic area is affected by adolescent idiopathic scoliosis with a lordotic tendency. As for lumbar lordosis, the results of the control and AIS groups showed no significant difference and they were proven unrelated to the frontal appearance of the deformities.

4.2 Ethnic differences of the spino-pelvic unit

Although there are considerable individual differences, spino-pelvic parameters of different ethnic groups show clear differences with a general tendency, according to previous studies in medical literature that evaluated sagittal pelvic profile. Our results of pelvic incidence of Central European patients of Caucasian race (control 46.2°, AIS 47.3°) were below both the value of our Lebanese asymptomatic patient (52.0°) and the results of other studies involving Caucasian, but not Central European patients. Mexican patients demonstrated even higher values (56.7°) than Caucasians, similarly to Afro-American patients with scoliosis. In turn, the lowest values were associated with patients of the Asian race. It is also worth highlighting that several authors found nearly equivalent values of asymptomatic and AIS cases, which is similar to our findings.

As the different ethnic groups demonstrate various spino-pelvic appearance unrelated to the presence of scoliosis, there are rather anthropometric differences in the background than the effect of spinal deformities.

4.3 Well-known causes of pelvic parameter change

The development of the spine and pelvis during growth causes the whole spino-pelvic complex and thus the connection among all its “components” to change from infancy, through childhood, till adolescence and adulthood, respectively. Apart from the physiological spino-pelvic adaptation observed during growth, some authors found a significant difference between pelvic parameters of patients with and without (control group) spinal condition. Thus some authors noted a significant difference in AIS cases as well, while others did not.

In our present study, there was no statistically significant difference in pelvic parameters between AIS and control groups. Not only the summarized values of the 458 AIS cases, but also the results after dividing the patients into subgroups according to the Lenke classification were identical.

4.4 Correlation between pelvic incidence and body position

During previous targeted physical examinations performed at the Department of Orthopaedics in Pécs, the possibility of a detectable mobility in the pelvis (sacroiliac joint) was raised in some cases, which may be associated with certain spinal conditions and lower back complaints. Although there is little information regarding this theory in medical literature, its credibility may partly be supported by those findings that proved a difference in pelvic parameters between control groups and patients with spinal conditions. It is not yet clarified whether the proven difference is slowly developing in connection with the spinal condition or is rather part of a dynamic component as an "existing mobility", appearing "immediately" or possibly these two impacts concur. It is important to highlight the fact that though the difference could be confirmed in individual cases, pelvic parameters of control and AIS groups did not differ significantly in our present research.

The results of our research targeted at pelvic parameter changes, which included the cases with the possibility of sacroiliac instability raised during outpatient physical examination, showed no significant difference in pelvic incidence. Our results may suggest that sacroiliac mobility can be disregarded. Apart from this, we observed that when evaluating the results individually, significant position-dependent changes occur in some cases. These differences were in some cases negative and in other cases positive, but their absolute value was equal. It is still unknown what causes this difference in both directions, equally in number and extent, however, we suspect that it may be a coincidence. Another important outcome of our research is that from the 48 patients involved with the possibility of sacroiliac mobility, the condition was only proven in 30% of the cases using high-accuracy radiological imaging. Furthermore, a connection between the possibility of sacroiliac mobility and scoliosis as primary disease could not be confirmed.

The involved patients presented with low back pain which suggests that there may be a connection between sacroiliac joint movements and low back pain. Unfortunately, we could not prove this theory without an adequate control group.

4.5 Importance of the examination of the spino-pelvic profile

To summarize our results, AIS patients with similar frontal spinal curve appearance showed various sagittal appearance and it also occurred that different frontal profiles showed similar sagittal images. These findings suggest that no clear conclusion can be drawn of spatial curvatures judging the sagittal profile only by the frontal profile and vice versa.

It is a well-known fact that despite the significant individual differences, the spino-pelvic appearance of various ethnic groups is clearly different, therefore the diagnosis, treatment design and administration of a given case may benefit from the knowledge of different ethnic characteristics.

5 Conclusions

The spino-pelvic unit can be examined in physiological (standing) body position using EOS 2D/3D imaging system and its 3D reconstruction software. The device enabled spinal disorders that have been surgically reconstructed in 3D for years (but examined only in 2D) to be examined in 3D using this high-accuracy device with low radiation exposure.

Our results confirmed the idea that the sagittal image of patients with scoliosis is irregular. Sagittal appearance cannot be clearly judged by the frontal image of the deformity, therefore frontal and sagittal plane images should be evaluated separately.

Adolescent idiopathic scoliosis, which affects all three dimensions of the spine, has a significant influence only on the thoracic area of the sagittal spino-pelvic unit.

Our results also support the previous theory that the nowadays routinely applied scoliosis classification systems do not provide adequate information about the sagittal profile. The development of 3D diagnostic devices generates an increased demand for a new classification system that includes 3D parameters as well. The findings of the present study of a large patient population may be used to establish such a classification system.

It is also widely known that despite the significant individual differences in spino-pelvic parameters of certain cases, the sagittal profile of various ethnic groups shows obvious difference. These mostly originate in population variations rather than being the effect of spinal deformities on the pelvis.

In our research of a uniquely large patient population, the detailed sagittal profile of Central European and Caucasian population was constructed regarding idiopathic scoliosis and its distribution due to main frontal curve types.

Our results about pelvic mobility can be considered novel findings which suggests that increased sacroiliac mobility may be present in a small part of the population and may be associated with abnormalities of the spino-pelvic unit and idiopathic low back pain as well. On the other hand, it is necessary to highlight that the clear reason and background of the observed pelvic mobility could not be evaluated by the present research, partly due to the lack of an adequate control group. Therefore, further research is required in this field.

6 Novel findings and conclusions of the present dissertation

- We were the first in Hungary to conduct complex research which evaluated the spino-pelvic unit based on 3D reconstruction in patients with idiopathic scoliosis, using EOS 2D/3D diagnostic device.
- We constructed the sagittal spino-pelvic profile of a native, Central European population of Caucasian race, focusing on adolescent idiopathic scoliosis.
- The results of the present study of a large population are exceptional in Hungary and are of great international significance as well. Thus, they may serve as reference values. We compared our results with other authors' findings from medical literature and they can be used for similar comparisons in the future.
- Our studies on the connection between sagittal spino-pelvic profile and frontal curve appearance proved that there is no correlation between frontal and sagittal images. Therefore, the examination of one plane is inadequate to judge the other one.
- We proved that adolescent idiopathic scoliosis, affecting all three dimensions of the spine, significantly influences only the thoracic kyphosis of the sagittal profile, leaving the lumbar lordosis and pelvic appearance intact.
- Based on our findings, the question whether present scoliosis classification systems in today's era of the latest 3D visualisation techniques are relevant, was raised.
- Other authors previously noted the possibility of sacroiliac mobility but based on their results using conventional imaging techniques, they considered it unimportant. Based on our results using the high-accuracy EOS 2D/3D device, we assume that there is detectable sacroiliac mobility in some cases.
- A clear correlation between sacroiliac mobility and spinal deformities could not be confirmed, therefore we suppose that the mobility is not caused by scoliosis. However, the background of this phenomenon is still to be discovered, thus we plan to conduct further research in this field.

7 List of publications

7.1 Publications releated to the thesis

- **Burkus M**, Márkus I, Niklai B, Tunyogi-Csapó M. [Assessment of sacroiliacal joint mobility in patients with low back pain]. Orv Hetil. 2017;158(52):2079-85. **IF:0,322; SJR: 0,16 (Q3)**
  DOI: 10.1556/650.2017.30921

- **Burkus Máté,** József Kristóf, Niklai Bálint, Márkus István, Tunyogi-Csapó Miklós. A collodiaphysealis szög vizsgálata gerincferdülés esetén, háromdimenziós képalkotás segítségével. Magyar Traumatológia Ortopédia Kézsebészet Plasztikai Sebészet. 2017;60(1-2):13-20.
  DOI: 10.21755/MTO.2017.060.0102.002

- **Burkus Máté**, József Kristóf, Bálint Gergely, Niklai Bálint, Márkus István, Tunyogi-Csapó Miklós. Gerincferdülés esetén tapasztalt sagittalis megjelenés vizsgálata EOS 2D/3D képalkotás használatával. Magyar Traumatológia Ortopédia Kézsebészet Plasztikai Sebészet. 2017;60(1-2):21-31.
  DOI: 10.21755/MTO.2017.060.0102.003

- **Burkus M**, Schlégl Á, O'Sullivan I, Márkus I, Vermes C, Tunyogi-Csapó M. Sagittal plane assessment of spino-pelvic complex in a Central European population with adolescent idiopathic scoliosis: a case control study. Scoliosis Spinal Disord. 2018;13:10. **IF: 1,023; SJR: 0,843 (Q2)**
  DOI: 10.1186/s13013-018-0156-0

- Márkus I, Schlégl Á, **Burkus M**, József K, Niklai B, Than P, et al. The effect of coronal decompensation on the biomechanical parameters in lower limbs in adolescent idiopathic scoliosis. Orthop Traumatol Surg Res. 2018;104(5):609-16. **IF: 1,413, SJR: 0,937 (Q1)**
  DOI: 10.1016/j.otsr.2018.06.002

Cumulative impact factor releated to the thesis: **2,758.**

7.2 Further publications

- Illés TS, **Burkus M**, Somoskeöy S, Lauer F, Lavaste F, Dubousset JF. The horizontal plane appearances of scoliosis: what information can be obtained from top-view images? Int Orthop. 2017;41(11):2303-11. **IF: 2,377; SJR: 1,502 (Q1)**
  DOI: 10.1007/s00264-017-3548-5

- Illés TS, **Burkus M**, Somoskeöy S, Lauer F, Lavaste F, Dubousset JF. Axial plane dissimilarities of two identical Lenke-type 6C scoliosis cases visualized and analyzed by vertebral vectors. Eur. Spine J. 2018;27(9):2120-9. **IF: 2,634; SJR: 1,535 (Q1)**
  DOI: 10.1007/s00586-018-5577-1

- Kretzer András, Tömböl Ferenc, **Burkus Máté.** A serdülőkori lábszártörés kezelése felfúrás nélküli, tömör, reteszelt velőűrszegezéssel. Magyar Traumatológia Ortopédia Kézsebészet Plasztikai Sebészet. 2018. Epub ahead of print.

Cumulative Impact factor: **5,011.**

7.3 List of presentations on conference, related to the thesis

- **Burkus Máté**, Szuper Kinga, Burkus László. Az arthritis psoriatika okozta komplex csontelváltozások EOS megjelenítése esetbemutatás kapcsán. 55. MOT Kongresszus, 2012. Június 14-16, Győr;

- **Burkus Máté**, Szuper Kinga, Somoskeöy Szabolcs, Tunyogi-Csapó Miklós. A medenceparaméterek pozíciófüggő értékelése EOS képalkotás segítségével. MOT-MTT 2013. évi Közös Kongresszusa, 2013. Június 27-29, Budapest;

- **Burkus Máté**, Kretzer András, Pellek Sándor, Balogh Péter. Adolescens kórban felfedezett congenitalis sacrum deformitás összetett 3D megjelenítése, esetbemutatás. A Magyar Gyermeksebész és Gyermektraumatológus Társaság XXI. Gyermektraumatológiai Vándorgyűlése, 2014. Szeptember 18-20, Budapest;

- Márkus István, Schlégl Ádám, József Kristóf, Niklai Bálint, Bogyó Csaba, **Burkus Máté**, Than Péter, Tunyogi-Csapó Miklós. Az alsó végtag csontos anatómiájának vizsgálata adolescens idiopathiás scoliosban szenvedő betegeknél. A Magyar Gerincgyógyászati Társaság 25 Éves Jubileumi Tudományos Ülése, 2016. December 2-4, Balatonfüred;

- **Burkus Máté**, Tunyogi-Csapó Miklós. A kora gyermekkori gerincferdülés és korszerű kezelési elvei. Győr-Moson-Sopron Megyei Orvos-Gyógyszerész Napok, 2017. Március 2-4, Győr;

- **Burkus Máté**, Tunyogi-Csapó Miklós. Kora gyermekkori gerincferdülés kezelési lehetőségei. A Magyar Gyermeksebész Társaság 2017. évi Tavaszi Tudományos Ülése, 2017. Május 5-6, Budapest;

- **Burkus Máté**, Schlégl Ádám, Márkus István, József Kristóf, Niklai Bálint, Somoskeöy Szabolcs, Tunyogi-Csapó Miklós. A proximális femur paraméterek értékelése gerincferdülés esetén. A Magyar Ortopéd Társaság 60. Kongresszusa, 2017. Június 29-Július 01, Debrecen;

- **Burkus Máté**, Márkus István, Tunyogi-Csapó Miklós. A gerincferdülés esetén tapasztalt szagittális megjelenés értékelése. A Magyar Ortopéd Társaság 60. Kongresszusa, 2017. Június 29-Július 01, Debrecen;

- Schlégl Ádám, O'Sullivan Ian, Varga Péter, Kerekes Kamilla, József Kristóf, **Burkus Máté**, Tunyogi-Csapó Miklós, Vermes Csaba, Csontkor mérési lehetőségek vizsgálata FL-FS és EOS felvételeken. A Magyar Ortopéd Társaság 60. Kongresszusa, 2017. Június 29-Július 01, Debrecen;

- Márkus István, József Kristóf, **Burkus Máté**, Schlégl Ádám, Tunyogi-Csapó Miklós. A coronalis balance és az alsó végtagi radiológiai paraméterek összefüggései idiopathiás adolescens scoliosisban. A Magyar Ortopéd Társaság 60. Kongresszusa, 2017. Június 29-Július 01, Debrecen;

- **Burkus Máté**, Schlégl Ádám, Márkus István, József Kristóf, Niklai Bálint, Somoskeöy Szabolcs, Tunyogi-Csapó Miklós. A serdülőkori gerincferdülés és az alsóvégtagi paraméterek kapcsolatának vizsgálata. XXIV. Gyermektraumatológiai Vándorgyűlése 2017. Október 27-28, Miskolc;

- Ádám Tibor Schlégl, István Márkus, **Máté Burkus**, Kristóf József, Bálint Niklai, Péter Than, Miklós Tunyogi-Csapó. Effect Of Coronal Decompensation On The Biomechanical Parameters In Lower Limbs In Adolescent Idiopathic Scoliosis. 19th EFORT Congress, Barcelona, Spain, 2018 May 30-June 01;

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8 Acknowledgements

I would first like to thank Prof. Tamás Illés MD, who has initiated my career in spine surgery research.

I would like to thank Prof. Péter Than MD, clinic director, for undertaking the coordination of my scientific work. Without his help, persistent motivation and guidance, my thesis could not have been successfully conducted.

I am grateful to my supervisor, Miklós Tunyogi-Csapó MD, who helped in my scientific work and was also eager to introduce me into the world of spine surgery. I am pleased that we established not only a professional, but also a friendly relationship during the years of working together.

I would especially like to thank my young colleague and friend, Ádám Tibor Schlégl MD, who plays an important role in the scientific work at the Department of Orthopaedics, for being a permanent scientific partner throughout my work.

I must express my gratitude to Szabolcs Somokeöy MD, who is responsible for the EOS at the Department of Orthopaedics, for the enormous professional help during the years. I could always ask for his help during my research.

I would also like to thank my excellent colleagues, Ian O'Sullivan MD and István Márkus MD, and all the employees of the Department of Orthopaedics for their generous help in my work.

I must express my very profound gratitude to my family, especially to my wife, Viktória, for her patience in enduring the increased burden on our family due to my work and for her unfailing support and continuous encouragement in difficult times.

Finally, I dedicate my scientific work to my son, Marcell. May he read it with as much enthusiasm as much strength he gave me during my work.