METHOD AND SYSTEM FOR SURGICAL PLANNING

TECHNICAL FIELD

[001]The present invention relates to a computer implemented method for anatomically planning or generating planning and visualisation data or information for at least part of a planning procedure related to performing surgery on a morbid body part.

BACKGROUND

[002] Any references to methods, apparatus or documents of the prior art are not to be taken as constituting any evidence or admission that they formed, or form part of the common general knowledge.

[003] It is common for surgeons to undertake detailed planning and often use computer simulations and other computer implemented methods or systems to plan surgical procedures where the anatomy is complex (i.e., revision surgeries where implants are already in-place, or complex pathologies which have altered the bone anatomy). The understanding of the bone anatomy is critical prior to surgery, to allow surgeons to plan the surgical procedure to use, as well as subsequent components and their optimal positions.

[004] By way of example, accurate implant positioning is crucial to ensure a successful outcome of shoulder arthroplasty. Malpositioning of the glenoid component can lead to scapular notching, implant loosening or instability. Significant glenoid bone defects can be encountered in patients with severe osteoarthritis,

previous failed shoulder replacement procedure, cuff tear arthropathy with glenoid erosion, or chronic glenohumeral dislocation. Moreover, intraoperative view of the scapula is limited, and difficult surgical exposure pose significant challenges for the orthopaedic surgeon intraoperatively. Preoperative evaluation of scapular and glenoid anatomy and surgical planning are crucial steps to ensure successful postoperative outcomes.

[005] Three-Dimensional (3D) planning software has assisted in preoperative planning of complex glenoid deformities. However, known methods have failed to reliably define or visualise a pre-morbid condition of a scapula joint and it is desirable to provide an improved method and system to assist surgeons with preoperative planning.

SUMMARY OF INVENTION

[006] In an aspect, the invention provides a computer implemented method of generating a premorbid visualization model of an actual morbid body part, comprising the steps of:

accessing a computer memory, the computer memory storing a statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part;

retrieving identifiers associated with pre-defined landmarks of the body part from the statistical shape model;

accessing data derived from the morbid body part of the patient to form a geometric model that represents the three-dimensional shape of the body part;

performing rigid alignment of the geometrical model of the morbid body part and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical model of the morbid body part and the statistical shape model (SSM);

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid body part and its anatomical equivalent in the rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid body part and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid body part wherein the extracted geometrical model of the morbid body part and the extracted model of the mean shape (MS) represent non-damaged regions of the body part respectively;

marginalizing the statistical shape model (SSM) of the body part to the extracted model of the mean shape (MS) to obtain a marginalized SSM and non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid body part to generate a premorbid visualization model of the morbid body part.

[007] In another aspect, there is provided a computer implemented method of calculating premorbid anatomical measurements of an actual morbid body part, comprising the steps of:

accessing a computer memory, the computer memory storing a statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part;

retrieving identifiers associated with pre-defined landmarks of the body part from a mean shape (MS) of the statistical shape model;

accessing data derived from the morbid body part of the patient to form a geometric model that represents the three-dimensional shape of the body part;

performing rigid alignment of the geometrical model of the morbid body part and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical models of the morbid body part and the statistical shape model (SSM);

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid body part and rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid body part and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid body part wherein the extracted geometrical model of the morbid body part and the extracted model of the mean shape (MS) represent non-damaged regions of the body part respectively;

marginalizing the statistical shape model (SSM) of the body part to non-damaged regions of the morbid body part to obtain a marginalized SSM and non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid body part to generate a premorbid visualization model of the morbid body part; and utilizing the pre-defined landmarks from the extracted model of the mean shape (MS) for calculating the premorbid anatomical measurements.

[008] In another aspect, the invention provides a computer implemented method of generating a premorbid visualization model of an actual morbid human scapula, comprising the steps of:

accessing a computer memory, the computer memory storing a statistical shape model (SSM) of a scapula built based on training set data and corresponding to an actual scapula;

retrieving identifiers associated with pre-defined landmarks of the scapula from a mean shape (MS) of the statistical shape model;

accessing data derived from the morbid scapula of the patient to form a geometric model that represents the three-dimensional shape of the scapula of the patient;

performing rigid alignment of the geometrical model of the morbid scapula and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical models of the morbid scapula and the statistical shape model (SSM);

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid scapula and its anatomical equivalent in the rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid scapula and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid scapula wherein the extracted geometrical model of the morbid scapula and the extracted model of the mean shape (MS) represent non-damaged regions of the morbid scapula respectively;

marginalizing the statistical shape model (SSM) of the scapula to the extracted model of the mean shape (MS) to obtain a marginalized SSM and non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid scapula to generate a premorbid visualization model of the morbid scapula.

[009] In another aspect, the invention provides a computer implemented method of generating a premorbid visualization model of an actual morbid human scapula, comprising the steps of:

accessing a computer memory, the computer memory storing a statistical shape model (SSM) of a scapula built based on training set data and corresponding to an actual scapula;

retrieving identifiers associated with pre-defined landmarks of the scapula from a mean shape (MS) of the statistical shape model;

accessing data derived from the morbid scapula of the patient to form a geometric model that represents the three-dimensional shape of the scapula of the patient;

performing rigid alignment of the geometrical model of the morbid scapula and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical model of the morbid scapula and the statistical shape model (SSM);

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid scapula and its anatomical equivalent in the rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid scapula and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid scapula;

marginalizing the statistical shape model (SSM) of the scapula to the extracted model of the mean shape (MS) to obtain a marginalized SSM and non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid scapula to generate a premorbid visualization model of the morbid scapula and utilizing the pre-defined landmarks from the mean shape and the premorbid visualization model for calculating the premorbid anatomical measurements.

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[0010] In an embodiment, the step of retrieving the identifiers is carried out by non-rigid coherent point drift (CPD) fitting of the statistical shape model (SSM) to the geometric model of the three-dimensional shape of the scapula or body part of the patient by using an increased Gaussian process variability of the statistical shape model (SSM).

[0011] In an embodiment, the identifiers are used to further refine fitting of the statistical shape model (SSM) to the pathological shape and generate cutting

landmarks by projecting the pre-defined landmarks from the result of the fitting to the geometric model that represents the three-dimensional shape of the morbid scapula/body part of the patient and wherein the cutting landmarks are utilized for extracting portions from the geometrical model of the morbid body part and rigidly aligned model of the mean shape (MS) to form the extracted geometrical model of the morbid body part and the extracted model of the mean shape (MS) respectively.

[0012] In an embodiment, the rigid alignment step comprises running a pose estimation algorithm to match the point clouds of the mean shape (MS) of the statistical shape model (SSM) and the geometric model that represents the three-dimensional shape of the morbid body part/scapula.

[0013] In an embodiment, the computer implemented method further comprises running an Iterative Closest Points (ICP) algorithm to further refine the rigid alignment step.

[0014] In an embodiment, the step of utilizing the pre-defined landmarks from the extracted model of the mean shape (MS) to retrieve required landmarks for calculating the premorbid anatomical measurements.

[0015] In an embodiment, the computer implemented method further comprises the step of calculating anatomical measurements on the three-dimensional model of the morbid body part/scapula.

[0016] In an embodiment, the step of calculating anatomical measurements on the three- dimensional shape of the body part with predefined landmark-based shape condition for an intended population.

[0017] In an embodiment, the step of calculating anatomical measurements on the three- dimensional shape of the body part with predefined landmark-based shape condition for an intended population to use in surgical component design.

[0018] In another aspect, the invention provides computer implemented method of generating a visualization model of an actual body part, comprising the steps of: accessing a computer memory, the computer memory storing statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part; retrieving identifiers associated with pre-defined landmarks of the body part from the statistical shape model; accessing data derived from the SSM of body part of the patient to form a geometric model that represents the three-dimensional shape of the body part with predefined landmark- based shape condition.

[0019] In yet another aspect, the invention provides computer implemented method to calculate landmark-based measurement for a generated visualization models of an actual body part, comprising the steps of: accessing a computer memory, the computer memory storing statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part; retrieving identifiers associated with pre-defined landmarks of the body part from the statistical shape model; accessing data derived from the SSM of body part of the patient to form a geometric model that represents the three-dimensional shape of the body part with predefined shape condition for an intended population; and calculating the landmark based predefined measurements on the derived data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the invention. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings as follows:

Figure 1 is a refers to a sequence of steps for creating a statistical shape model of the scapula.

Figure 2 provides an overview of the various steps involved in generating the visualisation of the premorbid scapula and the associated anatomical calculations.

Figure 3 illustrates measurement of scapula width and scapula height for an exemplary scapula.

Figure 4 is a visual representation of the Mean Shape (MS) of the SSM that is rigidly aligned with the three-dimensional model of the pathological scapula.

Figure 5A is an automatically generated three-dimensional model of the pathological scapula with identified glenoid and coracoid region (red). Figure 5B denotes the MS of the SSM with the identified glenoid and coracoid region (red). Figure 5C denotes a pathological scapula blade with the three cutting landmarks (pink). Figure 5D denotes the MS scapulae blade with the three cutting landmarks (green).

Figure 6A shows a posterior model of the marginalized SSM to the scapula blade of the pathological shape; Figure 6B shows the premorbid shape (grey) fitted to the pathological scapula (transparent beige).

Figure 7 is a detailed workflow for the premorbid shape and anatomical measurements described in this document, which includes a detailed breakdown of the main steps, outlining the specific process involved. The Figure describes the application of pre-processing, both rigid and non-rigid alignment techniques, highlighting how they are implemented. Additionally, the retrieval of landmarks from Pathological and SSM is specified, emphasizing their subsequent utilization in the following stages of the process.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0021] The detailed embodiment described herein refers specifically to a computer implemented method of generating a premorbid model of a morbid scapula of a patent. However, it must be understood that the broadly described invention is not in any way limited to only developing a premorbid model of the scapula joint. The invention may be used for generating premorbid models and associated premorbid anatomical calculations for other morbid body parts without departing from the spirit and scope of the invention.

[0022] Figures 1 refers to a sequence of steps for creating a statistical shape model of the scapula. The input data consists of a set of 113 3D models of morphologically healthy scapulae selected by an experienced surgeon (Table 1).

Sex	**Number of samples**	**Mean Age**
Female	41	50
Male	72	32
TOTAL	**113**	**39**

These 3D models originated from CT scans which were acquired using a standardised clinical protocol. The Digital Imaging in Communications and Medicine (DICOM) images of each scan were manually segmented by trained independent personnel with relevant training in shoulder anatomy and manual medical image segmentation using Mimics 24.0 software (Materialise, Leuven, Belgium), and 3D mesh models were reconstructed. All the included CT images had a slice increment or thickness of less than 1mm. All the left scapulae were mirrored to right. Pre-processing was then required to ensure an isotropic vertex placement over the surface and no holes in the final meshes. Same number of vertices was attributed to each of the meshes. Further analysis was performed to define morphometric characteristics of the reconstructed 3D models of the scapula using 3D measurements. These measurements include scapula width and scapula height (Figure 3). 3D measurements of scapula height and scapula width. Scapula height is defined as the distance between the superior angle landmark (SP) and Angulus Inferior (AI) points. Scapular width is calculated distance between the tip of the Angulus Acromialis (AA) and the medial end of the scapular spine, called also the Trigonum Spinae (TS).

[0023] Scapula height is defined as the distance between the superior angle landmark (SP) and Angulus Inferior (AI) points. Scapular width is calculated distance between the tip of the A*ngulus Acromialis* (AA) and the medial end of the scapular spine, called also the Trigonum Spinae (TS).

[0024] The 3D meshes had to be rigidly aligned before building the model to establish true shape representations of the data. Rigid alignment was performed using rigid CPD (Coherent Point Drift), which involves bringing all the shapes into the

same 3D space and aligning them using an automated iterative implementation of the rigid CPD algorithm, ensuring they are positioned accurately for further processing.

[0025] Once all the shapes are rigidly aligned using the rigid CPD algorithm, a crucial phase in the SSM development process is establishing one-to-one correspondence across all the 3D models in the dataset. During the step of generating the SSM, this correspondence was achieved through the non-rigid implementation of the CPD algorithm.

[0026] This data in correspondence was then used to create a Point Distribution Model (PDM) using Principal Component Analysis (PCA). PCA is a projection-based reduction method to reduce data dimensionality by linearly transforming the data to a new coordinate system. PCA is used to explore the patterns or the major allowable variations within the high dimensional 3D surface data after the adequate alignment and shape correspondence thus establishing statistical shape models for the scapula.

3D meshes of scapulae were aligned and mirrored to create Statistical Shape Models (SSMs) for both the right and left sides. These SSMs enable the representation of the average scapula shape and its various statistical variations (mode of variations). Right and left SSMs were created and saved as .h5 files.

[0027] Figure 1 illustrates an exemplary process for generating the SSM. It must be understood that the invention is in no way limited to the specific way of generating the SSM. Methods of generating the SSM may vary depending on the body part and the surgical requirements.

[0028] Once the SSM has been created, the next step allows the reconstruction of the premorbid shape of the scapula from a 3D mesh of pathological scapula by fitting the built SSMs on the pathological scapular blade. This is the main module as the outputs of this module will be used as input in the calculation of premorbid and pathological landmarks and measurements. The following Figure summarizes the main steps of the premorbid shape reconstruction and measurements calculation for reference. Figure 2 provides an overview of the various steps involved in generating the visualisation of the premorbid scapula and the associated anatomical calculations.

[0029] In the presently described embodiment, scapula with glenoid bone defect can range from mild to severe as pathological scapula. To reconstruct the premorbid glenoid shape of the pathological scapula, the fitting method takes into considerations the scapular shape except the glenoid and the coracoid process. For these reasons, scapula bone with fractures, bony abnormalities or any previous surgeries in any part other than the glenoid and the coracoid process are not eligible for this module.

[0030] At this stage, the input data is the two (.h5) files of right and left SSMs, the identifiers of the key scapular landmarks and the (.stl) file of the pathological scapula mesh. According to the user input of the side of the pathological scapula (Right or Left), one of the .h5 files, including the SSM of the same side, is going to be uploaded. All input data may be entered manually or data entry may be automated.

Preprocessing and Alignment of SSM and 3D Model

[0031] The first step consists of performing a preprocessing of the pathological shape involves cleaning the mesh in order to remove all the extra pieces and decimate the mesh while maintaining the same shape representation and generate a three-dimensional geometric model of the pathological scapula.

A rigid alignment step between the three-dimensional geometric model of the scapula and the SSM is carried out. The rigid alignment step consists of running a pose estimation algorithm to 3D match the point clouds of the Mean Shape (MS) of the SSM and the pathological scapula and then run an Iterative Closest Points (ICP) algorithm to further refine the rigid alignment. This 3D point clouds matching method presents the best fit frame for MS as well as the pathological scapula and determines the best transformation matrix between the non-corresponding point clouds. This transformation is then applied to the MS to rigidly align with the pathological scapula. Iterative Closest Points (ICP) algorithm is applied to rigidly align the MS of the SSM to the pathological scapula using number of points uniformly distributed over the surface (according to a decimation percentage). The idea of ICP is that we can approximate the correspondences between the reference and the target meshes, by simply assuming that the corresponding point of the reference mesh is always the closest points on the target mesh.

[0032] Figure 4 is a visual representation of the Mean Shape (MS) of the SSM that is rigidly aligned with the three-dimensional model of the pathological scapula.

Glenoid and Coracoid extraction

[0033] Once both the MS of the SSM and Pathological shape are rigidly aligned, the extraction of the glenoid and coracoid is performed to cut out regions that represent the glenoid bone defect. To achieve this, a two-stages non-rigid CPD + non-rigid landmark-based CPD was used to fit the SSM to the pathological shape and use the identifiers of the predefined landmarks to identify and extract glenoid and coracoid regions of both pathological and result of the fitting.

[0034] Using the rigidly aligned shapes, the first stage non-rigid CPD was performed to non-rigidly fit the SSM to the target pathological shape using an increased Gaussian process variability of the SSM. The aim for this stage is to retrieve the AI, AA, and TS landmarks on the pathological scapula. This was achieved using the projected landmarks of the results of the fitting on the pathological scapula shape.

[0035] These landmarks were then used in the second stage landmark based CPD fitting to refine even further the fitting of the SSM to the pathological shape and retrieve the cutting landmarks. The resulted shape from fitting the SSM to the pathological shape is a shape in correspondence with the SSM dataset. Using this shape in correspondence and the landmarks Identifiers, the cutting landmarks were retrieved by projecting these landmarks from the result of the fitting to the pathological shape.

[0036] These cutting landmarks include: Infraglenoid tubercle, the Great scapular notch, and suprascapular notch. Then, the glenoid and coracoid region extraction was performed using these landmarks on the MS of the SSM and the pathological

shape.The new shape in correspondence is also used to better adjust the landmark estimation of TS, AA and AI of pathological shape for further steps.

[0037] We will henceforth, in this document, refer to the scapula shape with the glenoid and coracoid region cut out as the scapular blade. Both the scapular blades of the pathological scapula and MS are going to be used in the next step of retrieving the premorbid shape of the scapula.

[0038] Figure 5A denotes a three-dimensional model of the pathological scapula with identified glenoid and coracoid region (red). Figure 5B denotes the MS of the SSM with the identified glenoid and coracoid region (red). Figure 5C denotes a pathological scapula blade with the three cutting landmarks (pink). Figure 5D denotes the MS scapulae blade with the three cutting landmarks (green).

Output Premorbid Scapula and Anatomic Landmarks

[0039] Initially, the SSM was marginalised to the MS scapular blade obtained after cutting out the glenoid and coracoid region. The distribution of the SSM is represented as a Gaussian process. The marginalization property of the Gaussian process enables the distribution for a subset of points to be obtained from the full Gaussian process. The result of marginalization is a discrete Gaussian process. In this instance, the SSM initially built on the full shape of the scapula was marginalized to the scapular blade after cutting out the glenoid and coracoid region.

Then, the gaussian process of the marginalized SSM along with its MS is used to non-rigidly fit to the pathological scapula blade without the bone defect region. The fitting process in this case is based on the use of a third non-rigid landmark based CPD algorithm stage, using the three previously estimated landmarks as reference (AI, AA, and TS) .

[0040] This fitting process returns the posterior fitted model of the marginalized SSM to the scapula blade of the pathological shape.

[0041] Once the fitted posterior model obtained, its updated parameters are then retrieved and applied to the SSM with the full scapula shape (glenoid/coracoid region included), obtaining the scapula blade fitting output along with the glenoid/coracoid region calculated from the posterior model parameters.

[0042] This approach ensures the preservation of the anatomical integrity of the glenoid and coracoid region, maintaining a representation consistent with healthy scapula morphology. The resulting premorbid scapula shape serves as the foundation to calculate the premorbid and pathological glenoid anatomical measurements.

[0043] Figure 6A shows a posterior model of the marginalized SSM to the scapula blade of the pathological shape; Figure 6B shows the premorbid shape (grey) fitted to the pathological scapula (transparent beige).

Calculation of the anatomical measurements of the premorbid shape of the scapula

[0044] The calculation of the premorbid anatomical measurements was carried out after the model or visualisation of the premorbid scapula was prepared in a manner as outlined in the preceding sections. In the preferred embodiment, an algorithm may be used to calculate anatomical landmarks coordinates and anatomical measurements of the premorbid shape reconstruction, which may be then optionally reviewed manually for correction and acceptance.

[0045] At this stage, the input data is the reconstructed premorbid shape of the pathological scapula in correspondence with the mean shape (MS) (output from 03.02.1). The landmarks required for the anatomical parameters' calculation are included on the mean shape of the SSM. These include Angulus Acromialis (AA), Angulus Inferioris (AI), Trigonum Spinae (TS), the Supra Glenoid Tubercle (SGT), 10 points selected on the inferior glenoid rim, and the points representing the glenoid rim surface.

[0046] As mentioned above, the reconstructed premorbid shape of the scapula is in one-to-one correspondence with the MS of the SSM. Landmarks' identifiers are then collected to retrieve the required landmarks for measurements' calculation. These measurements include Glenoid centre, the radius of the best-fit circle, glenoid version, glenoid inclination, glenoid height, and glenoid width.

[0047] The glenoid centre (GC) is defined as the centre of the best-fit circle calculated from the 10 points of the inferior rim of the reconstructed premorbid shape of the glenoid. The radius of the best-fit circle is also provided.

[0048] The glenoid version represents the angular orientation of the glenoid with respect to the body of the scapula.

[0049] To calculate the glenoid version of the premorbid shape of the scapula, the steps bellow are followed:

- Calculate the scapular plane defined as the plane going through GC, TS and AI.
- Define the plane perpendicular to the scapular plane passing through the GC point. We refer to this plane as the “XY scapular plane”.
- Calculate the glenoid plane defined as the plane going through GC, SGT and TS.
- Two points are defined as the intersection of the plane perpendicular to the glenoid plane passing through GC and the glenoid rim. These two points represent the most anterior (Anterior glenoid Point) and the most posterior (Posterior glenoid) points of the glenoid rim and the line between them is called the “Version Line”.
- The glenoid version is calculated as the angle (in Degrees) between the “XY scapular plane” and the “Version Line”.

[0050] The glenoid width is calculated as the distance (in millimetres) between the most anterior and the most posterior points of the glenoid rim used to calculate the glenoid version.

[0051] To calculate the glenoid inclination, the most superior (glenoid superior point) and the most inferior (Glenoid inferior point) points of the glenoid rim are defined as the intersection between the scapular plane the premorbid glenoid rim. Then, angle (in degrees) between the “Inclination line” formed between these two points and the “XY scapular plane” is calculated.

[0052] The glenoid height is calculated as the distance (in millimetres) between the most superior and the most inferior points of the glenoid rim used to calculate the glenoid inclination.

[0053] The output is one csv file with the following data:

- Anatomical landmarks (anterior glenoid point , posterior glenoid point, superior glenoid point, inferior glenoid point, AA, AI, TS, SGT) and GC coordinates
- Anatomical measurements (best-fit circle radius, glenoid version, glenoid inclination, glenoid width, glenoid height)

[0054] In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. The term “comprises” and its variations, such as “comprising” and “comprised of” is used throughout in an inclusive sense and not to the exclusion of any additional features.

[0055] It is to be understood that the invention is not limited to specific features shown or described since the means herein described comprises preferred forms of putting the invention into effect.

[0056] The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted by those skilled in the art.

CLAIMS

1. A computer implemented method of generating a premorbid visualization model of an actual morbid body part, comprising the steps of:

accessing a computer memory, the computer memory storing statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part;

retrieving identifiers associated with pre-defined landmarks of the body part from the statistical shape model;

accessing data derived from the morbid body part of the patient to form a geometric model that represents the three-dimensional shape of the body part;

performing rigid alignment of the geometrical model of the morbid body part and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical models of the morbid body part and the SSM;

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid body part and its anatomical equivalent in the rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid body part and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid body part wherein the extracted geometrical model of the morbid body part and the extracted model of the mean shape (MS) represent non-damaged regions of the body part respectively;

marginalizing the statistical shape model (SSM) of the body part to the extracted model of the mean shape (MS) to obtain a marginalized SSM; and;

non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid body part to generate a premorbid visualization model of the morbid body part.

2. A computer implemented method of calculating premorbid anatomical measurements of an actual morbid body part, comprising the steps of:

accessing a computer memory, the computer memory storing a statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part;

retrieving identifiers associated with pre-defined landmarks of the body part from a mean shape (MS) of the statistical shape model;

accessing data derived from the morbid body part of the patient to form a geometric model that represents the three-dimensional shape of the body part;

performing rigid alignment of the geometrical model of the morbid body part and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical models of the morbid body part and the statistical shape model (SSM);

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid body part and rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid body part and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid body part wherein the extracted geometrical model of the morbid body part and the extracted model of the mean shape (MS) represent non-damaged regions of the body part respectively;

marginalizing the statistical shape model (SSM) of the body part to the extracted model of the mean shape (MS) to obtain a marginalized SSM; and

non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid body part to generate a premorbid visualization model of the morbid body part; and utilizing the pre-defined landmarks from the extracted model of the mean shape (MS) for calculating the premorbid anatomical measurements.

3. A computer implemented method of generating a premorbid visualization model of an actual morbid human scapula, comprising the steps of:

accessing a computer memory, the computer memory storing a statistical shape model (SSM) of a scapula built based on training set data and corresponding to an actual scapula;

retrieving identifiers associated with pre-defined landmarks of the scapula from a mean shape (MS) of the statistical shape model;

accessing data derived from the morbid scapula of the patient to form a geometric model that represents the three-dimensional shape of the scapula of the patient;

performing rigid alignment of the geometrical model of the morbid scapula and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical models of the morbid scapula and the statistical shape model (SSM);

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid scapula and its anatomical equivalent in the rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid scapula and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid scapula wherein the extracted geometrical model of the morbid scapula and the extracted model of the mean shape (MS) represent non-damaged regions of the scapula respectively;

marginalizing the statistical shape model (SSM) of the scapula to the extracted model of the mean shape (MS) to obtain a marginalized SSM; and

non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid scapula to generate a premorbid visualization model of the morbid scapula.

4. A computer implemented method of generating a premorbid visualization model of an actual morbid human scapula, comprising the steps of:

accessing a computer memory, the computer memory storing a statistical shape model (SSM) of a scapula built based on training set data and corresponding to an actual scapula;

retrieving identifiers associated with pre-defined landmarks of the scapula from a mean shape (MS) of the statistical shape model;

accessing data derived from the morbid scapula of the patient to form a geometric model that represents the three-dimensional shape of the scapula of the patient;

performing rigid alignment of the geometrical model of the morbid scapula and of the mean shape (MS) of the statistical shape model (SSM) to obtain a rigidly aligned geometrical model of the morbid scapula and the statistical shape model (SSM);

utilizing the identifiers for extracting damaged portions from the geometrical model of the morbid scapula and its anatomical equivalent in the rigidly aligned model of the mean shape (MS) to form extracted geometrical model of the morbid scapula and extracted model of the mean shape (MS) respectively; the damaged portions representing damaged regions of the morbid scapula wherein the extracted geometrical model of the morbid body part and the extracted model of the mean shape (MS) represent non-damaged regions of the scapula respectively;

marginalizing the statistical shape model (SSM) to non-damaged regions of the morbid scapula to obtain a marginalized SSM; and

non-rigidly fitting the marginalized SSM with the extracted geometric model of the morbid scapula to generate a premorbid visualization model of the morbid scapula and utilizing the pre-defined landmarks from the mean shape and the premorbid visualization model for calculating the premorbid anatomical measurements.

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5. A computer implemented method in accordance with any one of the preceding claims wherein the step of retrieving the identifiers is carried out by non-rigid coherent point

drift (CPD) fitting of the statistical shape model (SSM) to the geometric model of the three-dimensional shape of the scapula or body part of the patient by using an increased Gaussian process variability of the statistical shape model (SSM).

6. A computer implemented method in accordance with claim 5 wherein the identifiers are used to further refine fitting of the statistical shape model (SSM) to the pathological shape and generate cutting landmarks by projecting the pre-defined landmarks from the result of the fitting to the geometric model that represents the three-dimensional shape of the morbid scapula/body part of the patient and wherein the cutting landmarks are utilized for extracting portions from the geometrical model of the morbid body part and rigidly aligned model of the mean shape (MS) to form the extracted geometrical model of the morbid body part and the extracted model of the mean shape (MS) respectively.

7. A computer implemented method in accordance with any one of the preceding claims wherein the rigid alignment step comprises running a pose estimation algorithm to match the point clouds of the mean shape (MS) of the statistical shape model (SSM) and the geometric model of the morbid body part/scapula that represents the three-dimensional shape of the morbid body part/scapula.

8. A computer implemented method in accordance with claim 7 further comprises running an Iterative Closest Points (ICP) algorithm to further refine the rigid alignment step.

9. A computer implemented method in accordance with any one of the preceding claims wherein the step of utilizing the pre-defined landmarks from the extracted model of the mean shape (MS) to retrieve required landmarks for calculating the premorbid anatomical measurements.

10. A computer implemented method in accordance with any one of the preceding claims further comprising the step of calculating anatomical measurements on the three-dimensional model of the morbid body part/scapula.

11. A computer implemented method in accordance with any one of the preceding claims further comprising the step of calculating anatomical measurements on the three- dimensional shape of the body part with predefined landmark-based shape condition for an intended population.

12. A computer implemented method in accordance with any one of the preceding claims further comprising the step of calculating anatomical measurements on the three- dimensional shape of the body part with predefined landmark-based shape condition for an intended population to use in surgical component design.

13. A computer implemented method of generating a visualization model of an actual body part, comprising the steps of:
accessing a computer memory, the computer memory storing statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part;
retrieving identifiers associated with pre-defined landmarks of the body part from the statistical shape model;
accessing data derived from the SSM of body part of the patient to form a geometric model that represents the three-dimensional shape of the body part with predefined landmark- based shape condition.

14. A computer implemented method to calculate landmark-based measurement for a generated visualization models of an actual body part, comprising the steps of:

accessing a computer memory, the computer memory storing statistical shape model (SSM) of a body part built based on training set data and corresponding to an actual body part;

retrieving identifiers associated with pre-defined landmarks of the body part from the statistical shape model;

accessing data derived from the SSM of body part of the patient to form a geometric model that represents the three-dimensional shape of the body part with predefined shape condition for an intended population; and

calculating the landmark based predefined measurements on the derived data.