Three-Dimensional Printed Orthopedic Implants

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Origination: 08/2018  Next Review: 8/2021

Policy
Blue Cross and Blue Shield of Kansas City (Blue KC) will provide coverage for Three-Dimensional Printed Orthopedic Implants when it is determined to be medically necessary because the criteria shown below are met.

When Policy Topic is covered
Custom 3D printed implants for patients with bone or joint deformity may be considered medically necessary when the devices are produced at a central manufacturing facility and meet FDA custom device exemption requirements.

When Policy Topic is not covered
Three-dimensional (3D) printed orthopedic implants that have a design that is approved or cleared by the Food and Drug Administration (FDA) and produced in standard sizes for patients with typical bone and joint anatomy are investigational.

Patient-matched 3D printed implants that are based on non-standard shapes and sizes for patients with typical bone and joint anatomy and do not qualify as custom devices according to FDA custom device exemption requirements are investigational.

Three-dimensional printed orthopedic implants produced outside of FDA-regulated manufacturing facilities are investigational.

Considerations
This policy does not address custom mandible or maxillofacial implants.

There are no specific codes for 3-dimensional printed orthopedic implants. It is possible that providers may use the following code:

L8699 Prosthetic implant, not otherwise specified.
# Description of Procedure or Service

<table>
<thead>
<tr>
<th>Populations</th>
<th>Interventions</th>
<th>Comparators</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| **Individuals:**  
- Who have typical bone and joint anatomy and are undergoing standard orthopedic procedures | Interventions of interest are:  
- Standard-sized 3-dimensional printed implant | Comparators of interest are:  
- Standard implants produced by traditional manufacturing | Relevant outcomes include:  
- Symptoms  
- Functional outcomes  
- Quality of life |
| **Individuals:**  
- Who have typical bone and joint anatomy and are undergoing standard orthopedic procedures | Interventions of interest are:  
- Patient-matched 3-dimensional printed implant | Comparators of interest are:  
- Patient-matched implants produced by traditional manufacturing | Relevant outcomes include:  
- Symptoms  
- Functional outcomes  
- Quality of life |
| **Individuals:**  
- With bone or joint deformity requiring a custom orthopedic implant | Interventions of interest are:  
- Custom 3-dimensional printed implant | Comparators of interest are:  
- Custom implants produced by traditional manufacturing | Relevant outcomes include:  
- Symptoms  
- Functional outcomes  
- Quality of life |

**Summary**

This evidence review addresses orthopedic implants that are constructed by additive manufacturing, commonly known as 3-dimensional (3D) printing. Three situations are considered: 3D printing of standard-sized implants, 3D printing of patient-matched implants for individuals who have typical bone and joint anatomy, and custom 3D printed implants for patients who have bone or joint deformity.

For individuals who have typical bone and joint anatomy and are undergoing standard orthopedic procedures who receive a standard-sized 3D printed implant, the evidence includes a randomized controlled trial and systematic review. Relevant outcomes include symptoms, functional outcomes, and quality of life. Three-dimensional printed implants are often manufactured with titanium and allow greater porosity than can be achieved with traditional manufacturing techniques. Greater porosity is believed to facilitate bony in-growth and theoretically improve the stability of the implant. However, the effect of these devices on the adjacent bone, particularly subsidence and resorption, is unknown. Studies are needed that compare these newer devices with the established alternatives. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have typical bone and joint anatomy and are undergoing standard orthopedic procedures who receive a patient-matched 3D printed implant, the evidence includes no comparative studies. Relevant outcomes include symptoms, functional outcomes, and quality of life. Studies are needed to determine whether patient-matched implants improve outcomes compared with conventional implants. It is noted that other methods for the customization of orthopedic procedures, specifically patient-specific cutting guides and sex-specific implants, have failed to demonstrate improvements in health outcomes.
Demonstration of improvement in key outcome measures is needed to justify the greater resource utilization (eg, time, imaging) of patient-matched 3D printed devices. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have bone or joint deformity requiring a custom orthopedic implant who receive a custom 3D printed implant, the evidence includes case series. Relevant outcomes include symptoms, functional outcomes, and quality of life. The largest case series with the longest follow-up is from outside of the United States. The most commonly reported indications are for revision total hip arthroplasty with severe acetabular defects, reconstruction following orthopedic tumor resection, and spinal abnormalities. These cases would require a custom process for design and manufacturing, even with traditional manufacturing methods. Therefore, the design and manufacturing of a single implant with 3D printing is an advantage of this technology. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

**Background**

Three-dimensional (3D) printed implants are made by a process of additive manufacturing. Additive manufacturing uses a computer-aided process with a 3D printer to build devices 1 layer at a time. The most commonly used technologies in medical devices are powder bed fusion, stereolithography, fused filament fabrication, and liquid-based extrusion. Stereolithography systems use a vat of liquid that is cured by light. Fused filament fabrication melts a solid filament at the point of deposition, after which it solidifies, while liquid-based extrusion systems eject a liquid which then solidifies. Orthopedic implants are frequently made with cobalt-chromium or titanium powder bed fusion, which uses an energy source such as laser or electron beam to melt or sinter a layer of metal powder onto the layer below.

Additive manufacturing contrasts with the traditional methods of manufacturing, which include forging (shaped by hammering or bending), casting (formed by molten metal poured into a mold), and machining (removes material to create the desired geometry). Traditional manufacturing methods are frequently used with cobalt-chromium alloys for orthopedic implants. Titanium is also used for implants, including the femoral stems and acetabular cups used for total hip arthroplasty. The manufacturing of titanium and titanium alloys with traditional production methods is more difficult. Production of complex shapes is also limited with forging, casting, or machining.

Advantages of additive manufacturing include the ability to manufacture complex structures that traditional manufacturing processes cannot, and to create devices individually matched to the patient’s anatomy. Additive manufacturing also allows rough or porous surface textures that promote bone ingrowth, and some have proposed that fully porous implants may reduce bone resorption around the implant. Three-dimensional printed models of a joint or spine can also be constructed to plan and practice complex surgeries. In addition
to increased design flexibility and potential improvements in function, additive
manufacturing wastes less raw materials and may reduce processing costs.

Additive manufacturing may, however, introduce variability into the manufacturing
process. A number of factors affect the production of patient-matched orthopedic
implants. One factor is whether the device is based on a standard template or
custom-designed. Another is if the design could be affected by image quality,
rigidity of anatomic structures, or clarity of anatomic landmarks. Some patient-
matched devices are based on a standard-sized template with specific features
modified within a defined design or performance envelope. Patient-matched
devices that follow the patient anatomy more precisely are more vulnerable to
design errors.

Manufacturing processes that occur after printing can also affect device
performance and material properties. Postprocessing may include removal of
manufacturing residues, heat treatments, and final machining and polishing when
needed and where surfaces are accessible. For devices made with additive
manufacturing, the U.S. Food and Drug Administration (FDA) recommends process
validation, revalidation if there are any changes to the device or process, and
mechanical device testing in a manner similar to testing of devices made with a
traditional manufacturing method. Three-dimensional printing of orthopedic
implants at a central facility permits the manufacturer to regulate quality,
biocompatibility of materials, and sterility.

**Regulatory Status**

In 2017, UFDA published guidance for industry and technical considerations for 3D
printed medical devices. The recommendations in this guidance are intended to
supplement any device-specific recommendations and represent FDA’s initial
thinking and recommendations. The guidance does not apply to 3D printing at the
point-of-care.

FDA expects “that AM [additive manufacturing] devices will follow the same
regulatory requirements and submission expectations as the
classification and/or regulation to which a non-AM device of the same type is
subject.” The required information, characterization, and testing will depend on a
variety of factors, such as whether it is an implant or instrument, and whether it is
available in standard sizes or is patient-matched.

The FDA has noted that although patient-matched devices are sometimes
referred to as customized devices, they are not custom devices meeting custom
device exemption requirements under the U.S. Federal Food, Drug, and Cosmetic
Act unless they comply with all of the criteria of section 520(b). FDA published
guidance for industry and on the custom device exemption act in 2014. Custom
devices are those created or modified to comply with the order of an individual
physician or dentist, do not exceed 5 units per year, and are reported by the
manufacturer to FDA for devices manufactured and distributed under section
520(b) of the Food, Drug, and Cosmetic Act.
Under Section 520(b) of the Food, Drug, and Cosmetic Act, custom devices are exempt from premarket approval (PMA) requirements and conformance to mandatory performance standards.

“A device not covered by an existing marketing approval would require either a PMA or a valid exemption from the requirements to obtain PMA approval in order to be introduced into interstate commerce. Examples of potential valid exemptions or alternatives from the PMA requirement include: (1) establishing the substantial equivalence of the new device to a valid predicate device, (2) approval of an Investigational Device Exemption (IDE) or (3) meeting all custom device exemption requirements.”

“Custom Devices are not exempt from any other requirements, including, but not limited to, the Quality System Regulation, including Design Controls (21 CFR Part 820); Medical Device Reporting (21 CFR Part 803); Labeling (21 CFR Part 801); Corrections and Removals (21 CFR Part 806); and Registration and Listing (21 CFR Part 807).”

A custom device may not be marketed to the general public.

FDA has also noted that most patient-matched devices will fall within the existing regulatory pathway for that device type. In addition to standard labeling, specific labeling information is recommended for AM devices that are patient-matched. FDA has stated that “modifications to a 510(k)-cleared device that maintain its original intended use and could be clinically studied do not appropriately qualify as a custom device.”

A number of titanium spinal interbody implants with increased roughness and porosity than traditional designs have received marketing clearance by FDA through the 510(k) process. They have a biomechanical stiffness similar to polyetheretherketone cages and less than solid titanium. They include:

- Cascadia™ Cervical and Cascadia™AN Lordotic Oblique Interbody Systems (K2M)
- EIT (Emerging Implant Technologies)
- IB3D (Medicrea)
- Modulus XLIF (NuVasive)
- NanoHive interbodies (HD Lifesciences).

Porous 3D printed titanium implants for minimally invasive sacroiliac joint fusion have received 510(k) clearances.

- iFuse 3D (SI Bone).

Custom knee implants include:

- ConforMIS iTotal® Cruciate Retaining Knee Replacement System (ConforMIS)
- ConforMIS iTotal® Posterior Stabilized Knee Replacement System (ConforMIS)
- ConforMIS iUni® Unicondylar Knee Replacement System (ConforMIS)
- ConforMIS iTotal Hip system (ConforMIS).

**Rationale**

This evidence review was created in May 2018 with a search of the MEDLINE database through May 21, 2019.

Evidence reviews assess the clinical evidence to determine whether the use of technology improves the net health outcome. Broadly defined, health outcomes are the length of life, quality of life (QOL), and ability to function-including benefits and harms. Every clinical condition has specific outcomes that are important to patients and managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of technology, two domains are examined: the relevance, and quality and credibility. To be relevant, studies must represent one or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. RCTs are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

**Standard-Sized 3-Dimensional printed Orthopedic Implants**

**Clinical Context and Therapy Purpose**

One proposed benefit of standard sized 3D printed orthopedic implants in patients who have typical bone and joint anatomy is to allow rough or porous surface textures that promote bone in-growth. Increased porosity may also increase the flexibility of metal implants, potentially leading to less bone resorption and subsidence.

The question addressed in this evidence review is: Do standard sized 3D printed orthopedic implants improve the net health outcome?

The following PICO was used to select literature to inform this review.

**Patients**

The relevant population of interest are patients with typical bone and joint anatomy.
Interventions
The therapy being considered is standard sized 3D-printed implants.

Comparators
The comparator is orthopedic implants made by traditional manufacturing methods.

Outcomes
The general outcomes of interest are a reduction in pain, typically measured by a visual analog scale (VAS), and improvement in function and QOL measured by joint-specific questionnaires. The minimally clinically significant difference on the Oswestry Disability Index (ODI) is 15 points.

A beneficial outcome would be a reduction in pain and improvement in function and QOL.

A harmful outcome would be an adverse event requiring revision surgery.

Pain and function may be measured after three to six months for short-term outcomes and after at least two years to evaluate the effect of the implant on the bone (eg, ingrowth or subsidence).

Study Selection Criteria
a. To assess efficacy outcomes, we sought comparative controlled prospective trials, with a preference for RCTs.
b. In the absence of such trials, we sought comparative observational studies, with a preference for prospective studies.
c. To assess long-term outcomes and adverse effects, we sought single-arm studies that capture longer periods of follow-up and/or larger populations.
d. Within each category of study design, we preferred larger sample size studies and longer duration studies.

Review of Evidence

Interbody Devices for Spinal Fusion
There is limited data on the performance of orthopedic implants produced by additive manufacturing. Porosity can be increased with 3D printing, and basic research has suggested an increase in osteointegration with more porous surfaces. Although a number of spinal interbody spacers are currently manufactured with 3D printing, it is not clear at this time whether the titanium implants lead to improved health outcomes compared with standard polyetheretherketone (PEEK) cages. Recent evidence, described below, has suggested an increase in subsidence (sinking or settling into the adjacent bone) with titanium compared with PEEK cages. The movement of an implant into the adjacent vertebra can result in a loss of disc height.
One RCT found that use of solid titanium interbody cages for anterior cervical discectomy and fusion resulted in worse clinical and radiologic outcomes compared with PEEK interbody cages at a mean at seven-year follow-up. In this trial, 80 patients with cervical spondylotic myelopathy were randomized to multilevel anterior cervical discectomy and fusion with titanium or PEEK interbody cages. The group who received anterior cervical discectomy and fusion with solid titanium implants had greater loss of Cobb angle and a greater proportion of patients showing loss of intervertebral height over 3 mm (34.5%), indicating cage subsidence, compared with the PEEK group (5.4%, p<0.05). Clinical outcome measures (Japanese Orthopaedic Association and Neck Disability Index) were significantly worse in the group with titanium cages.

A meta-analysis by Seaman et al (2017), which identified 6 studies (3 level IV evidence and 2 level III [all retrospective], and the level II prospective RCT described above), found no statistically significant difference between solid titanium and PEEK implants for spinal fusion rates, but there was a statistically significant increase in the rate of subsidence with titanium implants (odds ratio, 3.59; 95% confidence interval, 1.28 to 10.07; p=0.015). Most studies used solid titanium implants and evaluated interbody devices of different designs. Comparison of porous 3D-printed titanium implants with PEEK implants has not been reported. The only RCT identified found significant differences in favor of the PEEK group for the patient-reported outcome measures.

**Total Hip Arthroplasty**
The effect of 3D-printed titanium on bone resorption is unclear. The literature on femoral stems for hip arthroplasty indicate that osteolysis and long-term failure might increase with titanium compared with cobalt-chromium stems, which some authors have suggested is due to the increased flexibility of titanium compared with cobalt-chromium. Other investigators suggest that fully porous 3D printed titanium femoral stems may reduce bone resorption and loosening from stress-shielding. In addition to the choice of metal, the process of additive manufacturing may also result in more flexibility of the orthopedic implant than traditional manufacturing. 3D-printing of the acetabular component allows greater porosity, which in turn may lead to greater osteointegration and reduce aseptic loosening. Given the conflicting reports, additional study is needed.

**Total Knee Arthroplasty**
3D-printing of titanium implants allows a porous design to allow bone in-growth and may reduce the need for cement interfaces, which may be more prone to aseptic loosening. Cohen et al (2018) reported 3-year results from a prospective study of total knee arthroplasty with 3D-printed tibial and patellar components; outcomes were compared to matched historical controls who received cemented prostheses. There was no significant difference between the groups in the flexion range of motion through two-year follow-up. Functional outcomes were obtained only for the prospective study of the uncemented prostheses. No implants showed signs of migration or change in position at an average of 37 months postoperatively.
Sacroiliac Joint Fusion
Patel et al (2019) reported preliminary 6-month outcomes from the first 28 patients in the Study of Bone Growth in the Sacroiliac Joint after Minimally Invasive Surgery with Titanium Implants (SALLY). The study is powered for a non-inferiority comparison to prior studies using the conventionally manufactured implant, with a sample size of 50 and a non-inferiority margin of 10 points on the ODI. Preliminary data showed non-inferiority to results from the machined implant on VAS, ODI, and EuroQOL-5D. Two-year follow-up in the complete sample of patients is needed to establish non-inferiority. A randomized comparison would be needed to determine any benefits of the 3D-printed implant, such as a reduction in revision, compared to machined implants. As of June 30, 2018, there had been 11070 cases with the machined implant and 3140 cases with the 3D-printed implant. Post-market surveillance showed a 1-year cumulative probability of revision of 1.5% for machined and 1% for 3D-printed implants (p=0.041). Out of all surgical revisions, insufficient fixation was the cause of revision for 51/252 (20.2%) machined implant revisions compared to 1/26 (3.8%) 3D-printed implant revisions. The other 25 revisions of the 3D-printed implant (96.8%) were due to malpositioning. Interpretation is limited by the non-concurrent controls.

Section Summary: Standard-Sized 3D-printed Orthopedic Implants
There is limited data on the performance of orthopedic implants produced by additive manufacturing. 3D-printed implants are often manufactured with titanium and permit greater porosity than traditional manufacturing techniques. The literature on solid titanium implants has suggested greater subsidence compared with PEEK interbody spacers for spinal fusion and greater bone resorption compared with cobalt-chromium femoral stems in total hip arthroplasty. Other evidence suggests that porous titanium implants produced by 3D-printing may improve osteointegration and reduce aseptic loosening. Due to these conflicting findings, clinical trials are needed to evaluate how 3D-printed implants perform over the long-term compared with conventionally manufactured devices.

Patient-Matched 3D-printed Orthopedic Implants

Clinical Context and Therapy Purpose
One proposed benefit of patient-matched 3D-printed orthopedic implants in patients who have typical bone and joint anatomy is to provide a more natural fit and improved function.

The question addressed in this evidence review is: Do patient-matched 3D-printed orthopedic implants improve the net health outcome?

The following PICO was used to select literature to inform this review.

Patients
The relevant population of interest are patients with normal bone and joint anatomy.
**Interventions**
The therapy being considered is standard sized 3D-printed implants.

**Comparators**
The comparator is orthopedic implants made by traditional manufacturing methods.

**Outcomes**
The general outcomes of interest are a reduction in pain, typically measured by a VAS, and improvement in function and QOL measured by joint-specific questionnaires. The minimally clinically significant difference on the ODI is 15 points.

A beneficial outcome would be a reduction in pain and improvement in function and QOL.

A harmful outcome would be an increase in pain or adverse event requiring revision surgery.

Pain and function may be measured after three to six months for short-term outcomes and after at least two years to evaluate the effect of the implant on the bone (eg, subsidence or revision).

**Study Selection Criteria**

a. To assess efficacy outcomes, we sought comparative controlled prospective trials, with a preference for RCTs.

b. In the absence of such trials, we sought comparative observational studies, with a preference for prospective studies.

c. To assess long-term outcomes and adverse effects, we sought single-arm studies that capture longer periods of follow-up and/or larger populations.

d. Within each category of study design, we preferred larger sample size studies and longer duration studies.

**Review of Evidence**
No published RCTs have been identified on patient-matched knee implants. Results from an RCT (NCT02494544) comparing the ConforMIS iTotal CR Knee Replacement System with off-the-shelf implants are expected in 2025 (see Ongoing and Unpublished Clinical Trials section).

It is notable that a number of RCTs have been performed with implants produced using traditional manufacturing and designed specifically for women. These studies with sex-specific implants have not shown improvements in clinical outcomes. Similarly, trials on patient-specific cutting guides have not shown improved clinical outcomes compared with standard cutting guides (see separate policy).
Section Summary: Patient-Matched 3D-printed Orthopedic Implants

Patient-matched implants refer to the production of orthopedic implants that are modified based on 3D images to match anatomy that is considered within a typical range. No studies have been identified to evaluate whether matching orthopedic implants to individual patient anatomy improves the net health outcome. It is noted that other methods for the customization of orthopedic procedures, specifically patient-specific cutting guides and sex-specific implants, have failed to demonstrate improvements in health outcomes. Demonstration of improvement in key outcome measures is needed to justify the greater resource utilization (eg, time, imaging) of patient-matched 3D-printed devices.

Custom 3D-printed Orthopedic Implants

Clinical Context and Therapy Purpose

One proposed benefit of custom 3D-printed orthopedic implants is to allow a custom fit in patients who have atypical bone and joint anatomy due to congenital factors, trauma, or revision surgery.

The question addressed in this evidence review is: Do custom 3D-printed orthopedic implants improve the net health outcome in patients with atypical bone and joint anatomy?

The following PICO was used to select literature to inform this review.

Patients

The relevant population of interest are patients with atypical bone and joint anatomy. Conditions that may result in atypical anatomy include congenital factors, trauma, tumor resection, and need for revision of acetabular implants.

Interventions

The therapy being considered is custom 3D-printed implants. Custom implants are defined by the U.S. Food and Drug Administration (FDA) as devices created or modified to comply with the order of an individual physician or dentist, do not exceed five units per year, and are reported by the manufacturer to the FDA.

Comparators

The comparator is custom orthopedic implants made by traditional manufacturing methods.

Outcomes

The general outcomes of interest are a reduction in pain, typically measured by a VAS for pain, and improvement in function and QOL measured by joint-specific questionnaires such as the Harris Hip Score; International Society of Limb Salvage; Musculoskeletal Tumor Society Score; and ODI. Implant survival (the need for revision) may also be a relevant outcome measure for orthopedic implants.
A beneficial outcome would be a reduction in pain and improvement in function and QOL.

A harmful outcome would be an increase in pain or adverse event requiring revision surgery.

Pain and function may be measured after three to six months for short-term outcomes and after at least two years to evaluate the effect of the implant on the bone (eg, ingrowth or subsidence).

**Study Selection Criteria**

Because of the population, which is by definition rare, RCTs are unlikely. Therefore, we sought comparative observational comparative studies and single-arm studies. Within each category of study design, we preferred larger sample size studies and longer duration.

**Review of Evidence**

Examples of custom implants are summarized in Table 1 and include implants for revision arthroplasty with severely compromised acetabulum, reconstruction following bone resection in orthopedic oncology, and complex spinal pathology. Most cases address severe acetabular defects with revision total hip arthroplasty that cannot be reconstructed using commercially available cages. In the report by Citak et al (2017), patients had undergone as many as 8 prior revision hip arthroplasties. The custom 3D printed implants are typically designed with flanges to attach the acetabular cup to the pelvis. Postoperative evaluations have shown 30- to 40-point improvements in the Harris Hip Score and up to 91% implant survival at 72 months.

The second most commonly reported indication for custom implants is pelvic or long bone reconstruction after tumor resection. Case series include up to 35 patients with a follow-up of approximately 2 years. Postoperative scores have ranged from 19 out of 30 on the Musculoskeletal Tumor Society Score (MSTS) for a tibial bone block to 25.8 on the International Society of Limb Salvage score for custom plate fixation or total joint (see Table 2). Liang et al (2017) have reported outcomes with the MSTS following pelvic tumor resection and reconstruction. The custom devices were designed with a hook, crest, and either flange or braids to attach the device to the adjacent bone. Mean MSTS scores at 20.5 months were 22.7 for an iliac prosthesis, 19.8 for a hemipelvic prosthesis, and 17.7 for a screw-rod connected prosthesis.

Three-dimensional printed spinal implants have also been used to treat complex spinal pathology. One case involved tumor resection and vertebral reconstruction, and another used a custom-designed titanium fusion cage for an unusual congenital deformity. The authors reported that the custom implants were easily placed in position, which reduced the surgical time and eliminated the need to harvest autograft bone to intraoperatively fit the defect.
### Table 1. Key Case Series Characteristics of Custom Orthopedic Implants

<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Participants</th>
<th>Treatment Delivery</th>
<th>Follow-Up, mo</th>
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<tbody>
<tr>
<td>Acetabulum</td>
<td></td>
<td></td>
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<tr>
<td>Mao et al (2015)</td>
<td>China</td>
<td>22 patients with revision THA and severe acetabular defects</td>
<td>Customized acetabular cages</td>
<td>82</td>
</tr>
<tr>
<td>Li et al (2016)</td>
<td>China</td>
<td>24 patients with revision THA and severe acetabular defects</td>
<td>Rapid prototyping with custom acetabular cages</td>
<td>67</td>
</tr>
<tr>
<td>Citak et al (2017)</td>
<td>Germany</td>
<td>9 patients with an average of 5 THA revisions and severe acetabular defects</td>
<td>Customized acetabular cages</td>
<td>29</td>
</tr>
<tr>
<td>Pelvis</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Liang et al (2017)</td>
<td>China</td>
<td>35 patients with pelvic tumor resection</td>
<td>3D printed modular iliac or hemipelvic prostheses</td>
<td>20.5</td>
</tr>
<tr>
<td>Distal femur or proximal tibia</td>
<td></td>
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</tr>
<tr>
<td>Ding et al (2013)</td>
<td>China</td>
<td>12 patients with osteosarcoma in the distal femur or proximal tibia</td>
<td>Plate fixation or full knee reconstruction</td>
<td>26.5 (range, 5-74)</td>
</tr>
<tr>
<td>Luo et al (2017)</td>
<td>China</td>
<td>4 patients with tumors of the proximal tibia</td>
<td>En-block resection with customized tibial bone block</td>
<td>5-8</td>
</tr>
<tr>
<td>Spine</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mobbs et al (2017)</td>
<td>Australia</td>
<td>1 patient with craniocervical chordoma and 1 patient with a congenital spine deformity</td>
<td>Vertebral reconstruction with customized spinal cages</td>
<td>9 and 12</td>
</tr>
</tbody>
</table>

THA: total hip arthroplasty.

### Table 2. Key Case Series Results of Custom Orthopedic Implants

<table>
<thead>
<tr>
<th>Study</th>
<th>Treatment</th>
<th>Outcome</th>
<th>Outcome</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>Acetabulum</td>
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<tr>
<td>Mao et al (2015)</td>
<td>Revision THA with custom acetabular cages</td>
<td>HHS 39.6 preoperatively to 80.9 at follow-up (p&lt;0.01)</td>
<td>Implant survival of 91.2% (95% CI, 58.10% to 73.95%)</td>
<td></td>
</tr>
<tr>
<td>Li et al (2016)</td>
<td>Revision THA with custom acetabular cages</td>
<td>HHS 36 preoperatively to 82 at follow-up (p&lt;0.001)</td>
<td>75% of patients could walk unaided and 21% used a cane</td>
<td></td>
</tr>
<tr>
<td>Citak et al (2017)</td>
<td>Revision THA with custom acetabular cages</td>
<td>HHS 22.1 preoperatively to 58.7 at follow-up (p&lt;0.001)</td>
<td>89% implant survival</td>
<td></td>
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<tr>
<td>Pelvis</td>
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Liang et al (2017)\textsuperscript{14}. Modular titanium iliac or hemipelvic prostheses MSTS of 22.7 for iliac prosthesis MSTS of 19.8 for standard hemipelvic prosthesis MSTS of 17.7 for screw-rod connected prosthesis

Distal femur or proximal tibia

Ding et al (2013)\textsuperscript{17}. Custom endoprosthesis ISLS score of 25.8 (range, 18-27)

Luo et al (2017)\textsuperscript{18}. Custom titanium tibial bone block with standard knee prosthesis MSTS score, 19

Spine

Mobbs et al (2017)\textsuperscript{15}. Spinal fusion with custom implants Case 1: successful tumor resection and fusion Case 2: Improvement in back and leg pain Case 2: ODI improved from 68\% to 0\%

CI: confidence interval; HHS: Harris Hip Score; ISLS: International Society of Limb Salvage; MSTS: Musculoskeletal Tumor Society Score; ODI: Oswestry Disability Index; THA: total hip arthroplasty.

**Section Summary: Custom 3D-printed Orthopedic Implants**

The most effective use of 3D printing in orthopedics may be for custom implants, defined by the FDA as devices created or modified to comply with the order of an individual physician or dentist, do not exceed five units per year, and are reported by the manufacturer to the FDA. Potential benefits of 3D printed custom devices are flexibility in design, reduced cost, and faster production time in comparison with conventionally manufactured custom implants. Consistent with the limited number of implants that are considered custom, the literature consists of case reports and case series. The largest series with the longest follow-up is from China and the largest number of cases is for revision hip arthroplasty in patients with severe acetabular defects. Another reported use is for bone reconstruction following tumor resection. These cases require a custom process for design and manufacturing. The design and manufacturing of a single implant with 3D printing is an advantage of this technology.

**Summary of Evidence**

For individuals who have typical bone and joint anatomy and are undergoing standard orthopedic procedures who receive a standard-sized 3D printed implant, the evidence includes an RCT and systematic review. The relevant outcomes include symptoms, functional outcomes, and QOL. There is limited data on the performance of orthopedic implants produced by additive manufacturing. 3D-printed implants are often manufactured with titanium and permit greater porosity than traditional manufacturing techniques. The literature on solid titanium implants has suggested greater subsidence compared with PEEK interbody spacers for spinal fusion and greater bone resorption compared with cobalt-chromium femoral stems in total hip arthroplasty. Other evidence suggests that porous titanium implants produced by 3D-printing may improve osteointegration
and reduce aseptic loosening. Due to these conflicting findings, clinical trials are needed to evaluate how 3D-printed implants perform over the long-term compared with conventionally manufactured devices. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have typical bone and joint anatomy and are undergoing standard orthopedic procedures who receive a patient-matched 3D printed implant, the evidence includes no comparative studies. The relevant outcomes include symptoms, functional outcomes, and QOL. Studies are needed to determine whether patient-matched implants improve outcomes compared with conventional implants. It is noted that other methods for the customization of orthopedic procedures, specifically patient-specific cutting guides and sex-specific implants, have failed to demonstrate improvements in health outcomes. Demonstration of improvement in key outcome measures is needed to justify the greater resource utilization (eg, time, imaging) of patient-matched 3D printed devices. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have a bone or joint deformity requiring a custom orthopedic implant who receive a custom 3D printed implant, the evidence includes case series. The relevant outcomes include symptoms, functional outcomes, and QOL. The largest case series with the longest follow-up is from outside of the U. S. The most commonly reported indications are for revision total hip arthroplasty with severe acetabular defects, reconstruction following orthopedic tumor resection, and spinal abnormalities. These cases would require a custom process for design and manufacturing, even with traditional manufacturing methods. Therefore, the design and manufacturing of a single implant with 3D printing is an advantage of this technology. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

SUPPLEMENTAL INFORMATION

Practice Guidelines and Position Statements

American Society for Testing and Material
The American Society for Testing and Material has drafted standards for additive manufacturing. The specification on Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion covers additively manufactured titanium-6aluminum-4vanadium components using full-melt powder bed fusion such as electron beam melting and laser melting. The Society states that "the components produced by these processes are used typically in applications that require mechanical properties similar to machined forgings and wrought products. Components manufactured to this specification are often, but not necessarily, post-processed via machining, grinding, electrical discharge machining, polishing, and so forth to achieve desired surface finish and critical dimensions."

U.S. Preventive Services Task Force Recommendations
Not applicable.
Medicare National Coverage
There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

Ongoing and Unpublished Clinical Trials
Some currently ongoing and unpublished trials that might influence this review are listed in Table 3.

Table 3. Summary of Key Trials

<table>
<thead>
<tr>
<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
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<tr>
<td>NCT03647501a</td>
<td>Lumbar Fusion With 3D-Printed Porous Titanium Interbody Cages - A Single-Blinded Randomized Controlled Trial Evaluating Nexxt Matrixx(TM) Versus PEEK Cages</td>
<td>70</td>
<td>Sep 2024</td>
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<tr>
<td>NCT02494544a</td>
<td>A Prospective, Randomized, Multicenter Study to Evaluate the ConforMIS iTotal® (CR) Knee Replacement System Versus Off-the-Shelf Replacement</td>
<td>800</td>
<td>Aug 2029</td>
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NCT: national clinical trial

REFERENCES


**Billing Coding/Physician Documentation Information**

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<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>L8699</td>
<td>Prosthetic implant, not otherwise specified</td>
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</table>

**ICD-10 Codes**

- **C40.20** Malignant neoplasm of long bones lower limb, code range
- **C40.22**
- **C47.20** Malignant neoplasm of peripheral nerves of lower limb, including hip, code range
- **C47.22**
- **C49.20** Malignant neoplasm of connective and soft tissue of lower limb, code range
- **C49.22** including hip, code range
- **D16.20** Benign neoplasm of long bones of lower limb, code range
- **D16.22**
- **D21.20** Benign neoplasm of connective and soft tissue of lower limb, code range
- **D21.22** including hip, code range
- **L40.50** Arthropathic psoriasis, unspecified
- **M05.051** Felty’s Syndrome, hip and knee, code range
- **M05.069**
- **M05.451** Rheumatoid myopathy with rheumatoid arthritis, hip and knee, code range
- **M05.469**
- **M05.551** Rheumatoid polyneuropathy with rheumatoid arthritis, hip and knee, code range
- **M05.569**
- **M05.751** Rheumatoid arthritis with rheumatoid factor without organ or systems involvement, hip and knee, code range
- **M05.769**
M05.851- Other rheumatoid arthritis with rheumatoid factor, hip and knee, code range
M05.869  
M06.051- Rheumatoid arthritis without rheumatoid factor, hip and knee, code range
M06.069  
M06.251- Rheumatoid bursitis, hip and knee, code range
M06.269  
M06.351- Rheumatoid nodule, hip and knee, code range
M06.369  
M06.851- Other specified rheumatoid arthritis hip and knee, code range
M06.869  
M07.651- Enteropathic arthropathies, hip and knee, code range
M07.669  
M08.051- Unspecified juvenile rheumatoid arthritis, hip and knee, code range
M08.069  
M08.251- Juvenile rheumatoid arthritis with systemic onset, hip and knee, code range
M08.269  
M08.451- Pauciarticular juvenile rheumatoid arthritis, hip and knee, code range
M08.469  
M08.851- Other juvenile arthritis, hip and knee, code range
M08.869  
M08.951- Juvenile arthritis, unspecified, hip and knee, code range
M08.969  
M12.051- Chronic postrheumatic arthropathy [Jaccoud], hip and knee, code range
M12.069  
M12.451- Intermittent hydrarthrosis, hip and knee code range
M12.469  
M12.551- Traumatic arthropathy, hip and knee, code range
M12.569  
M12.851- Other specific arthropathies, not elsewhere classified, hip and knee, code range
M12.869  
M13.0  Polyarthritis, unspecified
M16.0-  Osteoarthritis, hip and knee, code range
M17.9  
M24.651- Ankylosis, hip and knee, code range
M24.669  
M24.7  Protrusio acetabuli
M24.851- Other specific joint derangements, not elsewhere classified, hip code range
M24.859  
M25.251- Flail joint, hip and knee, code range
M25.269  
M25.351- Other instability, hip and knee, code range
M25.369  
M25.551- Pain; hip and knee, code range
M25.569  
M43.18  Spondylolisthesis, sacral and sacrococcygeal region
M43.27- Fusion of spine, code range
M43.28  
M46.1  Sacroiliitis, not elsewhere classified
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<td>M48.08</td>
<td>Spinal stenosis, sacral and sacrococcygeal region</td>
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<td>M51.17</td>
<td>Intervertebral disc disorders with radiculopathy, lumbosacral region</td>
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<td>M53.2X7</td>
<td>Spinal instabilities, code range</td>
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<td>M53.2X8</td>
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<td>M80.052A</td>
<td>encounter for fracture, femur code range</td>
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<td>Age-related osteoporosis with current pathological fracture, subsequent</td>
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<tr>
<td>M80.051K</td>
<td>fracture with nonunion, femur code range</td>
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<td>Age-related osteoporosis with current pathological fracture, sequela</td>
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<tr>
<td>M80.059K</td>
<td>femur code range</td>
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<td>M80.859A</td>
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<td>M80.851G</td>
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<td>M80.852K</td>
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<td>M80.859S</td>
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<td>M84.462A</td>
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<td>M84.461K</td>
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<td>M84.462K</td>
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<td>M84.461S</td>
<td>Pathological fracture, sequela, tibia code range</td>
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<td>M84.462S</td>
<td>Pathological fracture in neoplastic disease, initial encounter for</td>
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<td>M84.562A</td>
<td>fracture, tibia code range</td>
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<tr>
<td>M84.561A</td>
<td>Pathological fracture in neoplastic disease, subsequent encounter for</td>
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<td>M84.562G</td>
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<td>M84.561K</td>
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<td>M84.561S</td>
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<td>M84.562S</td>
<td>Pathological fracture in other disease, initial encounter for</td>
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<td>M84.661G</td>
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<td>Code Range</td>
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<td>M87.051-</td>
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<td>M87.059</td>
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<td>M87.151-</td>
<td>Osteonecrosis due to previous trauma, femur code range</td>
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<td>Other secondary osteonecrosis, femur code range</td>
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<td>M87.256</td>
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<td>M96.661-</td>
<td>Fracture following insertion of orthopedic implant, joint prosthesis, or bone plate, femur, tibia and fibula code range</td>
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<td>M96.679</td>
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<td>M97.01XD, M97.02XD</td>
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<td>M97.01XS, M97.02XS</td>
<td>Periprosthetic fracture around internal prosthetic knee joint, subsequent encounter, code range</td>
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<td>Q74.2</td>
<td>Other congenital malformations of lower limb(s), including pelvic girdle</td>
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<td>S33.2XXA-S33.2XXS</td>
<td>Dislocation of sacroiliac and sacrococcygeal joint, code range</td>
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<td>S72.401A, S72.402A, S72.409A</td>
<td>Unspecified fracture of lower end of femur, initial encounter for closed fracture code range</td>
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<td>S72.401G, S72.402G, S72.409G</td>
<td>Unspecified fracture of lower end of femur, subsequent encounter for closed fracture with delayed healing code range</td>
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<td>Unspecified fracture of lower end of femur, subsequent encounter for closed fracture with nonunion code range</td>
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<td>Unspecified fracture of lower end of femur, sequela, code range</td>
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<tr>
<td>T84.010-</td>
<td>Broken internal prosthesis, hip and knee code range</td>
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<td>T84.013</td>
<td>Dislocation of internal prosthesis, hip and knee code range</td>
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<tr>
<td>T84.020-</td>
<td>Mechanical loosening of internal prosthetic joint, hip and knee code range</td>
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Three-Dimensional Printed Orthopedic Implants 7.01.161

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<td>T84.033</td>
<td>Periprosthetic osteolysis of internal prosthetic joint, hip and knee code range</td>
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<td>T84.050-</td>
<td>Wear of articular bearing surface of internal prosthetic joint, hip and knee code range</td>
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<td>T84.060-</td>
<td>Other mechanical complication of internal joint prosthesis, hip and knee code range</td>
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<td>T84.090-</td>
<td>Infection and inflammatory reaction due to internal prosthesis, hip and knee code range</td>
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<td>Z96.641-</td>
<td>Presence of artificial joint, hip and knee code range</td>
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**Additional Policy Key Words**
N/A

**Policy Implementation/Update Information**

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<th>Date</th>
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<tr>
<td>8/1/18</td>
<td>New Policy. Three-dimensional printed implants are considered medically necessary for custom implants for patients with bone or joint deformity and investigational for standard and patient-matched implants.</td>
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<td>8/1/19</td>
<td>No policy statement changes.</td>
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<td>8/1/20</td>
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