Characterization of Ultrahigh Molecular Weight Polyethylene (UHMWPE) Used in Orthopedic Devices

Draft Guidance for Industry and Food and Drug Administration Staff

DRAFT GUIDANCE

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For questions regarding this document, contact the Division of Orthopedic Devices (DOD) at 301-796-5650.

U.S. Department of Health and Human Services
Food and Drug Administration
Center for Devices and Radiological Health
Office of Device Evaluation
Division of Orthopedic Devices

Preface

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This draft guidance, when finalized, will represent the Food and Drug Administration's (FDA's) current thinking on this topic. It does not create or confer any rights for or on any person and does not operate to bind FDA or the public. You can use an alternative approach if the approach satisfies the requirements of the applicable statutes and regulations. If you want to discuss an alternative approach, contact the FDA staff responsible for implementing this guidance. If you cannot identify the appropriate FDA staff, call the appropriate number listed on the title page of this guidance.

I. Introduction

FDA has developed this draft guidance document for members of industry who submit and FDA staff who review testing of orthopedic devices using ultrahigh molecular weight polyethylene (UHMWPE) material. In this document, the terms "you" and "your" refer to members of industry, also known as sponsors, submitters, or applicants; and the terms "we," "us," and "our" refer to FDA. This guidance is intended to assist you in determining the appropriate information and testing to submit in premarket notifications (510(k)s), *de novo* requests, premarket approval (PMA) applications, humanitarian device exemptions (HDEs), and investigational device exemptions (IDEs) for orthopedic devices that contain UHMWPE.

This guidance addresses the characterization and testing of orthopedic devices that use UHMWPE materials such as conventional UHMWPE, highly crosslinked UHMWPE, and highly crosslinked UHMWPE containing vitamin E. This document outlines the information we recommend you include in a submission to FDA to characterize the UHMWPE material (e.g., material description, sterility, biocompatibility, mechanical properties, and chemical properties).

Many standards are referenced in this document. Please refer to the current, FDA-recognized version of these standards, as well as the extent of recognition. A searchable database of FDA-recognized consensus standards is available at http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfStandards/search.cfm.

FDA's guidance documents, including this guidance, do not establish legally enforceable responsibilities. Instead, guidances describe the Agency's current thinking on a topic and should be viewed only as recommendations, unless specific regulatory or statutory requirements are cited. The use of the word *should* in Agency guidances means that something is suggested or recommended, but not required.

II. Scope

The recommendations in this document are applicable to Class II and Class III devices intended for orthopedic applications. A list of the current devices to which this document applies is provided in Appendix 1. If you intend to submit an original IDE for an investigational device containing UHMWPE, we recommend you submit a pre-submission to the appropriate review Branch within the Division of Orthopedic Devices to determine what level of characterization is needed for the UHMWPE material. For more information on pre-submissions, please see "Requests for Feedback on Medical Device Submissions: The Pre-Submission Program and Meetings with Food and Drug Administration Staff" (http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM311176.pdf).

This guidance does not address or discuss device-specific functional testing, such as wear testing, impingement testing, or interconnection strength testing. If you have any questions on these topics, please refer to the recommendations in any applicable device-specific guidance, when available, or contact the appropriate review branch within the Division of Orthopedic Devices.

III. Types of UHMWPE Materials

There are currently three types of UHMWPE materials in wide-spread clinical use in orthopedics: conventional UHMWPE, highly crosslinked UHMWPE, and vitamin E containing highly crosslinked UHMWPE. A fourth type of UHMWPE, non-conventional UHMWPE, consists of any other UHMWPE material not currently in widespread use.

A. Conventional UHMWPE

Conventional UHMWPE is made from UHMWPE powder and has been exposed to a total radiation dose less than 40 kilograys (kGy). This material is typically terminally sterilized by gamma radiation or by non-ionizing sterilization methods.

B. Highly Crosslinked UHMWPE (XLPE)

XLPE is made from UHMWPE powder that has been subjected to total doses of gamma and/or electron beam ionizing radiation greater than 40 kGy[1] for the purpose of generating

[1] ASTM F2565 "Standard Guide for Extensively Irradiation-Crosslinked Ultra-High Molecular Weight Polyethylene Fabricated Forms for Surgical Implant Applications."

crosslinks within the material. Following crosslinking, the material is either thermally annealed, mechanically annealed, or both, to reduce free radicals. Thermal annealing can either be below the melting point of the crystals in the material (typically less than 130°C) or above the melting point (typically greater than 135°C). This material is typically terminally sterilized by a non-ionizing sterilization method.

C. Vitamin E Highly Crosslinked UHMWPE (VEPE)

VEPE is made from UHMWPE powder, has α-tocopherol (an isomer of Vitamin E) added to the material, and has been exposed to a radiation dose greater than 40 kGy. Antioxidants are typically added to the material in one of two ways, either by soaking UHMWPE in a solution containing the antioxidant or by blending the UHMWPE powder with the antioxidant prior to material consolidation. Similar to XLPE, following crosslinking, the material is either thermally annealed, mechanically annealed, or both, to reduce free radicals. Thermal annealing for this material is typically below the melting point, since elimination of all measurable free radicals is not needed to prevent material oxidation due to the presence of antioxidants.

D. Non-Conventional UHMWPE

Non-conventional UHMWPE is a polyethylene material other than the three material types discussed above. Examples may include, but are not limited to, materials that are made from lower-molecular weight polyethylenes that have been extensively crosslinked, porous polyethylenes, or polyethylenes whose surfaces have been modified.

Regardless of the submission type (510(k), *de novo*, PMA, HDE, or IDE) or material type, FDA recommends that you provide the following general information regarding the UHMWPE material to establish the type of UHMWPE in use:

- Starting resin (e.g., GUR 1020, GUR 1050, HiMont 1900);
- Concentration and identification of antioxidant or other additives (in weight percent (wt.%) and parts per million (ppm));
- Resin consolidation method (e.g., ram extrusion, compression molding, etc.);
- Radiation dose and type (e.g., gamma, electron beam, etc.);
- Time and temperature of all post-consolidation thermal anneals (e.g., to reduce free radicals, relieve internal stresses, homogenize dopant concentration, etc.);
- Compression ratio of all mechanical anneals; and
- Terminal sterilization method.

IV. Material Characterization

Depending on the type of UHMWPE, different mechanical and chemical characterization should be provided, as discussed in more detail below. This characterization information is summarized in Appendix 2. Appendix 3 provides information that should be provided in the test method reports as discussed below. In cases where you believe the information or testing detailed in this

document do not apply to your device, you should provide a rationale detailing why you are not providing the recommended information or testing.

For some of the properties, such as tensile properties, impact resistance, and density, acceptance criteria are set forth in ASTM F648, "Standard Specification for Ultra-High-Molecular-Weight Polyethylene Powder and Fabricated Form for Surgical Implants." If the material meets the acceptance criteria, no additional information will typically be requested. However, if the material's properties are below the acceptance criteria, then additional information should be provided. For example, for a 510(k), a comparison to a valid predicate device with a similar UHMWPE material (and properties) for the same intended use is recommended; for a de novo or PMA, a sound scientific rationale including supporting literature, clinical study results, etc., should be provided to support that the device is reasonably safe and effective; and for an HDE or IDE, adequate information to demonstrate the safety of the material for its intended use should be provided (e.g., literature, comparison to the control, animal studies, etc.).

We recommend that you characterize the following properties of the material: crosslink density, *trans*-vinylene index (TVI), oxidation index (OI), crystallinity, melting temperature, and free radical concentration. If the measured values lie within the normal range, determined by comparison to literature (i.e., for *de novo*, PMA, HDE, or IDE) or a predicate device with the same intended use (i.e., 510(k)), no additional information will typically be requested. However, for some properties, FDA recommends that certain results be achieved. For example, TVI should demonstrate that the radiation dose has been absorbed consistently throughout the sample. OI testing should show levels of oxidation that are stable from pre- to post-accelerated aging and are not expected to adversely affect the material's mechanical properties.[2] Free radical concentration of materials annealed above the melting temperature should have no detectable free radicals.

Finally, some of the properties, such as biaxial mechanical properties, fatigue crack propagation resistance, and consolidation, are comparative in nature. When submitted in a 510(k), the results should be compared to a predicate device with the same intended use. When submitted in a *de novo*, PMA, HDE, or IDE, the results for these properties and their anticipated impact on device performance should be thoroughly discussed and supported with available literature and a scientific rationale and incorporated into the benefit/risk analysis for the device.

A. Conventional UHMWPE

We recommend you consider the information to characterize conventional UHMWPE summarized in Table 2 of the current, FDA-recognized standard ASTM F648, "Standard Specification for Ultra-High-Molecular-Weight Polyethylene Powder and Fabricated Form for Surgical Implants." Please provide the following mechanical properties of your conventional UHMWPE in your submission to FDA:

- Tensile properties (e.g., yield strength, ultimate tensile strength, and elongation at break);
- Impact resistance (either Charpy or Izod); and

[2] Currier, Barbara H., et al. "In Vivo Oxidation of γ-Barrier–Sterilized Ultra–High-Molecular-Weight Polyethylene Bearings." The Journal of arthroplasty 22.5 (2007): 721-731.

- Density

Standard test methods typically used to assess these properties include:

- ASTM D638 "Standard Test Method for Tensile Properties of Plastics"
- ASTM D792 "Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement"
- ASTM D1505 "Standard Test Method for Density of Plastics by the Density-Gradient Technique"
- Annex 1 of ASTM F648 "Standard Specification for Ultra-High-Molecular-Weight Polyethylene Powder and Fabricated Form for Surgical Implants"
- ISO 11542-2 "Ultra-high-molecular-weight polyethylene (PE-UHMW) moulding and extrusion materials -- Part 2: Preparation of test specimens and determination of properties"

B. Highly Crosslinked UHMWPE (XLPE)

XLPE primarily differs from conventional UHMWPE in that it absorbs a relatively larger radiation dose and is then annealed. These differences alter the mechanical, physical, and chemical properties of the material, and these properties should be characterized. In addition to the information that is requested for conventional UHMWPE in Section IV.A, please provide the following information in your submission to FDA:

- Comparison of the total absorbed radiation dose to the dose of a legally marketed device with the same intended use;
- Percent crystallinity;
- Melting temperature;
- Biaxial mechanical properties (ultimate load, ultimate displacement, work to failure);
- Post-accelerated aging oxidation index throughout the sample;
- *Trans*-vinylene index throughout the sample;
- Crosslink density;
- Fatigue resistance crack propagation testing ($\Delta K_{inception}$, Paris exponent, Paris coefficient); and
- Free radical concentration.

The following current, FDA-recognized standards describe test methods typically used to assess this information:

- ASTM E647 "Standard Test Method for Measurement of Fatigue Crack Growth Rates"
- ASTM F2003 "Standard Practice for Accelerated Aging of Ultra-High Molecular Weight Polyethylene after Gamma Irradiation in Air"
- ASTM F2102 "Standard Guide for Evaluating the Extent of Oxidation in Ultra-High-Molecular-Weight Polyethylene Fabricated Forms Intended for Surgical Implants"
- ASTM F2183 "Standard Test Method for Small Punch Testing of Ultra-High Molecular Weight Polyethylene Used in Surgical Implants"

- ASTM F2214 "In Situ Determination of Network Parameters of Crosslinked Ultra High Molecular Weight Polyethylene (UHMWPE)"
- ASTM F2381 "Standard Test Method for Evaluating Trans-Vinylene Yield in Irradiated Ultra-High Molecular Weight Polyethylene Fabricated Forms Intended for Surgical Implants by Infrared Spectroscopy"
- ASTM F2625 "Standard Test Method for Measurement of Enthalpy of Fusion, Percent Crystallinity, and Melting Point of Ultra-High-Molecular Weight Polyethylene by Means of Differential Scanning Calorimetry"

There currently is no standard test method for determining free radical concentration. Free radical concentration is typically assessed using electron paramagnetic resonance (EPR) spectroscopy, also known as electron spin resonance (ESR) spectroscopy. The test method you choose should be fully described and justified in your submission. For materials annealed above the melting temperature, the free radical concentration should yield no detectable free radicals. When submitted in a 510(k), the results should be compared to a predicate device with the same intended use. When submitted in a *de novo*, PMA, HDE, or IDE, the results of free radical concentration testing and their anticipated or known impact on device performance should be thoroughly discussed and supported with available literature and scientific rationale. We recommend that, in addition to supplying the measured concentration of free radicals, spectrographs showing the free radical spectra should also be provided.

C. Vitamin E, Highly Crosslinked UHMWPE (VEPE)

VEPE primarily differs from XLPE in that an antioxidant (Vitamin E, α-tocopherol) is added either before or after exposure to radiation and the material is not annealed above its melting temperature. In addition to the information that is requested for conventional UHMWPE in Section IV.A, and XLPE UHMWPE in Section IV.B., the following additional characterization information should be provided to address specific concerns raised by the addition of Vitamin E:

1. Stability of antioxidant in the material: It is possible that the added antioxidant may leech out over time due to loading and/or in-vivo fluids that act as a solvent for Vitamin E. The loss of the antioxidant may undermine the material's oxidation resistance. This concern can be addressed by demonstrating adequate oxidation resistance following wear testing where the material is exposed to clinically relevant loads and solvents. When submitted in a 510(k), the results should be compared to a predicate device with the same intended use. Alternatively, it may be possible to address this concern by supplying a scientific rationale comparing the antioxidant concentration, radiation dose, and radiation type (i.e., gamma or electron beam) to a legally marketed predicate device with the same intended use.

   When submitted in a *de novo*, PMA, HDE, or IDE, the results of the oxidation resistance testing, and their anticipated or known impact on device performance, should be thoroughly discussed and supported with available literature and a scientific rationale.

2. Effect of antioxidant on the wear mechanism: α-tocopherol is a small molecule that can act as a plasticizer and may affect the mechanism by which the material wears. When submitting a 510(k), FDA recommends that you assess if the wear mechanism has been altered by characterizing the wear debris from wear testing of the new device and a legally marketed predicate device with the same intended use per ASTM F1877, "Standard Practice for Characterization of Particles." In addition, wear testing under normal and abrasive wear conditions should be performed. An analysis of the wear surfaces in terms of type and extent of damage modes should also be provided. Alternatively, it may be possible to address this concern by supplying a scientific rationale comparing the antioxidant concentration, radiation dose, and radiation type (i.e., gamma or electron beam) to an antioxidant-containing predicate device.

   When submitting a *de novo*, PMA, HDE, or IDE, FDA recommends that you assess if the wear mechanism has been altered by characterizing the wear debris from wear testing of the new device per ASTM F1877. In addition, wear testing of the new device under normal and abrasive wear conditions, and an analysis comparing the type and extent of damage to the wear surfaces should be provided. The anticipated, or known, impact of the wear test results on device performance should be thoroughly discussed and supported with available literature and scientific rationale (e.g., comparison to the control, animal studies, etc.).

   The following current, FDA-recognized standards may be helpful when performing wear testing:
   - ASTM F732 "Standard Test Method for Wear Testing of Polymeric Materials Used in Total Joint Prostheses"
   - ASTM F1714 "Standard Guide for Gravimetric Wear Assessment of Prosthetic Hip Designs in Simulator Devices"
   - ASTM F2423 "Standard Guide for Functional, Kinematic, and Wear Assessment of Total Disc Prostheses"
   - ISO 14242 "Implants for surgery -- Wear of total hip joint prostheses"
   - ISO 14243 "Implants for surgery -- Wear of total knee joint prostheses"
   - ISO 18192 "Implants for surgery -- Wear of total intervertebral spinal disc prostheses"

   Please refer to FDA's consensus standards database (http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfStandards/search.cfm) to identify the most current version of the standard recognized by FDA, as well as the extent of recognition.

3. Effect of antioxidant on material consolidation: When an antioxidant is added to the UHMWPE powder prior to consolidation, its presence may hinder powder consolidation. Therefore, FDA recommends that the consolidation of the material be assessed as described in Annex 2 of the current, FDA-recognized standard ASTM F648. When submitting a 510(k), the consolidation results of the new material should be compared to a predicate device with the same intended use.

When submitting a *de novo*, PMA, HDE, or IDE, the anticipated impact of the consolidation results on device performance should be thoroughly discussed and supported with available literature and a scientific rationale.

The concerns discussed in this section may also apply to UHMWPE materials containing antioxidants other than α-tocopherol. If additional concerns not discussed above are identified based on the material characterization, additional information, such as obtaining clinical data, may be recommended to mitigate these concerns.

D. Non-Conventional UHMWPE

As non-conventional UHMWPE is not clearly defined, it is not possible to provide specific testing recommendations at this time. We encourage you to submit a pre-submission with specific questions to be discussed for non-conventional UHMWPE devices. For additional information regarding the pre-submission process please refer to the Guidance for Industry and FDA Staff, "Requests for Feedback on Medical Device Submissions: The Pre-Submission Program and Meetings with Food and Drug Administration Staff" (http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM311176.pdf).

In addition to the testing discussed above, we recommend you consider the following points:

- Compression properties of the material;
- Crystal size and structure;
- Creep resistance; and
- Durability of modified surface.

Clinical data may be requested to support the safe and effective use of non-conventional UHMWPE for its intended use.

V. Biocompatibility

For Class II devices, if the subject device has *identical* UHMWPE materials and manufacturing processes as a predicate device, with the same type and duration of patient contact, we recommend that you identify the predicate device as part of your biocompatibility evaluation in lieu of providing specific testing. If your device differs in terms of material or manufacturing process, we recommend that you evaluate the biocompatibility of the materials in your device as described in Blue Book Memorandum #G95-1, Use of International Standard ISO-10993, "Biological Evaluation of Medical Devices Part 1: Evaluation and Testing", dated May 1, 1995, and available at http://www.fda.gov/RegulatoryInformation/Guidances/ucm080735.htm.

For *de novos* and class III devices, PMA/HDE/IDE, we recommend you evaluate biocompatibility of UHMWPE materials in accordance with the above referenced Blue Book Memorandum #G95-1.

The addition of α-tocopherol (or other antioxidants) raises concerns regarding the biocompatibility of the antioxidant itself and the biocompatibility of radiation-induced degradation products. The second concern generally applies to materials that contain the antioxidant and have been exposed to radiation. For tissue/bone contacting, permanently implanted devices, FDA recommends that you submit biocompatibility testing as per Blue Book Memorandum #G95-1, referenced above.

In addition, as the body's response to wear debris is critical, the effect of these extracts on the biological response to wear debris should be investigated. This may be accomplished via injecting wear particles from the wear simulator or other representative particles into the pertinent joint of an appropriate animal model. The results of the test should be compared to a control. We encourage you to submit a pre-submission with a testing protocol for review prior to initiating animal testing. As an alternative to the animal testing, it may be possible to demonstrate that the antioxidant and its degradation products are not bioavailable. This may be accomplished by performing exhaustive extractions on the powdered material. Extractions should employ both polar and non-polar solvents. The extract solution should be compared to a legally marketed device to determine if new extracts are occurring. The analysis should be performed with both liquid chromatography mass spectroscopy (LCMS) and gas chromatography mass spectroscopy (GCMS) to capture all non-volatile, semi-volatile, and volatile residues. If new residues or larger amounts of residues are found, their effect may be assessed via a toxicological risk assessment. If the extracts cannot be adequately identified or if adequate toxicological data for the residues do not exist, the animal testing discussed above should be provided.

VI. Shelf Life

FDA recommends that you do not package UHMWPE containing unstable free radicals in air-permeable packaging because shelf-aging may degrade the mechanical properties of UHMWPE. The shelf life of UHMWPE that has not been exposed to ionizing radiation, or that has been irradiated but packaged in inert environment, is limited by the integrity of the packaging material.

Appendix 1. List of Applicable Device Regulations*

Class II

1. 888.3040 Smooth or threaded metallic bone fixation fastener.
2. 888.3100 Ankle joint metal/composite semi-constrained cemented prosthesis.
3. 888.3110 Ankle joint metal/polymer semi-constrained cemented prosthesis.
4. 888.3150 Elbow joint metal/polymer constrained cemented prosthesis.
5. 888.3160 Elbow joint metal/polymer semi-constrained cemented prosthesis.
6. 888.3310 Hip joint metal/polymer constrained cemented or uncemented prosthesis.
7. 888.3340 Hip joint metal/composite semi-constrained cemented prosthesis.
8. 888.3350 Hip joint metal/polymer semi-constrained cemented prosthesis.
9. 888.3353 Hip joint metal/ceramic/polymer semi-constrained cemented or nonporous uncemented prosthesis.
10. 888.3358 Hip joint metal/polymer/metal semi-constrained porous-coated uncemented prosthesis.
11. 888.3390 Hip joint femoral (hemi-hip) metal/polymer cemented or uncemented prosthesis.
12. 888.3490 Knee joint femorotibial metal/composite non-constrained cemented prosthesis.
13. 888.3500 Knee joint femorotibial metal/composite semi-constrained cemented prosthesis.
14. 888.3510 Knee joint femorotibial metal/polymer constrained cemented prosthesis.
15. 888.3520 Knee joint femorotibial metal/polymer non-constrained cemented prosthesis.
16. 888.3530 Knee joint femorotibial metal/polymer semi-constrained cemented prosthesis.
17. 888.3535 Knee joint femorotibial (uni-compartmental) metal/polymer porous-coated uncemented prosthesis.
18. 888.3540 Knee joint patellofemoral polymer/metal semi-constrained cemented prosthesis.
19. 888.3560 Knee joint patellofemorotibial polymer/metal/polymer semi-constrained cemented prosthesis.
20. 888.3565 Knee joint patellofemorotibial metal/polymer porous-coated uncemented prosthesis.
21. 888.3650 Shoulder joint metal/polymer non-constrained cemented prosthesis.
22. 888.3660 Shoulder joint metal/polymer semi-constrained cemented prosthesis.
23. 888.3670 Shoulder joint metal/polymer/metal non-constrained or semi-constrained porous-coated uncemented prosthesis.
24. 888.3800 Wrist joint metal/polymer semi-constrained cemented prosthesis.
25. 888.3810 Wrist joint ulnar (hemi-wrist) polymer prosthesis.

Class III

26. 888.3120 Ankle joint metal/polymer non-constrained cemented prosthesis.
27. 888.3200 Finger joint metal/metal constrained uncemented prosthesis.
28. 888.3220 Finger joint metal/polymer constrained cemented prosthesis.
29. 888.3410 Hip joint metal/polymer or ceramic/polymer semiconstrained resurfacing cemented prosthesis.

30. 888.3550 Knee joint patellofemorotibial polymer/metal/metal constrained cemented prosthesis.
31. 888.3640 Shoulder joint metal/metal or metal/polymer constrained cemented prosthesis.
32. 888.3680 Shoulder joint glenoid (hemi-shoulder) metallic cemented prosthesis.

The following are post-amendments class III devices, listed according to their three-letter FDA assigned product code.

33. NJL – Prosthesis, Knee, Patellofemorotibial, Semi-Constrained, Metal/Polymer, Mobile Bearing
34. NRA – Prosthesis, Knee, Femorotibial, Unicompartmental, Semi-constrained, Metal/Polymer, Mobile Bearing
35. MJO – Prosthesis, Intervertebral Disc

* Please note that this document may also be relevant to new device types that contain UHMWPE for which the above regulations or product codes may not apply.

Appendix 2. Summary of Characterization Information for Various UHMWPE Materials*

Property	Conventional	XLPE	VEPE	Acceptance criteria
Tensile Properties	X	X	X	See ASTM F648
Crystallinity Melting Temperature		X	X	Comparison to predicate (510(k)) Comparison to literature (PMA, IDE)
Impact Resistance	X	X	X	See ASTM F648
Biaxial Mechanical Properties		X	X	Comparison to predicate (510(k)) Comparison to literature, scientific rationale (PMA, IDE)
Trans-vinylene index		X	X	Uniform throughout sample
Post-accelerated Aging Maximum Oxidation Index		X	X	Stable pre- and post-aging
Density	X	X	X	See ASTM F648
Crosslink Density		X	X	N/A
Fatigue Resistance		X	X	Comparison to predicate (510(k)) Comparison to literature, scientific rationale (PMA, IDE)
Free Radical Concentration		X	X	N/A
Consolidation testing			X	Comparison to predicate (510(k)) Comparison to literature, scientific rationale (PMA, IDE)

* Please note that this table is not all-inclusive. Please refer to the main body of this guidance document for additional information that should be provided to characterize the material.

Appendix 3. Test Reporting

We recommend that you present test data in a complete test report that includes the elements described below.

A. Test Facility Information

You should provide the name and address of the facility performing the test. You should also provide the names of the study director, investigators, and supervisors participating in the study, as well as the dates that testing was initiated and completed and the date the final report was completed.

B. Test Objectives

You should state the purpose of the test.

C. Materials and Methods

You should describe the samples tested, including the differences, if any, in the composition, material structure, and processing methods between the test samples and your device. You should also submit your test method or protocol. It should contain enough detail so an individual familiar with the appropriate standard test method can interpret the test results.

D. Protocol Deviations

You should describe any protocol deviations and their effect on the ability of the test data to support your conclusions.

E. Test Parameters and Acceptance Criteria

You should report the test parameters and acceptance criteria that you use, including:

- an explanation of and rationale for critical test parameters;
- specifications or acceptance and rejection criteria; and
- a rationale that the specifications or acceptance and rejection criteria you selected are adequate for the clinical use of your device.

F. Experimental Data

We recommend that you submit all experimental data that includes enough information to support an independent analysis and conclusion.

G. Test Results

You should summarize your test results and include a statistical analysis, where appropriate. The results should include a mean plus or minus standard error, or standard deviation. You should provide a statistical analysis of the differences between the test results, where appropriate.

H. Data Analysis

You should analyze the data, including any outlying points and anomalous results, and explain whether the data meet acceptance criteria.

I. Conclusions

We recommend that you describe the conclusions drawn from the test results and the clinical significance of the conclusions.

J. Bibliography

You should provide a bibliography and include copies of all cited references pertinent to the report.