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The possibilities with decision support systems in surgery of spine-pelvic complex (analytical review)

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Objective To explore decision support systems (DSS) used in spine-pelvic surgery, analyze its functional possibilities and approaches that allow the surgeon to make a correct decision. **Material and methods** Functional possibilities with modern DSSs used in surgery of spine-pelvic complex were reviewed with unified criteria using websites of DSS manufacturers and publications in scientific journals. **Results** *MediCAD*, *TraumaCAD*, *Surgimap*, *Sectra AB and OrthoView* are most common DSSs used for spine and hip surgery planning. The above systems can be applied in orthopedic surgery of several independent anatomical regions (e.g., spine, pelvis, femur, tibia, foot). But none of the systems can be applied to spine-pelvic complex. DSS facilitates only geometrical planning with geometric measurements, simulation of physiologically normal location of anatomical elements as well as selection and semi-automatic implant positioning. **Conclusion** Both geometrical planning and biomechanical simulation are required to achieve positive long-term follow-up of surgical treatment. Biomechanical simulation allows assessment of an extent and pattern of injury caused by malalignment of spine-pelvic complex and surgical intervention planning with the help of reconstruction options offered. The use of DSS should involve geometric planning, biomechanical simulation of the expected surgical outcome and prediction of a long-term follow-up. Introduction of DSS into clinical practice will facilitate the quality of medical care and rehabilitation with concurrent optimization of the national expenditure on health care.
Keywords: decision support system, health information technology, spine-pelvic complex, surgery, geometric planning, biomechanical simulation

INTRODUCTION

Decision support system (DSS) is a software-based system intended to help decision makers to gather and interpret useful information and build a foundation for decision-making in any knowledge domain [1–5]. In healthcare, DSSs fall into intelligence managerial decision support system in healthcare [1, 2] and clinical decision support system [2, 3].

Managerial decision support systems in healthcare are aimed at managing resources, treatment process and medical care, critical thinking in decision making, sending alerts to specialists warning against threatening situations [4].

Clinical decision support systems allow reduction in timing of diagnosis, gathering and synthesizing expert opinions on clinical decision support best practices, compiling patient-specific information, improving resource distribution and decreasing mortality rate. Clinical decision making is a core competency of surgical practice with shortage of time, high dynamics in the course of a disease and the high cost of malpractice cases [2, 6–8].

The goal of the study was to explore DSS used in spine-pelvic surgery, analyze its functional possibilities and approaches that allow the surgeon to make a correct decision.

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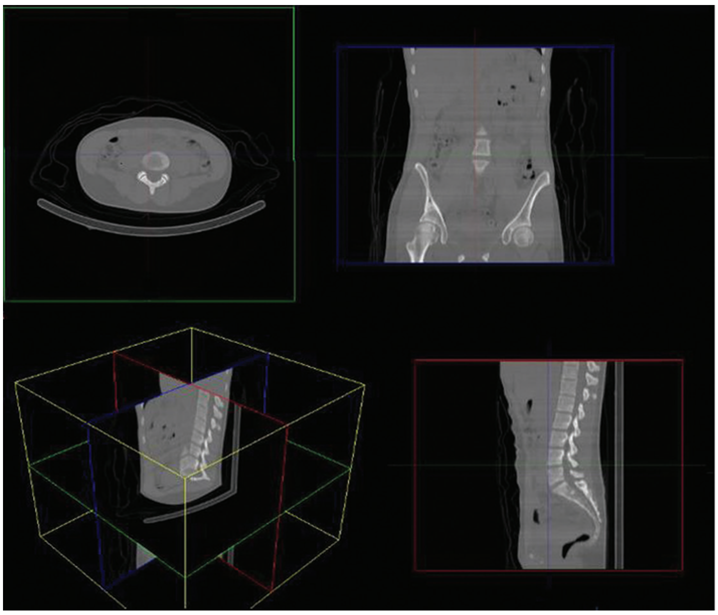
MATERIAL AND METHODS

Functionalities and capabilities of modern DSSs used in surgery of spine-pelvic complex were reviewed with unified criteria using websites of DSS manufacturers and publications in scientific journals [9–14]. MediCad, SectraAB, TraumaCAD, Surgimap, OrthoView, ZedHip, Orthopedic Surgery 2D Planner, Martell Hip Analysis Suite, HyperORTHO, ViewPro-X, OneFit Hip Planner, OneFit Knee Planner, Blueprint are most common DSSs used for preoperative planning. Overview of functional possibilities with DSS allowed identification of both common and specific characteristics of the systems. The clinical DSS can import, export and process images from CT, MRI, DEXA, conventional radiography, help geometric planning of surgical reconstructive treatment and realize construction skeletal function in horizontal, sagittal and coronal planes with 3D visualization (**Fig. 1, a**).

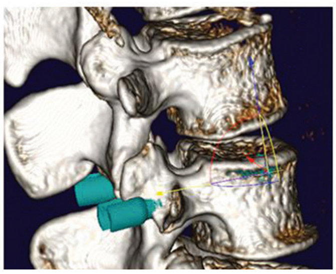
Preoperative planning is critical for decision making in spinopelvic surgery. DSS facilitstes geometric planning of surgical procedure. Geometric planning allows the surgeon to make geometric measurements using data from imaging modalities. The following parameters of spinopelvic complex to be used for adequate functioning of the preoperative planning systems were employed for the goals of this study: 1) a possibility of measuring distances, angles, sagittal balance in spine surgery, neck-to-shaft angle in hip surgery; 2) a possibility of simulating normal anatomical relationships at the site of interest and planning a surgical reconstruction using template database and fixation systems.

The DSSs have various functional possibilities of geometric planning in different anatomical locations. The anatomical segments are presented in Table 1 and are standalone modules with the DSSs. The modules can provide preoperative planning with implant templates available for specific anatomic locations only and unavailable for adjacent locations. MediCAD Classic DSS has Template icon with implant templates for various anatomical locations of orthopaedic surgery enabling geometric planning and template implant placing in adjacent anatomic locations (Table 1). However, Spine module is unavailable with MediCAD Classic and no preoperative planning can be performed for spinopelvic complex surgery.

DSSs with the function of 3D reconstruction allow multiplanar reconstruction using thin slices to create new images from a stack of images in planes other than that of the original stack [15]. All 2D slices are downloaded in DICOM to visualize 3D images. Graphic comparison is performed by representing several marking points that are simultaneously reflected in all real-time images and planes. A 3D rotation function is available for images in multiplanar reconstruction mode (**Fig. 1**).



a



b

Fig. 1 Images viewed in 3D mode: ***a*** multiplanar reconstruction mode [16]; ***b*** superficial 3D model [17]

Table 1

Systems of preoperative planning for different anatomical locations

Mode	Anatomical locations*					
	Spine	Hip joint	Knee joint	Lower limb (femur, tibia and fibula)	Upper limb / humerus (hand, elbow and shoulder joints)	Foot
2D	–	***MediCAD Classic***	***MediCAD Classic***	*MediCAD Classic*	*MediCAD Classic*	*MediCAD Classic*
3D	*MediCAD SPINE 3D*	*MediCAD hip 3D*	*MediCAD knee 3D*	*MediCAD hip 3D*	*MediCAD shoulder 3D*	*MediCADhip 3D*
2D/3D	*Sectra AB*	*Sectra AB*	*Sectra AB*	*Sectra AB*	*Sectra AB*	–
2D/3D	*TraumaCAD*	***TraumaCAD***	***TraumaCAD***	*TraumaCAD*	*TraumaCAD*	*TraumaCAD*
2D	*OrthoView*	*OrthoView*	*OrthoView*	–	*OrthoView*	–
2D/3D	*Surgimap*	*Surgimap*	–	*Surgimap*	–	–
2D/3D	–	*One Fit HipPlanner*	–	–	–	–
2D/3D	–	*ZedHip*	–	–	–	–
2D/3D		*Martell Hip Analysis Suite*				
2D	–	*Orthopedic Surgery 2D Planner*	–	–	–	–
2D	–	*HyperORTHO*	–	–	–	–
2D	–	*ViewPro-X*	–	–	–	–
2D	–	–	–	–	*Blueprint*	–
2D/3D	–	–	*OneFit Knee Planner*	–	–	–

* – DSSs in bold are those with comparative function of preoperative and postoperative parameters

RESULTS

DSSs have individual characteristics. MediCAD (HectecGmbH, Germany) releases basic version MediCAD Classic, versions MediCAD SPINE 3D, MediCAD Hip 3D, MediCAD Knee 3D, MediCAD Shoulder 3D, MediCAD Individual prosthesis, mediCAD MOBILE, MediCAD VETERINARY. The latter version is not intended for medical usage and would not be discussed in the article. It should be noted that MediCAD Classic and TraumaCAD exist as a Russian version. *MediCAD Classic* has *Trauma* module in addition to those presented in Table 1. *Trauma* module allows identification of a bone fracture, rotation and copy for reconstruction and accurate realignment of anatomical location in images prior to the template use. *MediCAD Classic* also has replenishing database of implant templates and interactive help menu. Automatic differences in standing and supine plain radiographs are evaluated and calculations produced. Table 2 presents implant manufacturers by anatomical locations for orthopaedic surgery in *MediCAD Classic*. *MediCAD* manual provides information on implants from 123 manufacturers.

Table 2

MediCAD Classic implant vendors for orthopaedic surgery by anatomical locations

Prostheses	Number of manufacturers
Humerus	25
Elbow	3
Hand	7
Foot	5
Femur:	67
Cup	67
Stem	0
Knee:	3
Femoral component	3
Tibial component	0
Osteosynthesis (fixation instruments)	10
Total	123

Software products of *MediCAD SPINE 3D, MediCAD Hip 3D, MediCAD Knee 3D, MediCAD Shoulder 3D* provide import and visualization of images being examined and of saved images in 3D mode only. Images can be adjusted for reconstruction of anatomical segment of interest with automatic segmentation using *MediCAD 3D* software products. The surgeon can use *MediCAD Individual* prosthesis software after preoperative planning with an implant of his choice. Information of an individual implant can be uploaded in a standalone tab from vendor. The surgeon is offered to fill out the form and download the ongoing planning in server platform with access allowed for doctors and vendors. Chat is available for effective communication between doctors and manufacturers.

MediCAD MOBILE software tool functions in 2D mode like *MediCAD Classic* with only *Knee* and *Leg* modules available what makes the difference with *MediCAD Classic*. *MediCAD MOBILE* incorporates implant details from three manufacturers only that is less in quantity as compared to *MediCAD Classic*. A number of implants offered by manufacturers in *MediCAD MOBILE* are much less than that in *MediCAD Classic*. For instance, there are 61 cups offered by Zimmer and 2842 cups offered by *MediCAD Classic*. *MediCAD* releases *IMPAX Orthopaedic Tools* (AGFA HealthcareN.V., Belgium) and *EndoMap* (Siemens, Germany). *IMPAX Orthopaedic Tools* and *EndoMap* can be supplied if the equipment is purchased from respective manufacturers.

Sectra AB (Sectra, Sweden), *TraumaCad* (BrainlabLtd, Germany), *OrthoView* (Meridian Technique Ltd, U.K.) and *Surgimap* (Nemaris Inc, U.S.A.) systems allow image realignment for reconstruction of anatomical segments of interest (prototype of *Trauma* module in MediCad), automatic segmentation of anatomical segments, geometric planning of surgical reconstruction using basic implant templates. These functions are not provided by the rest of DSSs presented in Table 1 facilitating solely 2D/3D based geometric measurements.

Three *TraumaCad* (BrainlabLtd, Germany) versions are available: client/server, standalone version and *TraumaCad Web*. The TraumaCad client/server consists of a server application that is set up by the administrator and client applications that run on any computers. The standalone version runs on a specific computer only and stores all its files, such as its configuration and implant templates. *TraumaCad Web* is a cloud application that runs on any computer.

OrthoView has no digital templating for vertebral column. *Surgimap*, in contrast to all DSSs presented in Table 1, is a free software tool that offers mobile application. The user has to initiate *desired implant vendor to use* function since it is not in default.

DSS overview suggests that *MediCAD, TraumaCAD, Surgimap, Sectra AB* and *OrthoView* are most suitable for planning orthopaedic procedure on spine and pelvis due to the availability of several anatomical locations. We'll further compare functional possibilities of the particular DSSs. Table 3 demonstrates total number of implant vendors for each DSS.

Mobile application is a vital trend in IT industry for physicians to allow diagnostic practices away from the workplace. Mobile technologies are closely associated with teleradiology systems providing remote consultations and transfer of radiological reports between physicians and medical organizations. Physician should get the knowledge of the platform (computer operating system) to use DSS on mobile devices or personal computer (PC). Table 3 presents mobile and PC operating systems to be used for DSS. Physician showed be aware of the operational platform (e.g. the DSS software application) considering its compatibility with user needs and operational context. Integration with a Picture Archiving and Communication System (PACS) improves the use of each of the above DSS. The own database can be developed with *TraumaCad* and *Surgimap* with one record being correspondent to one examination. The parameters can be automatically retrieved from DICOM [18] files.

Table 3

Data on implant vendors and platforms for physician's mobile devices and PC

DSS	Number of implant vendors	Platforms (OS) for mobile version	Platforms (OC) for physician PC
MediCad	123	Android 4.0+	Windows, Windows XP, Windows Vista, Windows 7, MacOS
TraumaCad	65	Win 8 and Win 10, iOS 9	Windows 7 и выше
Surgimap	13	iOS 8.0 и выше	Windows XP Service Pack 3 or and newer versions of Windows, MAC OS X
Sectra AB	54	–	Windows XP, Windows 7 и выше
OrthoView	76	–	Windows 7, 8 и выше, MacOS X

The parameters include full name, gender, date of birth, modality, date of investigation, description of investigation, diagnosis, number of series, ID (Table 4). Investigations can be ranged with the parameters and the desired lists can be stored. This allows image import from PACS system for an individual patient. Customized fields can be added to the *Surgimap* database that can be sorted and filtered by any field. Patient's name, gender, date of birth and national identifier are encoded with *SectraAB* and *OrthoView*.

3D images are presented as real-time 2D slices in horizontal, sagittal and coronal planes (MPR) with *TraumaCad* and *Surgimap*. Superficial 3D model can be added to MPR with *MediCAD* for more accurate planning due to habitual object construction (building). Measurements of 3D *MediCAD* model are concurrently reflected in 2D slices. The *MediCAD* function is termed as hybrid 2D/3D planning. The 3D model is most illustrative for implant placement or identification of implant geometric parameters. A *MediCAD* software tool is available for each anatomical location of orthopaedic surgery employing 3D images. 3D mode is incorporated with *TraumaCAD* and Surgimap systems by contrast to *MediCAD* with the mode being a separate program.

The DSS tools include:

General tools:

• Ruler tool: Measures a section of the image in pixels and millimeters;

• Circle tool: Measures the diameter of any round object;

• Angle tool: Measures an angles

• Interline angle: Measures the angle between two lines on an image;

• Line: Draws a line on an image.

***TraumaCad* specific tools**:

• Free hand line: Enables a surgeon to draw a free hand line on the image;

• Arrow: Draws an arrow to focus on the zone for further attention.

Table 5 presents additional functions of DSS. Measurements of the hip joint and the spine can be produced with the tools provided by the above DSSs. Comparative analysis of the DSS tools is given in Tables 6 and 7.

Table 4

General parameters of DSS databases

Parameter	DSS		
	MediCad	TraumaCad	Surgimap
Surname	+	+	+
First name	+	+	+
Gender	+	+	+
Date of birth	+	+	+
Modality	–	+	+
Date of examination	+	+	+
Description of examination	+	+	+
Diagnosis	–	–	+
Number of images	–	+	+
ID	+	+	+
Referring physician	+	+	–
Institution	–	+	–
Location	–	+	–
UID examination	–	+	–
UID series	–	+	–
Part of body	–	+	–
Description of series	–	+	–

Table 5

Additional DSS functions for geometric planning

Function	DSS				
	MediCAD Classic	Sectra AB	TraumaCAD	Surgimap	OrthoView
Implant synchronization	+	–	+	+	+
Image transparency	+	–	–	–	–
Segmentation	+	–	+	–	+
Detection of calibrators	+	–	+	–	+
Multimode image viewing	+	–	+	+	+
Zooming	+	+	+	+	+
Interactive help system	+	–	+	+	+

Table 6

Hip related measurements for geometric planning with DSS*

Target parameters	DSS				
	MediCAD Classic	Sectra AB	TraumaCAD	Surgimap	OrthoView
Iliac Angle [19]	–	–	–	–	+
Hilgenreiner Angle [20]	–	–	+	–	–
Hilgenreiner line [21]	–	–	–	–	+
Reimer Migration Index [22]	–	–	+	–	+
Leg Length Discrepancy [23]	+	–	+	+	+
Acetabular Angle [20, 24]	+	–	+	–	+
VCA Angle of Lequesne [25]	–	–	+	–	–
Center of Rotation [26]	–	–	+	–	–
Neck Shaft Angle [27]	+	–	+	–	+
Head Shaft (Slip) Angle	–	–	+	–	–
Articulo-trochanteric Distance [28]	–	–	+	–	–
Epiphyseal Index [29, 30]	–	–	+	–	–
Sharps Angle [31,32]	–	–	–	–	+
Range of Motion [33]	+	–	–	–	–
Transischial Line Wizard [34]	–	–	–	–	+
Perkins Line [20, 35]	–	–	–	–	+
Trans Teardrop Line [36]	–	–	–	–	+
Central Edge Angle [37]	–	–	+	–	+
Pelvic Parameters (Pelvic Incidence, Sacral Slope, Pelvic Tilt) [38]	+	+	+	+	–
Sacral Obliquity [39, 40]	–	–	+	–	–

* «+» denotes parameter measurements described in DSS User Guides

Table 7

Spine related measurements for geometric planning with DSS*

Description	DSS				
	MediCAD Spine	Sectra AB	TraumaCAD	Surgimap	OrthoView
Clavicie Angle [41]	–	–	+	–	–
Сагиттальный баланс [42-52]	+	+	+	+	–
Pelvic Incidence (PI)	+	+	+	+	–
Sacral Slope (SS)	+	+	+	+	–
Pelvic Tilt (PT)	+	+	+	+	–
Sagittal vertical axis (SVA)	–	+	–	+	–
C7 PL	+	–	–	+	–
Chin Brow Vertical Angle (CBVA)	–	–	–	+	–
Sagittal Pelvic Thickness	+	–	–	–	–
Pelvic Thickness	+	–	–	–	–
Pelvic Angulation	+	–	–	–	–
Pelvisacral Angle	+	–	–	–	–
Gravity Line	+	–	–	–	–
Lumbar lordosis	+	–	+	+	–
Spine Slip Angle	–	–	+	–	–
T1 Tilt Angle	–	–	+	+	–
Scoliosis using Cobb's method	+	–	+	+	+
Scoliosis using Ferguson's method	+	–	–	–	–
Thoracic Kyphosis Angle [53]	+	–	+	+	–
Instability using van Akkerveeken's method [54]	+	–	–	–	–
Spondylolisthesis (slippage of one vertebra versus another)	+	–	+	+	–
Intervertebral disc height [55]	+	+	+	+	+
Thoracic Trunk Shift [56]	–	–	+	–	–
Rib-vertebra angle difference	–	–	–	+	–
Stenosis	+	–	–	+	–
Vertebral Body Measurement	–	–	–	+	–

* «+» denotes parameter measurements described in DSS User Guides

Spine and hip related measurements were produced using **general tools** including Ruler, Circle, Angle and Line [43–49]:

- Gravity Line;
- C7TA;
- C7/SFD;
- Femoral gravity offset (FGO);
- Sacral gravity offset (SGO);
- Spino-sacral angle (SSA);
- Full Balance Integrated index (FBI);
- Angle of femur obliquity (FOA);
- Angle of tilt compensation (PTCA);
- Pelvic lordosis (PL);
- Central sacral vertical line (CSVL);
- Pelvic obliquity(PO);
- Sacral obliquity(SO);
- Wiberg Angle.

DSS also describes how to take anatomical measurements, compare them to normative standards and simulate corrective procedures for limb alignment analysis. **Figure 2** shows *TraumaCad* sacral obliquity tool measuring the angular deviation of the sacrum. Online prompt function is in the lower left corner to guide measurements of the parameter. The *TraumaCad* sagittal balance tool measures the alignment of the spine on the sagittal plane with vertical line. The *MediCad* sagittal balance is evaluated with the following parameters:

- Sacral Slope (SS) [43];
- Pelvic Tilt (PT) [43];
- Pelvic Thickness (SPT) [44];
- Pelvic Thickness (CS) [45];
- Pelvic Angulation (PA) [46];
- Pelvisacral Angle (PSA) [47];
- Pelvic Lordosis Angle (PLA) [48];
- Pelvic Incidence (PI) [49].

Overview of the DSSs is based on the analysis of geometric parameters and the systems can be evaluated as straightforward.

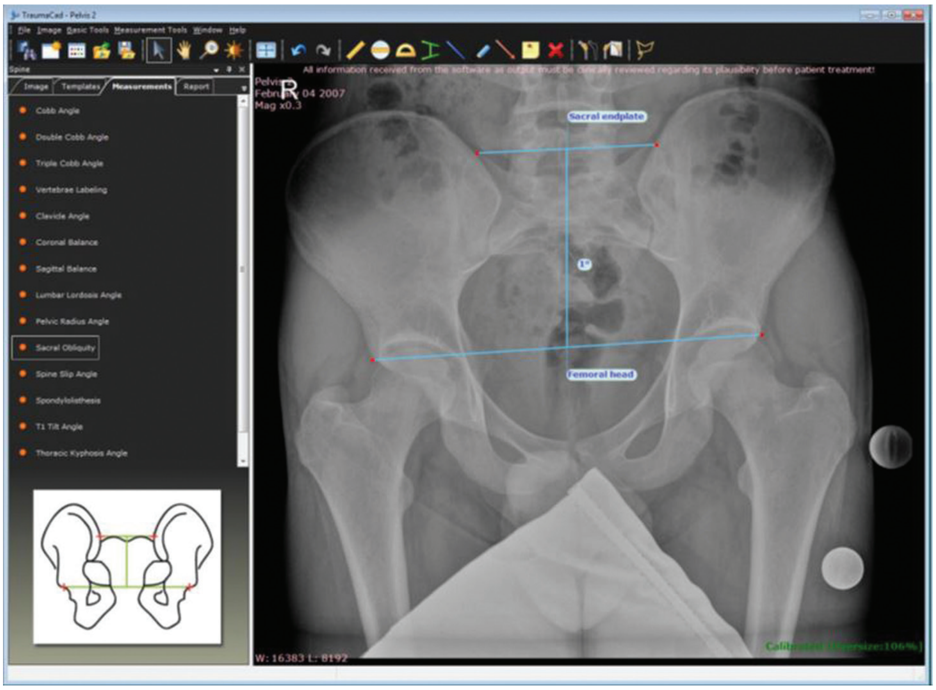


Fig. 2 Measuring sacral obliquity with *TraumaCad* tool [57]

DISCUSSION

Planning of reconstructive surgery is associated with complicated scientific technical and practical considerations to ensure successful procedure and beneficial outcome. Computer based programs termed DDS have been developed to address challenging anatomical disorders offering preoperative planning procedure. Review of the functional features of DDS showed that *MediCAD, TraumaCAD, Surgimap, Sectra AB* and *OrthoView* were most applicable for planning spine and hip surgery with software tools available for several anatomical locations of orthopedic surgery including spine, hip joint, knee, foot, femur, tibia, fibula, joints of upper limbs, and also offering an extensive implant template database. Comparison of parameters measured with the systems indicated to *MediCad* and *TraumaCad* as having greater potentials for spine and hip related measurements. None of the reviewed DSS can be used for all spine and pelvis related measurements although the estimated incidence of degenerative spine disorders is 5 120 per 100 000, and the estimated incidence of degenerative hip disorders is 250 per 100 000. Injuries to the spine are third cause of disability. Absolute number of spinal and skeletal injuries was 1 143 039 in 2015 with spinal fracture rate of 12.7 % (n = 145 166). The incidence of injuries to cervical and lumbar spine increased in 2016 with the prevalence being 60 fractures per 100 000 population [58].

Systems of preoperative planning including *MediCad, TraumaCad, Surgimap*, etc. allow geometric planning with geometric measurements and manipulations, realignment of anatomical structures, simulation of surgical procedure, selecting and positioning an implant. However, geometric planning only is not sufficient for providing rational treatment choices and some options made by the surgeon cannot guarantee positive outcome. Both geometrical planning and biomechanical simulation can be employed to improve quality of surgical planning. Biomechanical simulation allows assessment of the extent and pattern of disorders caused by malaligned SPC considering volume of surgical correction and fixation in view of new biomechanical circumstances with reconstruction options offered. Surgeons normally focus on spine and pelvic related measurements, sagittal and coronal alignment as important tools to calculate mechanical characteristics and estimate success of a surgery from biomechanical point of view. The role of biomechanical simulation in modern medicine has become increasingly prominent but none of the systems can fully realize the specified function [59–61]. It is the biomechanical modeling that is the basis for the biomechanical approach to preoperative planning facilitating individual implant selection and accurate positioning for global spine balance correction and postoperative prognosis.

CONCLUSION

We suggest that the concept of the DSS should involve geometrical planning, biomechanical modeling of postoperative condition and prognosis of long-term follow-up based on statistical data analysis. Introduction of DSS into clinical practice will facilitate the quality of medical care and rehabilitation with concurrent optimization of the national expenditure on health care through intended reduction in length of hospital stay, postoperative complication rate, untimely revision procedures and period of medical rehabilitation.

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