# The New Standard of Care for Duodenoscope Reprocessing: Terminal Sterilization Using the STERIZONE® VP4 Sterilizer

## STERIZONE VP4 Sterilizer

### How it works

**Single Cycle**. The STERIZONE VP4 Sterilizer offers a single preset sterilization cycle designed for the sterilization of a wide variety of loads consisting of general instruments, single, double or multi-channel flexible endoscopes, and rigid and semi-rigid channeled devices including single channel and double channel rigid endoscopes.

**Dual Sterilants.** The STERIZONE VP4 Sterilizer uses dual sterilants, vaporized hydrogen peroxide ($H_2O_2$) and ozone ($O_3$), in a multiphase process, and is the only dual-sterilant sterilizer cleared for use in the United States.

**Sterilization Process** (**Figure 1**). After a **preconditioning** step, which creates a vacuum inside the chamber, the first cycle phase is initiated with the **Dynamic $H_2O_2$ exposure** step. During this step, a 50 weight-percent hydrogen peroxide solution (referred to as 125-280 Solution™) is injected at a fixed injection rate in vapor form into the sterilization chamber. The patented micro-pulsed injection (referred to as Dynamic Sterilant Injection System™) continues until a differential pressure set point of 19 Torr is reached. The total amount of hydrogen peroxide introduced into the sterilization chamber, and thus the duration of the injection, varies depending on load composition, weight and temperature. The STERIZONE VP4 Sterilizer is the first sterilizer to automatically vary the amount of sterilant based on the load, and why a single cycle can be used to sterilize a wide variety of different loads.

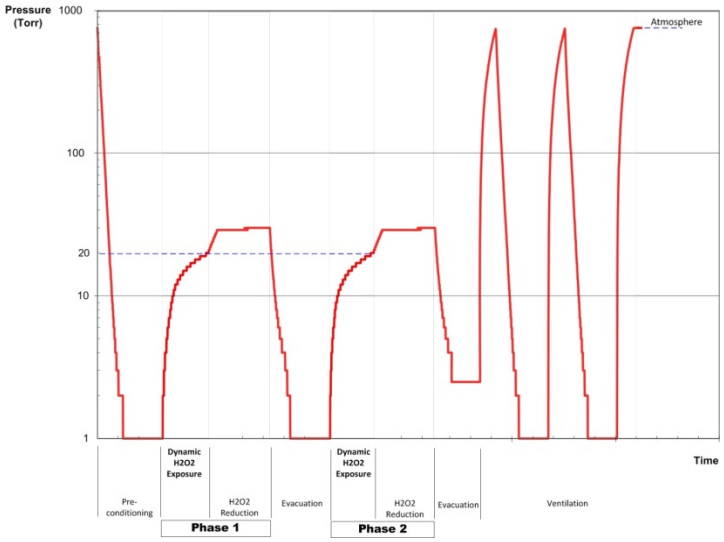


**Figure 1:** STERIZONE VP4 Sterilizer cycle graph corresponding to the two injection phases followed by evacuation and ventilation.

A small amount of ozone is then added in the **$H_2O_2$ reduction** step. The ozone reacts with residual hydrogen peroxide to form hydroxyl radicals. The formation of these hydroxyl radicals further enhances the overall lethality of the process. The ozone used in the process is generated within the sterilizer using oxygen. Oxygen required by the sterilizer can be supplied from a variety of sources, such as an oxygen concentrator or a portable oxygen cylinder.

The chamber is then subjected to a vacuum during the **evacuation** phase, which removes residual sterilant from the chamber. All microbial life is killed in the first phase. For additional

safety as required by regulations, the whole process is then repeated a second time for a complete second cycle. Then in the final **ventilation** phase, the system removes air to create a vacuum, and then returns to atmospheric pressure, repeating this process two times to safely remove residual sterilant from the chamber and the instrumentation.

**No toxic residues**. The STERIZONE VP4 Sterilizer produces no toxic residues, reducing risks to workers and potential patient health concerns. A user manual is provided and users must read, understand and follow the instructions provided in the manual.

More information about this sterilizer can be found in the STERIZONE VP4 Sterilizer Technical Monograph available at tso3.com/sterizone.

## Duodenoscope reprocessing

The effective reprocessing of duodenoscopes is known to be challenging due to the device's design complexity, including long, narrow lumens and a forceps elevator mechanism. Multiple duodenoscope related patient infections have been published, despite adherence to the device manufacturer's reprocessing instructions [1,2,3,4,5]. As a result, many healthcare facilities are seeking a solution for terminal sterilization of duodenoscopes because it offers a significantly greater margin of safety than the current standard of care using high-level disinfection. Efficient terminal sterilization of duodenoscopes is now possible with a low temperature sterilizer validated and FDA-cleared for this intended use, the STERIZONE VP4 Sterilizer.

In 2015, the STERIZONE VP4 Sterilizer was approved in Canada and Europe for the sterilization of multichannel flexible endoscopes. In June 2016, the FDA cleared the following endoscope claims (K153689):

> *one multi-channel flexible endoscope, with no more than 4 channels (Video Colonoscope), with inside diameters of 1.2 or more and lengths of 1955 mm or less, or 1.45 or more and lengths of 3500 mm or less; packaged in aluminum sterilization container*.

These indications for use were validated with data described in regulatory filings as Load #9. Validation for this Load #9 was performed with a colonoscope, the worst-case device sterilized in the sterilizer.

In May 2018, the STERIZONE VP4 Sterilizer received an industry first clearance in the United States for sterilization of duodenoscopes (K172191). This clearance adds duodenoscopes that are within the specified indications for use for the gastrointestinal multi-channel flexible endoscopes already cleared in Load #9. Endoscope models that fall outside of the channel dimensions described in validation load #9 are cleared for sterilization if they were directly validated following the same validation protocols in the K172191 clearance. In this case, the K172191 clearance was based upon validation data for the Olympus® EVIS EXERA II TJF-Q180V duodenoscope (**Figure 2).**

**Figure 2:** Olympus® EVIS EXERA II TJF-Q180V duodenoscope.

This document provides a high-level summary of the validation data submitted as part of the K172191 clearance for sterilization of the Olympus® EVIS EXERA II TJF-Q180V duodenoscope in the STERIZONE VP4 Sterilizer.

## Sterility validation in the STERIZONE VP4 Sterilizer

Comprehensive sterilization validation testing was completed for the Olympus® EVIS EXERA II TJF-Q180V duodenoscope in the STERIZONE VP4 Sterilizer. The validation studies included:

- demonstration of the Sterility Assurance Level (SAL)
- simulated use testing and
- clinical in-use testing.

All methods were validated and in accordance with FDA guidance [6]. Testing was performed using a minimum of three replicates.

### Demonstration of $10^{-6}$ Sterility Assurance Level

The sterilization of the Olympus® EVIS EXERA II Duodenovideoscope TJF-Q180V in the STERIZONE VP4 Sterilizer was validated with a half-cycle approach, commonly referred to as "overkill".

**Objective**: Validate the sterility assurance level (SAL) of the sterilizer with a specific device, in this case for sterilization of a duodenoscope.

**Test Methods**: The half-cycle method consists of inoculating the duodenoscope with at least $10^6$ CFU (Colony Forming Units) of the most resistant microorganism, and by demonstrating no growth following a sterilization half cycle. In this case, no growth indicates a 6-log reduction of the bacterial inoculum at the half-cycle. Extending this to a complete cycle will achieve a 12-log reduction of the test microorganism. This demonstrates a sterility assurance level of $10^{-6}$ that is required to claim terminal sterilization.

The microorganism used for this test was the *Geobacillus stearothermophilus* spore, which is recognized as the most resistant microorganism to oxidative sterilization processes, such as hydrogen peroxide and ozone. *G. stearothermophilus* spores are far more resistant to sterilization processes than viruses (lipid and nonlipid), fungi or mycobacteria, other vegetative spores and spore-forming bacteria, and multi-drug resistant organisms (MDROs).

As per testing guidelines, the half-cycle was performed with no washing steps after inoculating the device with resistant spores and then allowing the suspension to dry. The loads were conditioned to represent the worst-case sterilization conditions at a temperature of 79°F, which produces the shortest sterilant exposure in the STERIZONE VP4 Sterilizer. Following completion of the half cycle, the inoculated sites, which consisted of the elevator recess, the air and water channels (distal and umbilical sections), the suction channel and the instrument channel, were sampled for detection of viable microorganisms.

**Results**: All test results demonstrated sterilization of the Olympus® EVIS EXERA II Duodenovideoscopes TJF-Q180V using a half-cycle validation approach in the STERIZONE VP4 Sterilizer, confirming a sterility assurance level of $10^{-6}$. See **Table 1**.

**Table 1.** STERIZONE VP4 Sterilizer Half-Cycle Validation Results.

| Test sites | Microorganism contamination type | Results |
|---|---|---|
| Elevator recess | 1.0 – 2.5 x $10^6$ CFU of *G. stearothermophilus* spores | Pass |
| Air/water channels | | Pass |
| Suction channel | | Pass |
| Instrument channel | | Pass |

## Simulated Use Validation

The sterilization of the Olympus® EVIS EXERA II Duodenovideoscope TJF-Q180V in the STERIZONE VP4 Sterilizer was also validated with a simulated use method.

**Objective**: Validate the sterilization of the duodenoscope under worst-case, simulated-use conditions.

**Test Methods**: When performing this simulated use validation study, the most resistant microorganism known to the sterilization process is mixed with a soil containing organic and inorganic components designed to mimic clinical soils. Tests were performed by directly inoculating duodenoscopes with at least $10^6$ CFU of the *G. stearothermophilus* spores mixed with 5% fetal bovine serum and 400 ppm hard water and left to dry overnight. The inoculated duodenoscopes were then placed in compatible sterilization containers and reprocessed in the STERIZONE VP4 sterilization cycle.

This simulated use study was conducted with duodenoscopes that were repeatedly reprocessed in the STERIZONE VP4 Sterilizer prior to testing. The inoculation sites and load conditions were the same as the those previously identified in the half-cycle validation, with the addition of three sites where adhesives are used to join or secure materials (e.g., adhesive that joins bending rubber to insertion tube). These additional sites (**Figure 3**) were selected because adhesives are known to be susceptible to possible degradation from repeated reprocessing based on available literature [7]. Again, to simulate worst case conditions, the cleaning step was omitted prior to sterilization.

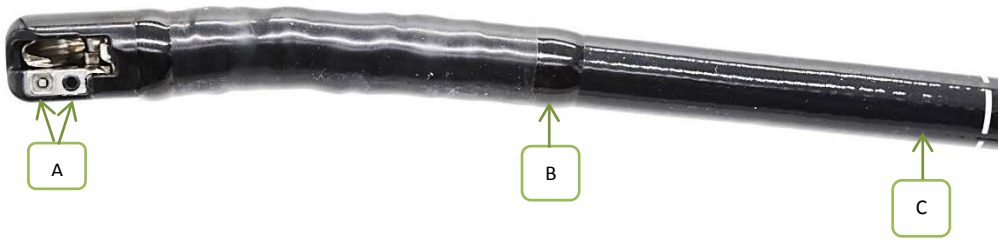


**Figure 3.** Picture of the distal end and additional inoculation sites on the Olympus® EVIS EXERA II TJF-Q180V duodenoscope (adhesives around the light source and camera objective lenses, the bending section adhesive, and the insertion tube).

After inoculation, the duodenoscopes were conditioned to worst-case temperature (79°F) and then sterilized. Following processing in STERIZONE VP4 Sterilizer, test sites were then sampled for detection of viable microorganisms.

**Results**: All testing was performed under worst-case conditions and demonstrated sterilization of the Olympus® EVIS EXERA II Duodenovideoscopes TJF-Q180V in the STERIZONE VP4 Sterilizer. See **Table 2**.

**Table 2**. STERIZONE VP4 Sterilizer Simulated-Use Validation Results.

| Test sites | Microorganism contamination type | Results |
|---|---|---|
| Elevator recess | $1.0 – 2.5 \times 10^6$ CFU of *G. stearothermophilus* spores mixed with organic and inorganic soils | Pass |
| Air/water channels | | Pass |
| Suction channel | | Pass |
| Instrument channel | | Pass |
| Light source and camera lens adhesives | | Pass |
| Flexible section adhesive | | Pass |
| Insertion tube | | Pass |

## Clinical In-Use Validation

The sterilization of the Olympus® EVIS EXERA II Duodenovideoscope TJF-Q180V in the STERIZONE VP4 Sterilizer was also validated under clinical in-use conditions.

**Objective**: Validate sterilization of the Olympus® TJF-Q180V when reprocessed in a healthcare facility using the STERIZONE VP4 Sterilizer.

**Test Methods**: During this study, trained healthcare personnel executed the recommended cleaning procedure in conjunction with the STERIZONE VP4 Sterilizer instructions for use (IFU) on clinically soiled duodenoscopes from patient procedures.

Hospital-owned duodenovideoscopes were used during clinical procedures and assessed for their sterility after processing in the STERIZONE VP4 Sterilizer. Study endoscopes were not in new condition, exhibiting visible signs of wear, like ridges on the insertion tube and cracks in the bending section. After the ERCP procedure, manual cleaning of the tested devices was performed by the hospital sterile processing department personnel according to their internal reprocessing procedure, which complies with the endoscope manufacturer instructions for cleaning. No automated endoscope reprocessor (AER) or high-level disinfection step was performed prior to terminal sterilization. The tested endoscopes were then packaged in compatible containers and reprocessed according to the STERIZONE VP4 Sterilizer indications for use. Following sterilization, the duodenoscopes were sampled for viable microorganisms under aseptic conditions. Samples from all channels, the elevator recess and the insertion tube surface were obtained from each clinically used duodenoscope.

**Results**: All clinical testing demonstrated sterilization of the Olympus® EVIS EXERA II Duodenovideoscopes TJF-Q180V in the STERIZONE VP4 Sterilizer. See **Table 3**.

**Table 3**. STERIZONE VP4 Sterilizer Clinical In-Use Validation Results.

| Recovery site | Microorganism contamination type | Results |
|---|---|---|
| Elevator mechanism | Aerobic and anaerobic bacteria plus yeast and molds, as found in a routine ERCP procedure | Pass |
| Air/water channels | | Pass |
| Suction channel | | Pass |
| Instrument channel | | Pass |
| Insertion tube | | Pass |

## Compatibility validation

The compatibility of the Olympus® EVIS EXERA II Duodenovideoscopes TJF-Q180V for sterilization in the STERIZONE VP4 was validated by simulated reprocessing.

**Objective**: Demonstrate the compatibility of the Olympus® TJF-Q180V when reprocessed in a healthcare facility using the STERIZONE VP4 Sterilizer.

**Test methods**: The duodenoscopes were repeatedly reprocessed, including complete manual cleaning between each sterilization cycle. The manufacturer's recommended inspection was performed following each cycle, including a leak test. Additionally, a modified leak test was performed while applying additional force to the elevator forceps, which was designed to provide additional challenge to the elevator mechanism seal. The duodenoscope maintained functionality after multiple sterilization cycles and no leakage was detected at the elevator forceps.

Furthermore, the integrity of the distal end cap seals following repeated reprocessing was evaluated because damage to these seals could lead to liquid ingress and cross-contamination that would not be detected during a standard leak test. Two different methods were performed, including an optical detection method (fluorescent probe method) and a biological detection method (blood and egg yolk soil method). See **Table 4**. Both methods demonstrated that no liquid ingress occurred under the distal cap, indicating that the distal end seals remained intact following repeated cycling in the STERIZONE VP4 Sterilizer.

**Results**: Collectively, these compatibility studies demonstrated that no additional failure modes were observed that were not detectable by the manufacturer's recommended inspection.

**Table 4**. STERIZONE VP4 Sterilizer Liquid Ingress Results.

| Liquid ingress study detection method | Duodenoscopes | Results |
|---|---|---|
| Optical method (fluorescent probe method) | 2 | No liquid ingress detected |
| Biological detection method (blood and egg yolk soil method) | 3 | No liquid ingress detected |

In general, sterilization processes are harsher on endoscope materials than high-level disinfection and users may observe an increased frequency of repair. The duodenoscope manufacturer's IFUs for visual, tactile and functional inspection of the duodenoscope between each cycle should be followed. Materials known to degrade quicker during reprocessing, such as adhesives at the distal end and the bending section, should be carefully inspected in accordance with professional guidelines using lighted magnification. Preventive maintenance recommended by the duodenoscope manufacturer should be performed.

## Clinical recommendations

Before sterilization of duodenoscopes in the STERIZONE VP4 Sterilizer:

- **Clean** the endoscope according to the manufacturer's instruction for use and professional guidelines.
- **Dry** the endoscope properly, including all internal channels.
- **Package** the duodenoscope in either a rigid sterilization container or a wrapped tray compatible with hydrogen peroxide-ozone sterilization.
- **Load** one duodenoscope per cycle, on the bottom shelf of the STERIZONE Loading Rack, following the STERIZONE VP4 Sterilizer instructions for use.

High-level disinfection is not necessary prior to terminal sterilization in the STERIZONE VP4 Sterilizer.

The $TSO_3$ clinical team is available to support the implementation and provide guidance on best practices for duodenoscope sterilization in healthcare facilities. Contact info@tso3.com or call 1-844-833-0003.

## Conclusions

The STERIZONE VP4 Sterilizer was successfully validated for the terminal sterilization of the Olympus® EVIS EXERA II TJF-Q180V duodenoscope. Tests were performed under simulated worst-case conditions and clinical in-use conditions. All data and results from this study were reviewed and cleared by the FDA. The STERIZONE VP4 Sterilizer is 510(k) cleared in the U.S. for the terminal sterilization of the Olympus® EVIS EXERA II TJF-Q180V duodenoscope.

The STERIZONE VP4 Sterilizer is an effective and efficient method of sterilization that can be central to an effective infection control strategy. Since 2017, the STERIZONE VP4 Sterilizer is being successfully adopted for sterilization of duodenoscopes by a growing number of hospitals around the world to elevate the standard of care and provide enhanced safety for patients.

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