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IMPACTOR DEVICE

[0001] This invention relates to a device for limiting a force applied by an impactor.

BACKGROUND

5 [0002] Many orthopaedic joint replacement procedures are performed each year, often involving a modular, i.e. multiple-part, replacement joint. Total hip replacements are one such procedure, where a surgeon selects a combination of a particular femoral stem and a particular femoral head and secures them together in the operating theatre. This kind of modular system provides an efficient way of ensuring the patient is given a replacement
10 joint that is most appropriate for them, as joint components will come in different shapes and sizes corresponding to the naturally occurring joint surfaces. The two joint components are typically secured together by hitting the femoral head onto the femoral stem with a hammer. An impactor is often placed against the femoral head component to prevent damage to the femoral head by the strike and to guide the force of the impact to the
15 components. It is down to the skill of the individual surgeon to know whether they have hit the impactor, and thus the femoral head, with sufficient force to secure the components together.

[0003] A Morse taper is one way of connecting the femoral head to the neck of the femoral stem. This involves a tapered male section on the femoral neck with a series of
20 ridges formed thereon and a corresponding tapered female section on the femoral head. Impacting the femoral head while connected to the femoral stem deforms the series of ridges and creates an interference fit between the two components, thus securing the femoral head to the femoral stem. While a tapered connection provides a convenient way of securing the two components together, it is not without problems.

25 [0004] One problem is the risk of corrosion between the femoral stem and the femoral head when a metal femoral stem and a metal femoral head are used. Corrosion between these two components occurs when metallic debris formed in the tapered sections causes trunnionosis, which is an adverse tissue reaction that can lead to total failure of the joint and require further corrective surgery.

30 [0005] Additional considerations arise when a ceramic femoral head is used with a metal femoral stem. Here, particular care must be taken when impacting the femoral head, as use of excessive force can cause the ceramic head to fracture. Conversely, if too little force is used, there will be insufficient energy to sufficiently deform the ridges on the femoral neck and a weak connection between the femoral stem and the femoral head will
35 be formed. A weak connection between the components of the replacement joint can result

in an increased fracture risk post-operatively as well as component failure due to the weak connection. Furthermore, as the modular components are secured *in vivo*, care should be taken to avoid using excessive force to secure the modular components, as the impact is also transferred to the patient as the different components are secured to each other.

- 5 **[0006]** Many other aspects of orthopaedic surgery rely on a similar, surgeon applied, impact technique. These include reaming cavities in the bone, seating cementless implants among other activities. The present invention may find application in a large number of processes that require surgical mallet strikes to deliver force.

[0007] The present invention seeks to address at least some of these problems.

10 **BRIEF SUMMARY OF THE DISCLOSURE**

- [0008]** Viewed from a first aspect, the present invention provides a device for limiting a force applied by a tool to a target object, the device comprising a first part , and a deformable member arranged to contact the first part and deform upon application of the force by the tool to the device. The first part and the deformable member are arranged to
15 define a load path between first and second sides of the device. The deformable member is configured to deform when the force through the load path is above a first pre-determined level, thereby absorbing a first amount of the force, so as to impart a resultant force to the target object no greater than the first pre-determined level.

- [0009]** Thus, the present invention provides a device that can be struck with forces
20 above a threshold, but will only transmit a force to the target object at the level of the threshold, while absorbing any impact forces above the threshold. This is particularly advantageous, for example, in orthopaedic surgery where joint replacement components need to be hit with sufficient force to secure the components together, but not with so much force that any of the components or adjacent bone surfaces become damaged.

- [0010]** The device may further comprise a visual indicator configured to display
25 information indicative of a state of the deformable member. This is advantageous as the surgeon is provided with a simple way of knowing whether or not the target object has been hit with sufficient force. Moreover, the visual indicator indicates when the deformable member should not be used again due to excessive deformation of the deformable
30 member. Specifically, the visual indicator will indicate when the deformable member has deformed to the extent that it can no longer absorb further strikes exceeding the pre-determined threshold, thus informing the surgeon the device, or the deformable member if separable from the device, should be replaced.

- [0011]** The visual indicator may comprise at least one surface feature disposed on a
35 surface of the device. The at least one surface feature may be indicative of the height of

the deformable member. The visual indicator may comprise at least one surface feature disposed on an outer surface of the second part. The visual indicator may comprise at least one surface feature disposed on an outer surface of the deformable member.

[0012] The visual indicator may comprise a slotted section in a side wall of the first part.

- 5 The at least one surface feature may comprise at least one protrusion extending away from the surface of the device and into the slotted section. The first part may comprise an outer surface having at least one surface feature indicative of the height of the deformable member.

- [0013]** The visual indicator may comprise at least one surface feature disposed on a side
10 surface of the deformable member. The visual indicator may comprise a slotted section in a side wall of the first part. The at least one surface feature may comprise at least one protrusion extending away from the side surface of the deformable member and into the slotted section.

- [0014]** The tool may comprise an impactor head having a distal end and the device may
15 comprise an attachment for mounting on the impactor head. When so mounted, the deformable member is secured to the distal end of the impactor head. The first part may be mountable to the impactor head. This is advantageous, as the surgeon does not need to hold the device and the modular component in the same hand when striking the device with their other hand. This increases the usability of the device, as the surgeon is able to
20 hit the modular components as before while only needing to hold the modular component, but can now more readily use higher levels of force to efficiently secure the components together without the risks of using excessive force.

- [0015]** The device may be comprised within an impactor head of the tool. This would be particularly advantageous as the force-limiting components would be integrated within the
25 tool itself, thus providing greater usability to the surgeon. In one advantageous case, the tool can be a hammer having the force-limiting components integrated therein.

- [0016]** At least a first section of the deformable member may be configured to plastically deform when the force is greater than the first pre-determined level. This is advantageous, as plastic deformation is permanent, and the surgeon is able to confirm the amount of
30 force used based on the height of the deformable member after striking the device.

[0017] The deformable member may comprise a lattice structure or a foam region. These structures provide greater control over how the deformable structure will yield, thus providing greater tolerances in the amount of excess force that may be absorbed.

[0018] The deformable member may be separable from the first part. This is particularly advantageous, as a separable deformable member allows for the device to be re-useable, as deformable members may be replaced once they have been used.

5 **[0019]** The deformable member may comprise any of a plastic or a metal material. This is particularly advantageous, as the deformable member may thus be made using additive manufacturing techniques.

[0020] The device may further comprise at least one frangible member in the load path. The frangible member may be configured to break when the load exceeds a second pre-determined level. In use, breaking the frangible member can provide visual, audible and/or
10 haptic feedback. This is particularly advantageous, as the surgeon is provided with feedback in different modalities.

[0021] The second pre-determined level may be less than the first pre-determined level. This is advantageous, as it informs the surgeon whether or not they have applied enough force to the device to properly secure the modular components together, that is to say, to
15 ensure sufficient deformation of mating Morse taper surfaces to provide a reliable connection between the modular components.

[0022] The frangible member may be connected to the first part or the second part by a first connection. The first connection may be configured to break when the load exceeds the second pre-determined level.

20 **[0023]** The first side may be located on the first part and be arranged to contact the target surface.

[0024] The device may further comprise a second part configured to move relative to the first part upon application of the force by the tool. The second side may be located on the second part. The deformable member may be disposed between the first part and the
25 second part.

[0025] Viewed from a further independent aspect, the present invention also provides a method of impacting a target object, comprising the steps of: providing a device according to the first aspect, placing the first side of the first part against the target object, and impacting the second side with a force up to or exceeding the first pre-determined level,
30 resulting in the application of a force no greater than the first pre-determined level to the target object.

[0026] The target object may be a prosthetic component, a trial prosthetic component or a bone preparation tool.

[0027] The present invention also provides a kit of parts comprising a device according to the first aspect and instructions to carry out any of the claimed methods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] Embodiments of the invention are further described hereinafter with reference to
5 the accompanying drawings, in which:

Figure 1 illustrates a modular replacement hip joint and tools for its assembly;

Figure 2 illustrates an exemplary device according to an embodiment of the invention;

10 Figures 3A and 3B illustrate perspective and cross-sectional views of an embodiment of the device having a deformable member within an outer shell;

Figures 4A and 4B illustrate models of exemplary lattice structures for use in deformable members according to embodiments;

Figures 4C and 4D are photographs of an exemplary lattice structure in an uncompressed state and a compressed state respectively;

15 Figure 5A illustrates an exemplary device with a split pin;

Figures 5B and 5C illustrate cross-sectional views of the device of Figure 5A before and after impaction;

Figures 6A and 6B illustrate cross-sectional views of an exemplary device before and after impaction;

20 Figure 7 illustrates the force response due to use of an exemplary device when striking with increasing energy;

Figure 8 illustrates an exemplary force-limited hammer;

Figure 9 corresponds to Figure 1, but modified to illustrate alternative locations for the force-limiting device according to embodiments of the invention, which can be secured
25 to either of a hammer or an impactor;

Figure 10 corresponds to Figure 9, but illustrates the alternative locations for the force-limiting device in use when assembling a modular hip joint *in vivo*.

DETAILED DESCRIPTION

[0029] Figure 1 illustrates a modular replacement hip joint and associated tools for its
30 assembly. The replacement hip joint 1 comprises a femoral stem 2 and a femoral head 3. The femoral stem 2 has a tapered neck section 4 and the femoral head 3 has a corresponding internal tapered section (not shown) to receive the tapered neck section 4.

By placing the femoral head 3 on to the neck section 4 and placing a distal end of an impactor 7 against a joint surface 6 of the femoral head 3, a surgeon can strike a proximal end of the impactor 7 with a hammer⁹, to secure the femoral head 3 to the femoral stem 2. The impactor 7 typically has an polyethylene tip 8 at the distal end to avoid damaging the femoral head 3 when the surgeon strikes the impactor 7.

[0030] Figure 2 illustrates an exemplary device 10 that can be used to assemble a modular replacement hip such as that shown in Figure 1. The device 10 has a first part 12 and a second part 20 arranged to translate relative to the first part 12. The first 12 and second 20 parts each have a circular cross-section and the first part 12 is in the form of a hollow cylindrical shell, which receives the second part 20 through an opening at a proximal end of the first part 12. The first 12 and second parts 20 are also arranged concentrically about a longitudinal axis extending from a first, distal side 14 of the first part 12 to a second, proximal side 22 of the second part 20. The first 14 and second sides 22 preferably comprise respective surfaces that are generally parallel to one another and located at opposite ends of the device 10. The second part 20 is shown having a raised section on which the second surface 22 is formed. When combined, the first 14 and second 20 parts define a cavity in which a force-limiting lattice structure 30 can be received. As shown, the second part 20 is a hollow cylinder with an outer diameter less than the inner diameter of the first part 12 so that the second part 20 can be inserted into the first part 12. However, it would be apparent that the second part 20 need not be a hollow cylinder, as the space between a non-hollow second part 20 and the first part 12 would define a cavity in which the lattice structure 30 can be received.

[0031] The first side 14 may also have a polyethylene, polyoxymethylene (POM) or similar, coating applied thereto, to mimic the protective characteristics of the polyethylene tip 8 on the impactor 7. The first surface 14 may be concavely contoured to substantially match the corresponding convex joint surface 6 of the femoral head 3 against which it will be applied, in use.

[0032] The device 10 further comprises a lattice structure 30 (see Figures 4A to 4D) disposed between the first 12 and second 20 parts. The first part 12, lattice structure 30 and second part 20 define a load path between the first side 14 and second side 22. The lattice structure 30 is configured to yield and undergo plastic deformation when an impact on the second side 22 is above a pre-determined level. As the lattice structure yields, it absorbs impact energy exceeding the pre-determined level and continues to transfer a resultant load to the first part 12 that is limited to the first pre-determined level (see also Figure 7). When a lower level of force is applied to the second part 20, for example at the levels which would not secure the femoral head 3 to the femoral stem 2, a substantial

portion of the lattice structure 30 will not yield and will, therefore, not substantially deform, thereby indicating to the surgeon that insufficient force has been applied to the device 10.

[0033] The device 10 preferably includes a visual indicator 21 to clearly indicate the height, e.g. deformed state, of the lattice structure 30. The device 10 illustrated in Figure 2 illustrates an exemplary visual indicator 21 formed of a protrusion 23 extending from an outer surface of the second part 20 and into a slotted section 16 formed in a side wall of the first part 12. The visual indicator 21 also includes markings 18A, 18B on an outer surface of the first part 12 that are indicative of the height of the lattice structure 30. The height of the lattice structure 30 will depend on how much plastic deformation the lattice structure 30 has undergone, and can be used to indicate whether or not sufficient force has been applied to the device 10 to properly secure the modular joint components together. When the device 10 is struck by the surgeon, the second part 20 moves relative to the first part 12 and transfers the impact force received by the second part 20 to the lattice structure 30. First 18A and second 18B markings indicate a range of lattice structure 30 deformations that correspond to different levels of force applied to the device 10. In the example illustrated in Figure 2, when the protrusion 23 is above the first marking 18A, this indicates that insufficient force has been applied to the device 10, as the amount of plastic deformation is less than what is required to secure the femoral head 3 to the femoral stem 2. In this case, the surgeon can see that insufficient force has been used and that they need to use more force to secure the femoral head 3 to the femoral stem 2. When the protrusion 23 is below the second marking 18B, this indicates that the lattice structure 30 may not be able to absorb the energy of any further strikes. In this case, striking the device 10 may risk damaging the femoral head 3.

[0034] In another example, the visual indicator 21 has one or more markings on the outer surface of the second part 20 such that, as the second part 20 is received by the first part 12, the markings on the second part 20 are concealed by the side wall of the first part and the surgeon is thus able to see whether or not the lattice has undergone sufficient deformation, and therefore, whether or not sufficient force has been applied to the components. In another example, the visual indicator 21 includes a window in the outer wall of the first part through which any of the lattice structure 30 and/or the second part 20 are viewable. The surgeon will be able to view the lattice structure 30 through the window to determine whether sufficient deformation has occurred. Markings may be present on any of the first 12 and/or second 20 parts to indicate the height (deformed state) of the lattice structure 30.

[0035] While it is preferable for some of the second part 20 to be received by the first part, this is not essential. This is because, while the first 12 and second 20 parts are

shown as outer and inner parts respectively, it would be understood that the second part 20 may receive the first part 14 and be located at the distal end of the device 10 instead. Furthermore, it is also not essential that the lattice structure 30 be received by the first part 12, as the second part 20 may receive the lattice structure 30 and a portion of the first part 12.

[0036] Figures 3A and 3B illustrate an alternative device 10 formed of a first part 12 and a lattice structure 30. In this example, the first part 12 receives a portion of the lattice structure 30 and at least a top surface 34 of the lattice structure extends beyond a proximal end of the first part 12. The surgeon can strike the top surface 34 of the lattice structure 30 and directly deform the lattice structure 30. A protrusion 36 extending from a side of the lattice structure 30 acts as a visual indicator to the surgeon to indicate whether sufficient force has been applied to the device 10. In this example, the first part 12 has a slot 16 formed in a side wall through which the protrusion 36 of the lattice structure 30 can extend, so as to indicate the amount of deformation of the lattice structure 30. Markings 18A, 18B indicative of the deformation of the lattice structure 30 may be provided on the outer surface of the first part 12.

[0037] The lattice structure 30 preferably comprises metal, but may also comprise plastic. As shown in Figure 4A the lattice structure 30 may have struts 32 arranged in a periodic, non-stochastic arrangement. An alternative lattice structure shown in Figure 4B illustrates a lattice structure 30 with struts 32 arranged in a stochastic arrangement. It would be apparent that Figures 4A and 4B are exemplary lattice structures 30 and that other structures comprising one or more periodic, non-stochastic, stochastic, anisotropic and/or isotropic parts would be possible. A foam structure, or similar, would be equally suitable. Further, while the lattice structure 30 is shown between the first part 12 and the second part 20, it would be apparent this is not essential. The lattice structure 30 may be located elsewhere in the load path between one or more further intermediary components (not shown). In some cases, the device may comprise a lattice structure 30 having a visual indicator, such that when the lattice structure is struck with sufficient force, it deforms and the visual indicator indicates to the surgeon that the desired force has been transmitted to the replacement joint components, for example by having upper and lower markers that move closer together upon compaction of the lattice. Figures 4C and 4D illustrate an exemplary lattice structure 30 before and after being struck respectively. As shown in the Figures, after impacting the lattice structure 30 with sufficient force, for example above 5kN, a large proportion of the struts 32 in the lattice structure 30 have undergone significant plastic deformation and the height of the lattice structure 30 has been reduced considerably. The lattice structure 30 may comprise a honeycomb structure. The

honeycomb structure may comprise a series of interconnected cells. The interconnected cells may extend in a direction perpendicular or parallel to the load path.

[0038] Figures 5A, 5B illustrate cross-sectional views of an exemplary device with a split pin. In this example, the lattice structure 30 is received within the first part 12 and a split pin 42 extends through the side walls of the first part 12 and through the lattice structure 30. If the surgeon strikes the top surface 34 of the lattice structure 30 with sufficient force, this will compress the lattice structure 30 significantly and break the split pin 42 (see Figure 5C), for example by shearing. In breaking the split pin 42, the surgeon is provided with visual, tactile and audible feedback that they have struck the device 10 with sufficient force to ensure a proper connection of the modular joint components. It would be understood that the split pin 42 can be made of various frangible materials, similar to those described in relation to the glass plate 40 as described below, so that the split pin 42 will break into a number of fragments 42A, 42B. Preferably the split pin 42 comprises a metal material. In some cases, the split pin 42 comprises a plastic material. Preferably, the split pin 42 slides through concentric holes in the side wall of the first part 12 and through a corresponding hole in the lattice structure 30. This advantageously allows the lattice structure 30 and the split pin 42 to be replaced after each use.

[0039] Figures 6A and 6B illustrate cross-sectional views of an exemplary device 10 before and after impactation. In this example, a glass plate 40 located between the second part 20 and the lattice structure 30 is configured to break at a pre-determined compressive load. When the glass plate 40 breaks, the surgeon is provided with audible feedback and haptic feedback from the sound of the glass breaking and the shattered pieces within the device 10.

[0040] In an alternative example, the glass plate may be connected to an inner surface of the first part 12. In this case, when the second part 20 has moved sufficiently due to the deformation of the lattice structure 30, the connection between the inner surface of the first part 12 glass plate will break, and provide feedback to the surgeon. Once the glass plate 40 has broken, the shattered glass pieces will be contained within the first part 12. The glass pieces can be "felt" by the surgeon by manually moving the second part 20 relative to the first part 12, which provides the haptic feedback to the surgeon. Similarly, the movement of the glass pieces may also provide further audible feedback to the surgeon, indicating the glass plate is broken.

[0041] The load at which the glass plate 40 or the split pin 42 breaks may be equal to the first pre-determined level at which the lattice structure 30 limits the impact force. Alternatively, the load at which the glass plate 40 or the split pin 42 breaks may be at a load which has an increased risk of damaging the femoral head 3. However, the main

purpose of the frangible glass plate 40 or the split pin 42 is to provide feedback that enough force has been transmitted to ensure proper assembly of the modular parts, i.e. that a lower pre-determined force has been crossed (where the first pre-determined level at which the lattice structure 30 limits the impact force is an upper force threshold). In
5 embodiments where the visual indicator 21, 36 provides an indication that enough force has been applied for proper assembly to take place, the tactile and audible feedback provides an alternative way to check that sufficient force has been applied to the device 10. In essence, the audible and tactile 'click' or 'crack' from the glass plate or the split pin 42 breaking tells the surgeon that the impact will have resulted in a successful joining of
10 the modular component parts of the joint. The visual marker would tell the surgeon whether or not the device has any remaining absorptive effect.

[0042] While a glass plate 40 is described, it would be apparent that one or more rods or lattices made of glass, plastic, ceramic or a similar frangible material could be used. While the glass plate 40 is described as being located between the second part 20 and the lattice
15 structure 30, it would be apparent this is not essential, and that the glass plate 40 could be located elsewhere in the load path, for example between the first part 12 and the lattice structure 30 or on the second side 22 of the second part 20.

[0043] While the first 12 and second 20 parts are shown having concentric circular cross-sections, it would be apparent that this is not essential.

20 **[0044]** Whereas the device has been described in the context of a force being applied by striking a hammer against the second part 20 (Figs. 2 and 6) or the upper side 34 of the deformable member 30 (Figs. 3 and 5), and the resulting load being transferred through the device to the object via the first part 12, it will be apparent that the device could be inverted, with the hammer striking the end 14 of the first part 12 to transfer load to the
25 object via the second part 20 or the side 34 of the deformable member 30.

[0045] Figure 7 illustrates exemplary data showing the relationship between the strike energy imparted by the surgeon and the resultant force that is transmitted through the first side 14. As shown, the lattice structure 30 is able to limit the transmitted force to a pre-determined level. When the surgeon strikes the device 10 with energies between
30 approximately 1J and 4J, corresponding to relatively light hits with the hammer, a substantial portion of the lattice structure 30 does not yield, and therefore, does not significantly limit the transmitted force. This allows the transmitted force to increase with increasing strike energy, and the lattice structure 30 to act in an approximately elastic manner. If the device is struck with more energy, for example in the range of 3J to 6J, a
35 portion of the lattice structure 30 undergoes plastic deformation and transmits a force that is sufficient to secure the femoral head 3 to the femoral stem 2. This may be in the range

of 4kN to 6kN. However, if the surgeon strikes the device 10 with energies greater than 7J, corresponding to hard strikes that might damage the femoral head 3, the lattice structure 30 undergoes increasing levels of plastic deformation and absorbs the excess energy from the surgeon's strike. This limits the transmitted force to approximately 5kN and reduces the risk of damaging the femoral head 3 during impaction. While the illustrated example limits the force to approximately 5kN, it would be apparent that the lattice structure 30 may be configured differently to limit the force at a level higher or lower than 5kN, as appropriate for the specific intended application. The lattice structure 30 may be tuned according to one or more external parameters. Exemplary external parameters may include any of: the size of the implant; the joint or body part the implant is to be implanted into; a material of the implant; or a characteristic of the patient.

[0046] In one example, the device 10 may be a single-use component such that, after it has been used to secure the femoral components, it can be disposed of. Alternatively, if the lattice structure 30 is replaceable, this can provide a re-useable device 10. One way of achieving this would be for the first 12 and second 20 parts to be separable from one another. This would provide a way of opening the device 10 so that the deformed lattice structure 30 could be removed from the device 10, and a new, undeformed, lattice structure 30 could be inserted into the device 10. Different lattice structures 30 may be configured to yield at a different pre-determined loads or in a particular way based on the particular surgical requirements.

[0047] While the device 10 has been described as being held by the surgeon against the femoral head 3 before being struck by a hammer, for example by being secured to or incorporated into the distal end of an impactor 76 (see Figures 9 and 10), it would be apparent that the device 10 can be secured to the hammer, in a retrofittable manner, or formed integrally with the hammer for convenience. Figure 8 illustrates an exemplary force-limited hammer. That is to say, a hammer that will only transmit a resultant force to an object up to a desired limit. The illustrated hammer 50 includes a handle 52 and a head portion 54. The head portion 54 includes a first part 56 connected to a second part 58 by a slideable connection 60, and a deformable member, such as a lattice structure 30 or foam structure, within the first part 56. The first part 56 of the hammer 50 functions in a similar manner to the first part 12 of the device 10, while the second part 58 of the hammer 50 functions in a similar manner to the second part 20 of the device 10. The lattice structure 30 used in the hammer 50 may be the same as that used in the device 10. The hammer 50 of the present description does away with the need for a separate device 10, as the force-limiting means are contained within the head portion 54. This provides the surgeon with

greater freedom when striking the femoral head 3, as they do not also need to hold the separate device 10 against the femoral head 3.

[0048] Figure 9 illustrates an exemplary system, where the force-limiting lattice structure can be secured to either the head of a hammer 70 or an end of an impactor 76. In one example, the lattice structure 30A is secured to or integrated into the end of an impactor 76, such that the surgeon is able to use a standard hammer to strike the impactor 76 and benefit from the force-limiting capacities of the lattice structure 30 without needing to modify the hammer 70. In an alternative scenario, the lattice structure 30B is secured to a head 72 of the hammer 70 and the surgeon is able to use a standard impactor 7 to direct the energy of the impact to the femoral head 6. In another scenario, the impactor 76 may have a first lattice structure 30A secured thereto, and the head 72 of the hammer 70 may have a second lattice structure 30B secured thereto. In this case, configuring the first lattice structure 30A to yield at a first force and the second lattice structure 30B to yield at a second force can be used to indicate to the surgeon that the correct level of force has been applied, without requiring additional visual indicators. For example, if the second lattice structure 30B is configured to yield at an upper force limit and the first lattice structure 30A is configured to yield at a lower force limit, deformation of the first lattice structure 30A, but not of the second lattice 30B may indicate to the surgeon that sufficient force has been applied. The lower force limit may correspond to the minimum level of force to secure the replacement joint components together and the upper force limit may correspond to a maximum force, above which there is a risk of damaging the replacement joint components. It is also advantageous to locate the deformable member at the distal end of the system, for example the distal end of the impactor 76, as the influence of objects proximal to the deformable member, such as deformations of the impactor and the hammer, on the resultant transmitted force will be limited. As such, the force transmitted to the joint components will be more reliably at or near the pre-determined threshold, thus ensuring a more reliable fixation between the modular components once the device 10 has indicated the pre-determined threshold has been crossed.

[0049] While the device 10 has been described in the context of assembling a femoral head 3 onto a femoral stem 2, it would be apparent the present device 10 would be suitable for other applications, in particular where the surgeon assembles one or more components by hammer strike. This can include modular femoral stems in complex revision cases, Morse taper acetabular lines, modular acetabular cups, seating acetabular cups, seating femoral stems, rasping femoral cavity, impaction grafting, seating tibial trays, assembling modular tibial trays and modular knee implants in revision cases.

[0050] Figure 10 illustrates an exemplary force-limited hammer and force-limited impactor corresponding to Figure 9, but illustrates the alternative locations for the force-limiting device in use when assembling a modular hip joint *in vivo*. In this example, an acetabular cup 74 is being secured to the pelvis of a patient. The impactor 7 is shown
5 having a first lattice structure 30C secured thereto, and the hammer 70 is shown having a second lattice structure 30D secured thereto. While both lattice structure 30C, 30D are shown together, it would be apparent this was not essential, and either of lattice structure 30C or 30D may be omitted.

[0051] Throughout the description and claims of this specification, the words “comprise”
10 and “contain” and variations of them mean “including but not limited to”, and they are not intended to (and do not) exclude other components, integers or steps. Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the
specification is to be understood as contemplating plurality as well as singularity, unless
15 the context requires otherwise.

[0052] Features, integers or characteristics described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims,
20 abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying
25 claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A device for limiting a force applied by a tool to a target object, the device comprising:
 - a first part, and
 - 5 a deformable member arranged to contact the first part and deform upon application of the force by the tool to the device,
 - wherein the first part and the deformable member are arranged to define a load path between first and second sides of the device,
 - wherein the deformable member is configured to deform when the force
 - 10 through the load path is above a first pre-determined level, thereby absorbing a first amount of the force, so as to impart a resultant force to the target object no greater than the first pre-determined level.
2. A device according to claim 1 further comprising a visual indicator configured to display information indicative of a state of the deformable member.
- 15 3. A device according to claim 2, wherein the visual indicator comprises at least one surface feature disposed on a surface of the device, and wherein the at least one surface feature is indicative of the height of the deformable member.
4. A device according to claim 3, wherein the visual indicator comprises a slotted section in a side wall of the first part, wherein the at least one surface feature comprises at
- 20 least one protrusion extending away from the surface of the device and into the slotted section, and wherein the first part comprises an outer surface having at least one surface feature indicative of the height of the deformable member.
5. A device according to any preceding claim, wherein the tool comprises an impactor head having a distal end and the device comprises an attachment for mounting on the
- 25 impactor head, such that when so mounted the deformable member is secured to the distal end of the impactor head.
6. A device according to any of claims 1 to 4, wherein the device is comprised within an impactor head of the tool.
7. A device according to any preceding claim, wherein at least a first section of the
- 30 deformable member is configured to plastically deform when the force is greater than the first pre-determined level.
8. A device according to any preceding claim, wherein the deformable member comprises a lattice structure or a foam region.

9. A device according to any preceding claim, wherein the deformable member is separable from the first part.
10. A device according to any preceding claim, wherein the deformable member comprises any of a plastic or a metal material.
- 5 11. A device according to any preceding claim comprising at least one frangible member in the load path, wherein the frangible member is configured to break when the load exceeds a second pre-determined level, and wherein, in use, breaking the frangible member provides visual, audible and/or haptic feedback.
12. A device according to claim 11, wherein the second pre-determined level is less
10 than the first pre-determined level.
13. A device according to claim 11 or claim 12, wherein the frangible member is connected to the first part by a first connection, and wherein the first connection is configured to break when the load exceeds the second pre-determined level.
14. A device according to any preceding claim, wherein the first side is located on the
15 first part and is arranged to contact the target surface.
15. A device according to any preceding claim further comprising a second part configured to move relative to the first part upon application of the force by the tool, wherein the second side is located on the second part, and wherein the deformable member is disposed between the first part and the second part.
- 20 16. A method of impacting a target object, comprising:
providing a device according to any preceding claim,
placing the first side of the device against the target object, and
impacting the second side with a force up to or exceeding the first pre-
determined level, resulting in the application of a force no greater than the first pre-
25 determined level to the target object.
17. A method according to claim 16 or a device according to any of claims 1 to 15, wherein the target object is a prosthetic component.
18. A kit of parts comprising a device according to any of claims 1 to 15 and instructions to carry out a method according to claim 16 or claim 17.

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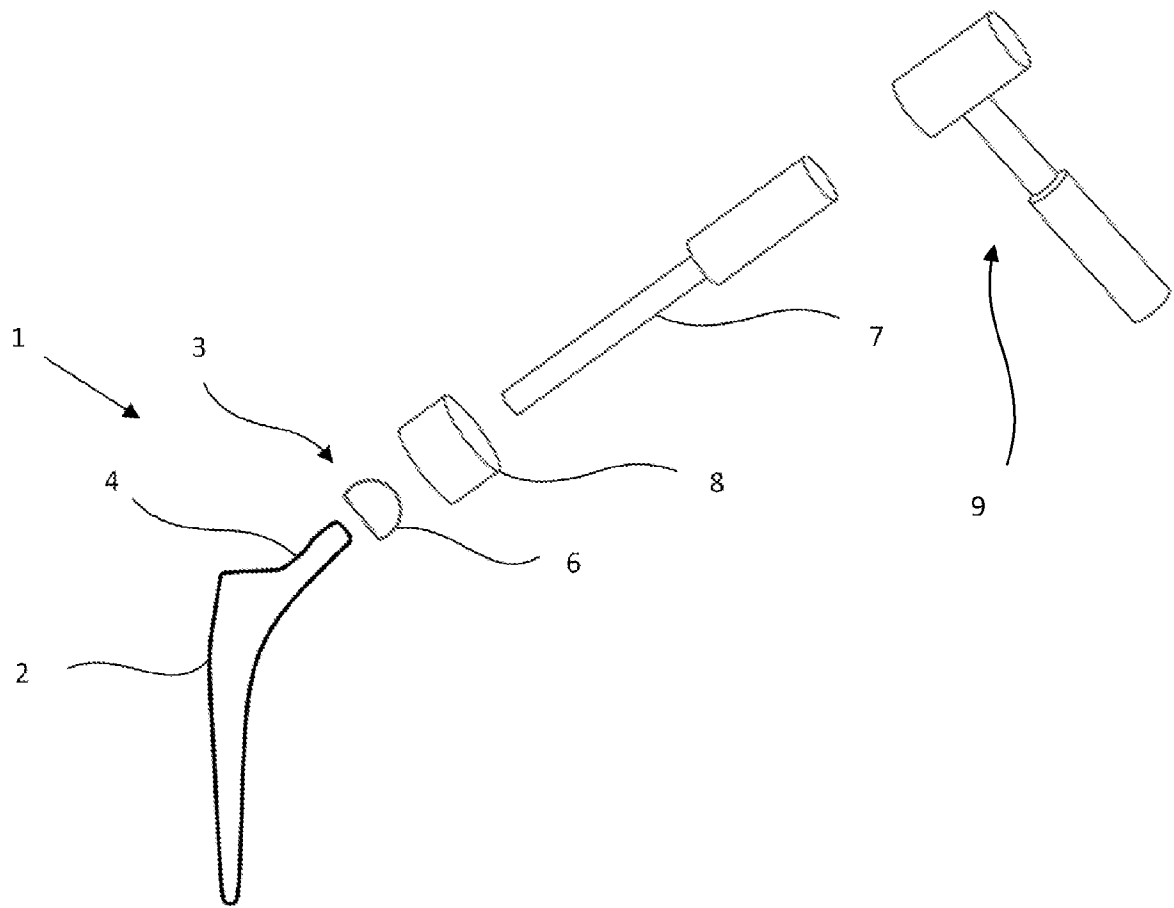


FIG. 1

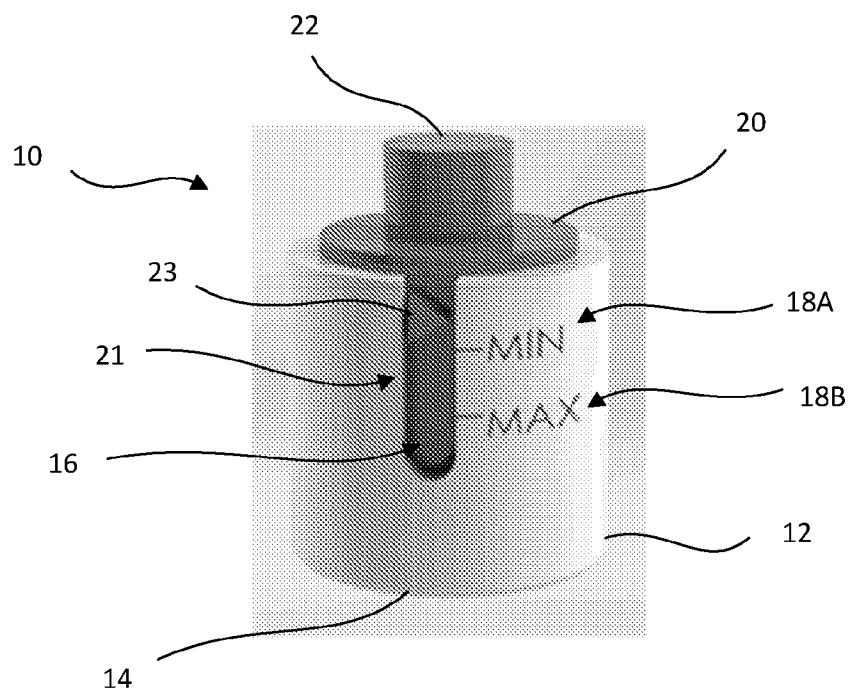


FIG. 2

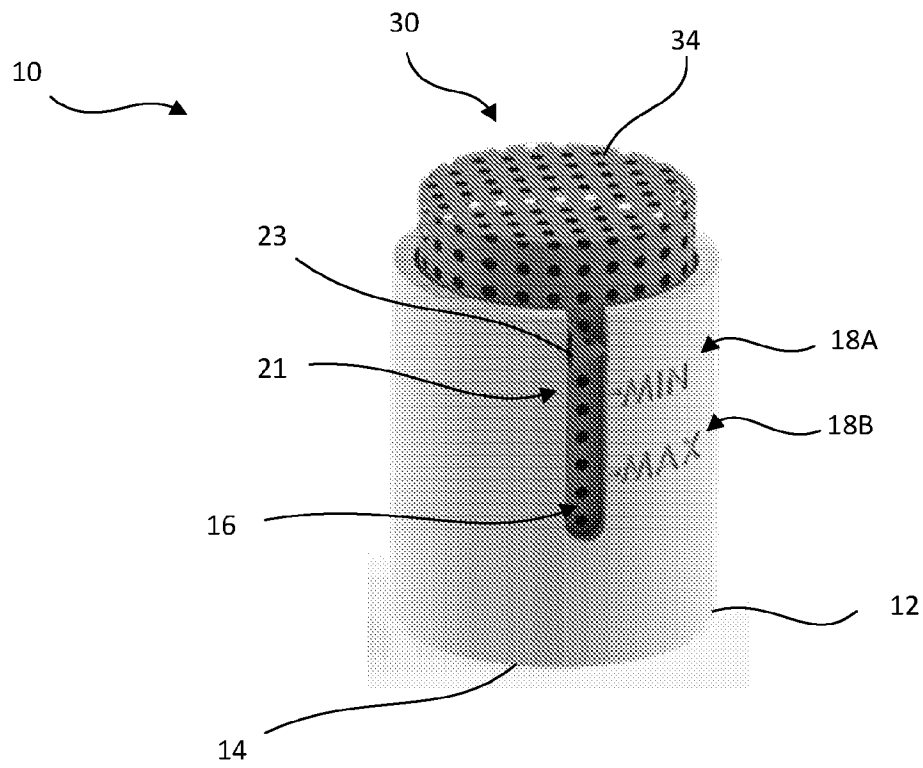


FIG. 3A

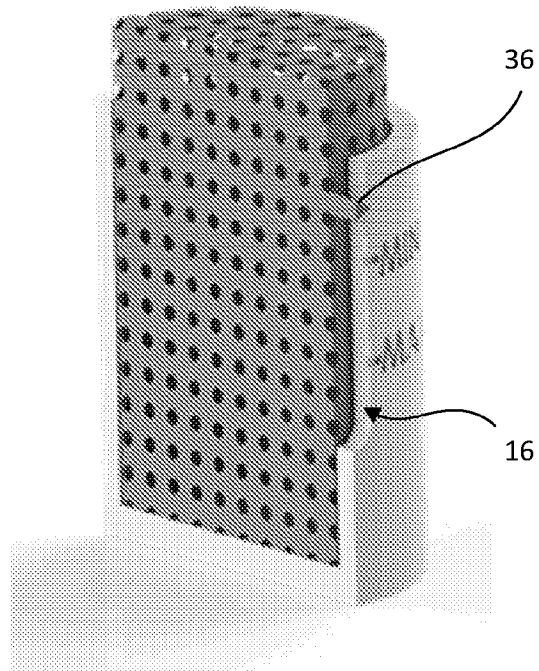


FIG. 3B

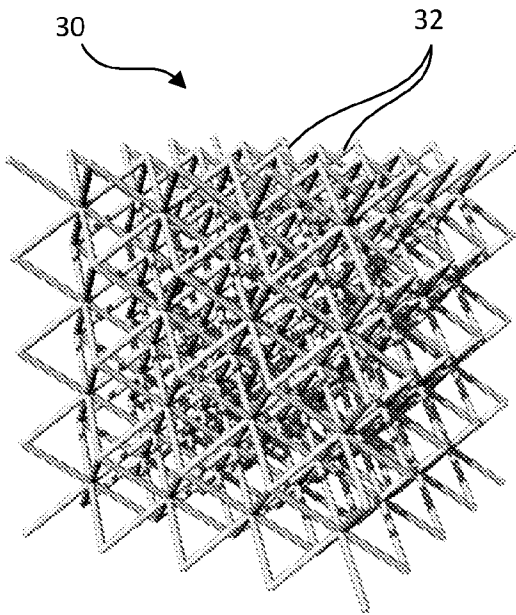


FIG. 4A

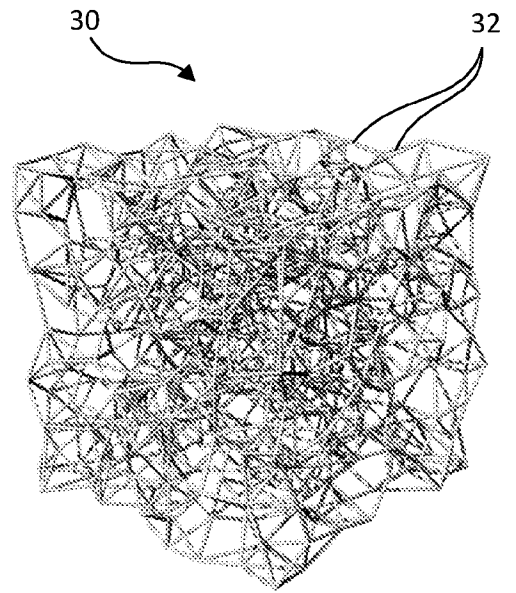


FIG. 4B

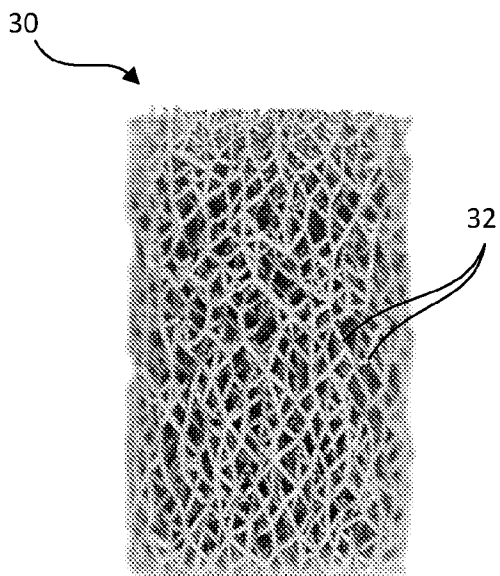


FIG. 4C

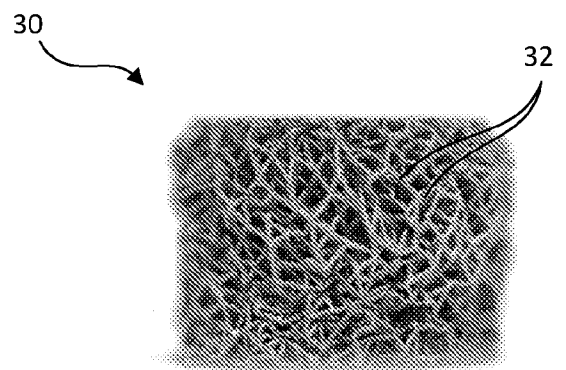


FIG. 4D

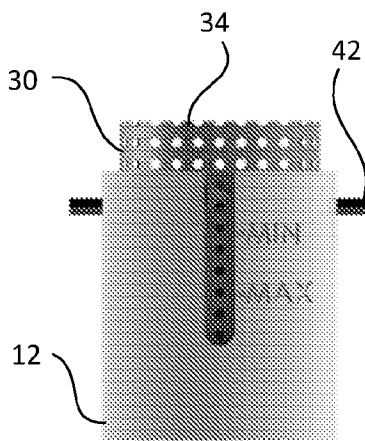


FIG. 5A

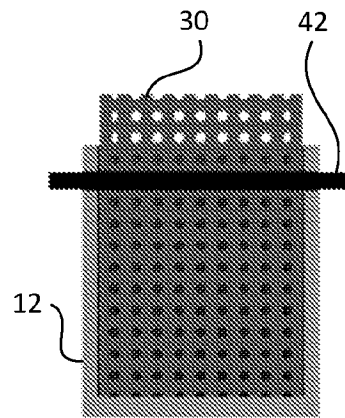


FIG. 5B

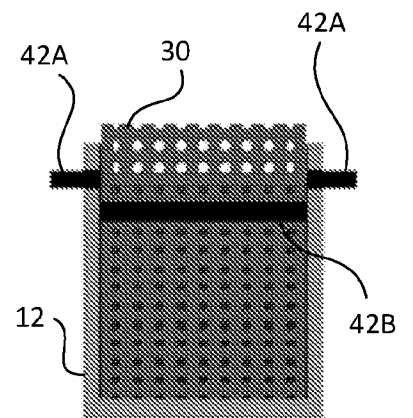


FIG. 5C

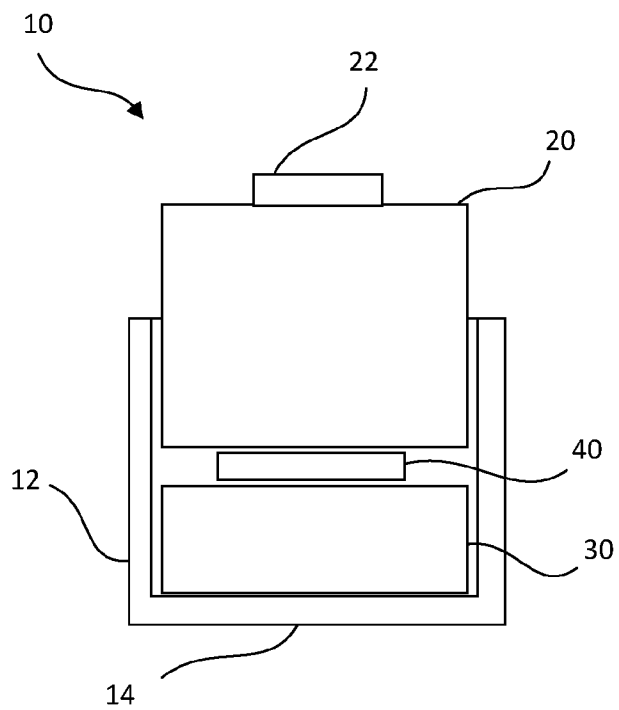


FIG. 6A

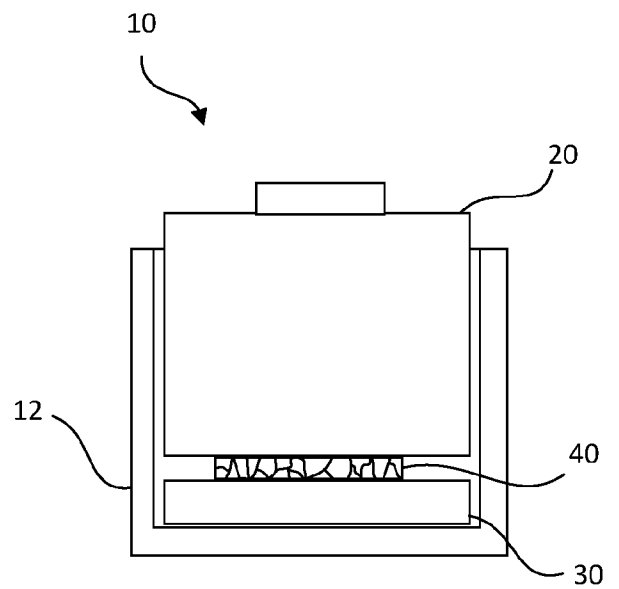


FIG. 6B

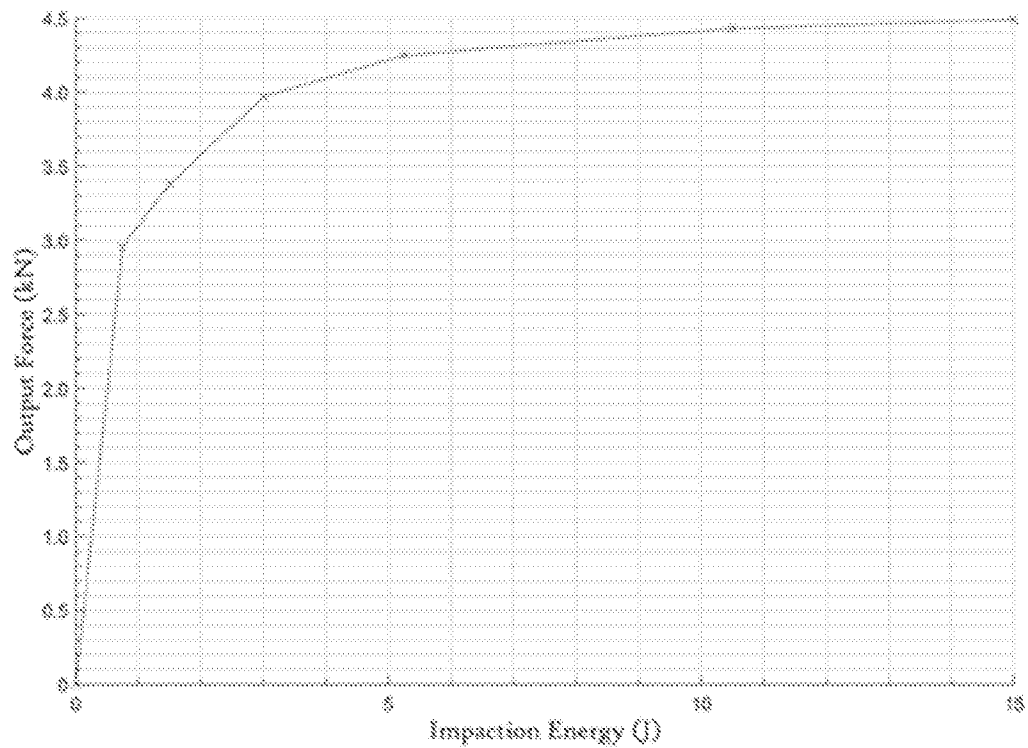


FIG. 7

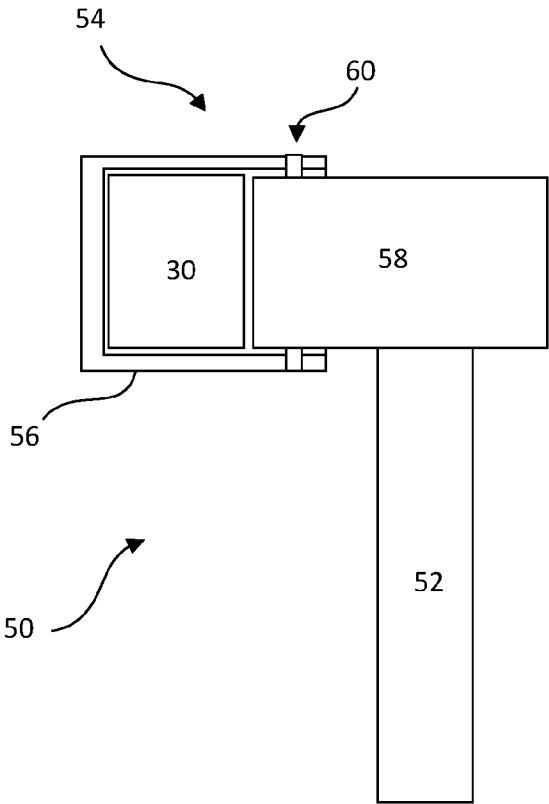


FIG. 8

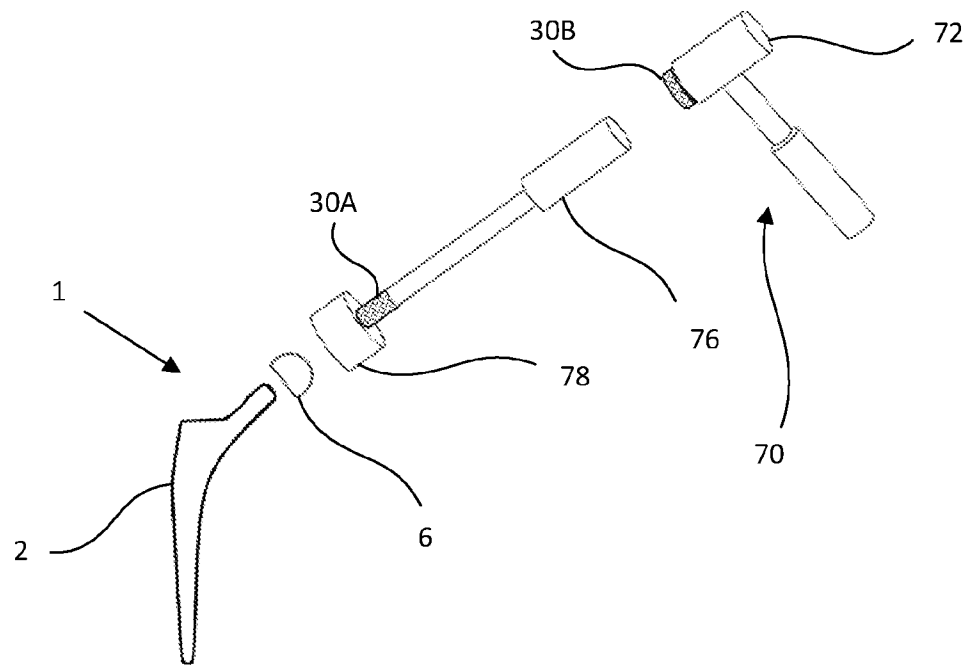


FIG. 9

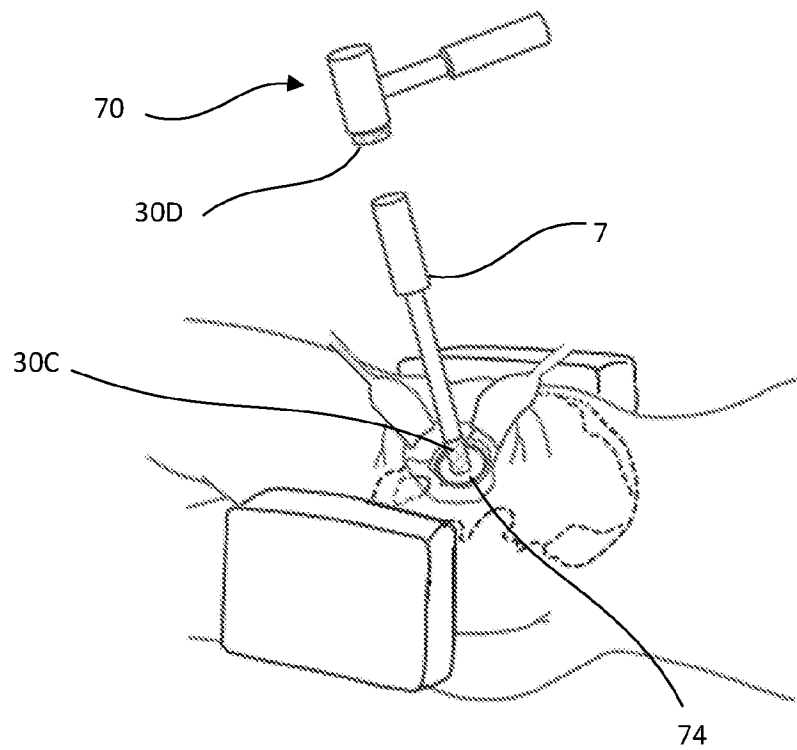


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2020/050507

A. CLASSIFICATION OF SUBJECT MATTER INV. A61B17/92 A61F2/46 B25D1/12 A61B90/00 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) A61B A61F B25D		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A X A	US 2011/264009 A1 (WALTER WILLIAM LINDSAY [AU] ET AL) 27 October 2011 (2011-10-27) figures 8,13-16,17 ----- US 2015/366601 A1 (HOEPPNER JACY [US]) 24 December 2015 (2015-12-24) figures 1-6 ----- DE 10 2017 009835 B3 (SILONY MEDICAL INT AG [CH]) 14 February 2019 (2019-02-14) figures 1-7 -----	1-3,5-18 4 1-4 1
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search	Date of mailing of the international search report	
20 May 2020	09/06/2020	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Hartnack, Kai	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2020/050507

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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			EP 2254504 A1 01-12-2010
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			WO 2009105817 A1 03-09-2009

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DE 102017009835	B3	14-02-2019	NONE
