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Orthopedic Non-Spinal Metallic Bone Screws and Washers – Performance Criteria for Safety and Performance Based Pathway

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Guidance for Industry and Food and Drug Administration Staff

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For questions about this document, contact the OHT6: Office of Orthopedic Devices/DHT6C: Division of Restorative, Repair and Trauma Devices at 301-796-5650.

U.S. Department of Health and Human Services
Food and Drug Administration
Center for Devices and Radiological Health

Preface

Public Comment

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This guidance represents the current thinking of the Food and Drug Administration (FDA or Agency) on this topic. It does not establish any rights for any person and is not binding on FDA or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. To discuss an alternative approach, contact the FDA staff or Office responsible for this guidance as listed on the title page.

I. Introduction

This guidance provides performance criteria for non-spinal metallic bone screws and their associated washers in support of the Safety and Performance Based Pathway. Under this framework, submitters planning to submit a 510(k) using the Safety and Performance Based Pathway for non-spinal metallic bone screws and washers will have the option to use the performance criteria proposed in this guidance to support substantial equivalence, rather than a direct comparison of the performance of the subject device to that of a predicate device.

For the current edition of the FDA-recognized consensus standard(s) referenced in this document, see the FDA Recognized Consensus Standards Database. If submitting a Declaration of Conformity (DOC) to a recognized standard, we recommend you include the appropriate supporting documentation. For more information regarding use of consensus standards in regulatory submissions, please refer to the FDA guidance titled Appropriate Use of Voluntary Consensus Standards in Premarket Submissions for Medical Devices.

In general, FDA's guidance documents 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 guidance means that something is suggested or recommended, but not required.

II. Scope/Device Description

The devices that are the subject of this guidance are Class II non-spinal metallic bone screws and washers regulated under 21 CFR 888.3040 and 21 CFR 888.3030, with the product codes listed in the table below:

Table 1. Relevant Product Codes

Product Code	Regulation Number	Name
HWC	21 CFR 888.3040	Screw, Fixation, Bone
HTN	21 CFR 888.3030	Washer, Bolt Nut
NDG	21 CFR 888.3030	Washer, Bolt, Nut, Non-Spinal, Metallic

Intended Use/Indications for Use: The bone screws that fall within the scope of this guidance document are intended for orthopedic non-spinal fracture fixation, osteotomy, or small joint fusion or arthrodesis. The washers that fall within the scope of this guidance document are intended for use with bone screws only to aid in load distribution at the screw head/bone interface. Bone screws or washers that are intended for mandibular, maxillofacial, cranial and orbital fracture fixation or for use in the spine are outside the scope of this guidance document. Devices intended for use with suture or chord components (e.g., bone anchors, syndesmosis tight ropes) as part of an implant system are also outside the scope of this guidance document.

Device Design Characteristics: Bone screws of varying designs (e.g., cancellous screws, cortical screws, cannulated screws, fully threaded screws, partially threaded screws) are included within the scope of this guidance. Devices that fall within the scope of this guidance document consist of bone screws and washers manufactured solely from one of the following materials in conformance with the associated FDA-recognized consensus standard:

- ASTM F136 *Standard Specification for Wrought Titanium-6Aluminum-4Vanadium ELI (Extra Low Interstitial) Alloy for Surgical Implant Applications (UNS R56401)*
- ASTM F1472 *Standard Specification for Wrought Titanium-6Aluminum-4Vanadium Alloy for Surgical Implant Applications (UNS R56400)* .
- ASTM F1295 *Standard Specification for Wrought Titanium-6Aluminum-7Niobium Alloy for Surgical Implant Applications (UNS R56700)*
- ASTM F67 *Standard Specification for Unalloyed Titanium, for Surgical Implant Applications (UNS R50250, UNS R50400, UNS R50550, UNS R50700)*
- ASTM F138 *Standard Specification for Wrought 18Chromium-14Nickel-2.5Molybdenum Stainless Steel Bar and Wire for Surgical Implants (UNS S31673)*
- ASTM F139 *Standard Specification for Wrought 18Chromium-14Nickel-2.5Molybdenum Stainless Steel Sheet and Strip for Surgical Implants (UNS S31673)*
- ASTM F1537 *Standard Specification for Wrought Cobalt-28Chromium-6Molybdenum Alloys for Surgical Implants (UNS R31537, UNS R31538, and UNS R31539)*

The inner diameter of a washer should be larger than the compatible screw's thread diameter to allow screw passage and smaller than the diameter of the compatible screw's head to allow for cortical load distribution.

Implants with the following features are outside the scope of this guidance:

- Combination products
- Resorbable devices
- Additively manufactured devices
- Devices that utilize surgical techniques or associated instruments outside the standard of care
- Devices with complex geometries or modularities (e.g., segmented, fenestrated)
- Devices with other unique technological characteristics (e.g., screw thread designs that differ substantially from recognized consensus standards for orthopedic bone screws)

Recommendations for information to be submitted in a 510(k) using the Safety and Performance Based Pathway but not otherwise outlined in this guidance document (e.g., labeling) can be found in the FDA guidance Orthopedic Non-Spinal Bone Plates, Screws, and Washers - Premarket Notification (510(k)) Submissions.

FDA may determine, on a case-by-case basis, that additional data are necessary to evaluate whether the device is appropriate for the Safety and Performance Based Pathway. In situations where you determine that additional testing outside of those identified in this guidance are necessary to determine whether the device is appropriate for the Safety and Performance Based Pathway, we encourage you to submit a Pre-Submission to engage in discussion with FDA prior to submission of the 510(k) as described in the FDA guidance Requests for Feedback and Meetings for Medical Device Submissions: The Q-Submission Program.

III. Testing Performance Criteria

If your device is appropriate for submission through the Safety and Performance Based Pathway, and you choose to use that option, you do not need to provide direct comparison testing against a legally marketed predicate device to demonstrate substantially equivalent performance characteristics. To ensure that the performance criteria outlined in this guidance remain contemporary and take into account relevant data from recent clearances, FDA recommends that you provide a results summary for all tests evaluated in addition to the other submission information (e.g., Declaration of Conformity (DOC)[1]) identified for each test or evaluation below. Consistent with FDA policy for all 510(k) submissions, for all 510(k) submissions under the Safety and Performance Based Pathway, FDA may request and review underlying data demonstrating that a new device meets the FDA-identified performance criteria and testing methodology, as necessary. Unless otherwise identified in the submission information sections below, test information such as results summary, test protocols, or complete test reports should be submitted as part of the 510(k) as described in the FDA guidance Safety and Performance Based Pathway. For additional information regarding the submission of non-clinical bench

[1] When you provide a DOC you are certifying that you are in conformance with that standard as defined in the guidance Appropriate Use of Voluntary Consensus Standards in Premarket Submissions for Medical Devices.

testing information, please see the FDA guidance Recommended Content and Format of Non-Clinical Bench Performance Testing Information in Premarket Submissions.

Mechanical Bench Testing

The following mechanical tests should be performed in conformance with the FDA currently-recognized version of ASTM F543 *Standard Specification and Test Methods for Metallic Medical Bone Screw*. We recommend that you perform all testing on screw designs that represent worst-case (e.g., most likely to loosen or fail) final design versions. You should also provide a rationale identifying how you identified the worst-case design. Additionally, axial pullout strength should be evaluated using an engineering analysis method described below. Acceptance criteria are listed below for each test.[2]

For each mechanical test below, you should provide a report as specified in the relevant reporting sections of ASTM F543, in addition to a DOC to the consensus standard. Any protocol deviations should be thoroughly described and justified; however, note that certain protocol deviations may invalidate comparison to the performance criteria listed below, resulting in the need for submission of a Traditional, Special, or Abbreviated 510(k), as appropriate.

1. **Test name:** Torsional Strength
   Methodology: ASTM F543 *Standard Specification and Test Methods for Metallic Medical Bone Screws*
   Performance Criteria: The worst-case bone screw should be selected for mechanical testing:

Nominal Major Diameter (mm)	Torsional Yield Strength (Nm)
1.5	0.16
2	0.35
2.5	0.60
2.7	1.0
3	1.0
3.5	2.1
4	2.3
4.5	3.5
5	4.3
5.5	5.9
6	9.5

[2] It should be noted that although ASTM F543 is FDA-recognized in full, FDA believes that for the purposes of the Safety and Performance Based Pathway, the testing, methods and criteria identified in this section on mechanical bench testing represent the least burdensome approach to demonstrating substantial equivalence for this pathway, although alternative or additional methods or acceptance criteria are identified in the recognized consensus standard for some tests. See the supplementary information sheet for ASTM F543 for information on extent of recognition.

Note that the acceptance criterion is based on the torsional yield strength, which is a more conservative indicator of screw failure strength than the maximum torque strength identified in ASTM F543.

Screws should be compared based on nominal diameter. For screws with nominal diameters that do not match a value in the table above, a comparison should be made to the next highest major diameter listed (e.g., a 4.25 mm screw should utilize the 4.5 mm acceptance criteria).
Performance Criteria Source: Criteria are based on aggregated mechanical testing data submitted to FDA in 510(k) submissions for orthopedic bone screws previously found to be substantially equivalent. It should be noted that the values in the table above were rounded to be the most inclusive and accurate based on the final data.
Additional Considerations: As specified in ASTM F543, a minimum of five samples should be tested. In addition, analysis of the data available to FDA on existing devices has shown that five samples should be adequate based on the mean torsional yield strength testing results compared to the criteria for each nominal diameter. To be considered a successful result, either: (1) All samples should meet or exceed the acceptance criteria listed above, (2) the average of all samples should meet or exceed the criteria above and the standard deviation should be ≤ 10% of the calculated average, or (3) the criteria derived from ASTM E122 *Standard Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process* should be met, as suggested in ASTM F543. The table value selected for the acceptance criterion should be based on the worst-case screw nominal major diameter. If the nominal major diameter is not listed in this table, the next highest diameter torsional strength value should be used as the acceptance criterion.
Submission Information: Results summary and DOC

2. **Test name:** Driving Torque
Methodology: ASTM F543 *Standard Specification and Test Methods for Metallic Medical Bone Screws*
Performance Criteria: The screw with the highest risk of failure during insertion (i.e., the screw with the lowest safety factor between the insertion torque and the yield torque) should be evaluated with Driving Torque testing results. Typically, the worst-case bone screw used in torsional strength testing should be tested in insertion and removal testing. However, tip geometry and surgical technique should also be considered in establishing the worst case. The maximum torque recorded in insertion and removal testing into a minimum of 20 pcf bone foam should be 50% of or less than the torsional yield strength of the bone screw. Additionally, visual inspection should be performed on screws following their removal, and images of the final test samples should be provided to demonstrate that the screw threads adequately resist damage, such as disassociation of the screw thread from the screw body.
Performance Criteria Source: Criteria are based on aggregated mechanical testing data submitted to FDA in 510(k) submissions for orthopedic bone screws previously found to be substantially equivalent.

Additional Considerations: A minimum of five samples should be tested. In order to be considered a successful result, all samples should meet or exceed the acceptance criteria listed above.
Submission Information: Results summary and DOC

3. **Test name:** Axial Pullout Strength
Methodology: An engineering analysis is recommended to assess axial pullout strength using the equation described by Chapman et al., 1996.[3] Note that for this analysis to be appropriate, the instrumentation identified in the associated surgical technique manual should allow for close to idealized thread engagement. If this assumption is not accurate for your scenario, then the identified engineering analysis may not be appropriate for the assessment of the proposed device as identified in this guidance.

For all screws, extract the relevant dimensions below (i.e. screw major diameter, screw minor diameter, screw pitch, and axial thread length). These dimensions will be used to quantify thread engagement and calculate the theoretical pullout strengths for the smallest axial thread lengthened screws in the device system using the following equation:

$$Fs = S * A = \{S * L * \pi * Dmajor * TSF\}$$

Fs = predicted shear failure force (N)
S = material ultimate shear stress (MPa)
A = thread shear area (mm^2)
L = axial thread length (mm) including only threads that have the nominal major diameter where complete purchase is expected (e.g., excluding the screw tip) of thread engagement in material
Dmajor = major diameter (mm)
TSF = Thread Shape Factor (dimensionless) = (0.5 + 0.57735 d/p)
d = thread depth (mm) = (Dmajor – Dminor)/2
Dminor = minor (root) diameter (mm)
p = thread pitch (mm)

Use a material ultimate shear stress value of 3.395 MPa (representative of 20 pcf bone foam) in your analysis. The resulting theoretical pullout strength value obtained for the device should be equivalent or greater to the following values depending on the nominal major diameter of the worst-case screws. A justification should be provided to support why the evaluated screws selected are worst case. Axial pullout performance is heavily influenced by amount of interface. Factors such as decreasing outer diameter and decreasing axial thread length may help identify the worst case.

Dimensions used for calculations should be clearly listed for each theoretical outcome. Dimensional values used in this calculation should be consistent with the values listed on the screw engineering drawings.

[3] Chapman, J. R. (1996). Factors Affecting the Pullout Strength of Cancellous Bone Screws. Journal of Biomechanical Engineering,118(3), 391. doi:10.1115/1.2796022

Performance Criteria:

Nominal Major Diameter (mm)	Theoretical Pullout Strength (N)
1.5	45.6
2	50.5
2.5	55.5
2.7	79.5
3	92.0
3.5	112.5
4	148.4
4.5	152.3
5	230.7
5.5	336.0
6	468.6
6.5	503.5

Screws should be compared based on nominal diameter. For screws with nominal diameters that do not match a value in the table above, a comparison should be made to the next highest major diameter listed (e.g., a 4.25 mm screw should utilize the 4.5 mm acceptance criteria).
Performance Criteria Source: Criteria are based on aggregated mechanical testing data and device description information submitted to FDA in 510(k) submissions for orthopedic bone screws previously found to be substantially equivalent.
Submission Information: Results summary and engineering analysis

Sterilization (devices labeled as sterile) and Reprocessing (end-user sterilized) Validation

4. **Test name:** Sterilization (devices labeled as sterile) and Reprocessing (end-user sterilized)
Methodology: FDA currently-recognized versions of the following consensus standards (as applicable – note that this is not an exhaustive or exclusive list):
    - International Organization for Standardization (ISO) 17665 *Sterilization of health care products – Moist heat - Requirements for the development, validation, and routine control of a sterilization process for medical devices*
    - ISO 11135 *Sterilization of health care products – Ethylene oxide - Requirements for development, validation, and routine control of a sterilization process for medical devices*
    - ISO 11137-1 *Sterilization of health care products - Radiation - Part 1: Requirements for development, validation, and routine control of a sterilization process for medical devices*
    - ISO 11137-2 *Sterilization of health care products - Radiation - Part 2: Establishing the sterilization dose*

- ISO 11137-3 *Sterilization of health care products - Radiation - Part 3: Guidance on dosimetric aspects of development, validation and routine control*
- ISO/TS 11137-4 *Sterilization of health care products - Radiation - Part 4: Guidance on process control*
- ISO 13004 *Sterilization of health care products - Radiation - Substantiation of selected sterilization dose: Method VDmaxSD*
- ISO 11607-1 *Packaging for terminally sterilized medical devices – Part 1: Requirements for materials, sterile barrier systems and packaging systems*
- ISO 11607-2 *Packaging for terminally sterilized medical devices – Part 2: Validation requirements for forming, sealing and assembly processes*
- ASTM F88/F88M *Standard Test Method for Seal Strength of Flexible Barrier Materials*
- ASTM F3039 *Standard Test Method for Detecting Leaks in Nonporous Packaging or Flexible Barrier Materials by Dye Penetration*
- ASTM F2096 *Standard Test Method for Detecting Gross Leaks in Packaging by Internal Pressurization (Bubble Test)*
- ISO 20857 *Sterilization of health care products — Dry heat — Requirements for the development, validation and routine control of a sterilization process for medical devices*

Performance Criteria: Validation testing should demonstrate the cleanliness and sterility of, or the ability to clean and sterilize to a sterility assurance level of 10^{-6}, the device and device-specific instruments. You should provide a description of the packaging (sterile barrier system) and how it will maintain the device's sterility, and a description of the package test methods, but not package test data.

Performance Criteria Source: FDA guidance:

- Submission and Review of Sterility Information in Premarket Notification (510(k)) Submissions for Devices Labeled as Sterile
- Reprocessing Medical Devices in Health Care Settings: Validation Methods and Labeling

Submission Information: If using an Established Category A sterilization method, you should provide the information described in Section V.A. of the FDA guidance Submission and Review of Sterility Information in Premarket Notification (510(k)) Submissions for Devices Labeled as Sterile; the validation data itself is not needed to demonstrate substantial equivalence.

Biocompatibility Evaluation:

To identify the biocompatibility endpoints to include as part of your biocompatibility evaluation you should use Attachment A of the FDA guidance Use of International Standard ISO 10993-1, "Biological evaluation of medical devices – Part 1: Evaluation and testing within a risk management process," referred to in the rest of this document as the FDA Biocompatibility Guidance for brevity. FDA considers the devices covered by this guidance to be categorized as Implanted Devices in contact with tissue/bone with a prolonged or "permanent" contact duration of > 30 days and you should assess the endpoints below per Attachment A of the FDA Biocompatibility Guidance.

- Cytotoxicity

- Sensitization
- Irritation or Intracutaneous Reactivity
- Acute Systemic Toxicity
- Material-Mediated Pyrogenicity
- Sub-acute/Sub-chronic Toxicity
- Genotoxicity
- Implantation
- Chronic Toxicity
- Carcinogenicity

Rationale in Lieu of Testing: If the subject device is manufactured from the identical raw materials using identical manufacturing processes as a predicate device with the same type and duration of tissue contact, and any changes in geometry are not expected to impact the biological response, this is typically sufficient to establish substantially equivalent biocompatibility, if documentation such as that outlined in Attachment F of the FDA Biocompatibility Guidance is also provided.

Testing: In rare cases, if you determined that testing is needed to address some or all of the identified biocompatibility endpoints, FDA recommends that complete test reports be provided for all tests performed unless a DOC without supplemental information can be appropriately provided, per Attachment E of the FDA Biocompatibility Guidance. Any test-specific positive, negative, and/or reagent controls should perform as expected, and protocol deviations should be thoroughly described and justified; however, note that certain protocol deviations may invalidate comparison to the performance criteria listed below and require submission of a Traditional, Special, or Abbreviated 510(k).

5. **Test name:** Biocompatibility endpoints (identified from FDA Biocompatibility Guidance)
   Methodology: FDA currently-recognized versions of biocompatibility consensus standards
   Performance Criteria: All direct or indirect tissue contacting components of the device and device-specific instruments should be determined to have an acceptable biological response.
   Performance Criteria Source: The FDA Biocompatibility Guidance
   Additional Considerations: For any biocompatibility test samples with an adverse biological response, the biocompatibility evaluation should explain why the level of toxicity seen is acceptable. Some comparison testing against a legally marketed predicate may be necessary (and is considered acceptable under the Safety and Performance Based Pathway) to support such a rationale as explained in the FDA Biocompatibility Guidance. For standard biocompatibility test methods that include comparison device control samples, the legally marketed comparison device control samples should perform as expected, as specified above for the subject device samples.
   Submission Information: Refer to FDA Biocompatibility Guidance.