STERILIZATION IN ORTHODONTICS

Vedika[1], Gursharan Kaur[2], Shubam Jindal[3]

ABSTRACT

Sterilization in orthodontics is a critical component of infection control, ensuring that instruments, materials, and clinical environments remain free from pathogenic microorganisms. Given the frequent exposure of orthodontic tools to saliva, blood, and aerosols, cross-infection risks involving pathogens such as Hepatitis B, Hepatitis C, HIV, and Mycobacterium tuberculosis are significant. This review outlines the microbiological risks specific to orthodontic practice and discusses the principles and classifications of sterilization, including the Spaulding system of criticality. Various sterilization techniques—such as steam autoclaving, dry heat, ethylene oxide gas, chemical vapor, and cold chemical sterilization—are analyzed with respect to their mechanisms, efficacy, and impact on orthodontic materials. Evidence from multiple studies demonstrates that while most orthodontic instruments can withstand standard heat-based sterilization without loss of mechanical function, elastomeric and coated materials may experience alterations after repeated cycles. The paper also emphasizes validated protocols for cleaning, packaging, sterilizing, and storing orthodontic instruments, highlighting the importance of biological and chemical indicators for process verification. Challenges in clinical implementation, including material compatibility, time constraints, and compliance issues, are addressed alongside emerging sterilization technologies such as plasma and UV-C systems. The article concludes that strict adherence to evidence-based sterilization protocols, coupled with continuous staff training and equipment maintenance, is indispensable for ensuring biosafety in orthodontic practice and maintaining public health standards.

Keywords: Sterilization, Orthodontics, Infection Control, Autoclave, Cross-Infection, Disinfection, Orthodontic Instruments.

Introduction

Sterilization in orthodontics refers to processes that ensure instruments, materials, and surfaces used in orthodontic practice are free of all living microorganisms, including bacteria, viruses, fungi, and spores. Given the nature of orthodontic treatment, with frequent manipulation of the oral environment, exposure to saliva, blood, and possibly aerosolized particles, orthodontic practitioners, staff, and patients are at risk of cross-infection from pathogens such as Hepatitis B, Hepatitis C, HIV, Mycobacterium tuberculosis, and others. Effective sterilization and disinfection protocols are thus essential for safe practice. 1,2

This article reviews: the microbiological risks in orthodontics; principles and classifications of sterilization and disinfection; the commonly used sterilization methods (their advantages, limitations, and effects on orthodontic materials); specific protocols for orthodontic instruments and materials; quality assurance; emerging or alternative methods; challenges and recommendations.

The Microbiological Risk in Orthodontics

Orthodontic procedures typically involve:

- Insertion, removal, or adjustment of appliances (brackets, bands, archwires, springs, elastics).
- Use of pliers, cutters, debonding burs, ligatures, and other instruments that contact mucosa or may become contaminated with saliva or blood.
- Exposure to aerosol generation (for example during removal of adhesives, finishing, polishing).
- Re-use or multiple contacts of certain components (e.g. elastomeric ties, springs, wires) which may have been handled or stored improperly.

Studies have shown that orthodontic supplies "as received" from manufacturers may already harbor bacterial contamination; exposure to the clinical environment increases contamination risk 3. One study found that stainless steel and NiTi wires, elastomeric chains ("e-chains") and ties showed 100% contamination in "as received" samples before any sterilization/disinfection 4. Thus, the need is not only for sterilizing after clinical use but also for ensuring items entering the clinic are free of significant microbial load.

Definitions, Classification, and Principles

Sterilization vs Disinfection vs Cleaning

- Cleaning: Removal of visible soil (blood, saliva, debris) and reduces microbial load but does not reliably kill pathogens in vegetative or spore form.
- Disinfection: Use of chemical agents or physical processes to kill many or all pathogenic microorganisms except bacterial spores. Levels include low, intermediate, and high level disinfection depending on organism types targeted.
- Sterilization: Complete elimination or destruction of all forms of microbial life, including spores.

Criticality of Instruments (Spaulding Classification)

- Critical items: Instruments that penetrate soft tissue or bone, contact the bloodstream, or otherwise carry a high risk of infection. These must be sterilized.

- Semi-critical: Instruments contacting mucosa or non-intact skin (e.g. retractors, some archwires, pliers contacting oral tissues). They should ideally be sterilized; if not possible, high-level disinfection.
- Non-critical: Items touching intact skin only. Lower level disinfection may suffice.

In many orthodontic practices, while some instruments might be semi-critical by definition, due to the risk and nature of contact, it is often safer to treat most instruments (especially reusable ones) as critical and sterilize them accordingly.

Standard Sterilization Methods in Orthodontics

Below are the various sterilization/disinfection methods used in orthodontic practice, with their pros, cons, and effects on orthodontic materials.

Method	**Principle/Mechanism**	**Typical Parameters**	**Advantages**	**Limitations / Effects on Ort. Materials**
Steam Autoclave (Moist Heat)	Saturated steam under pressure denatures proteins and kills microorganisms (including spores).	Usually 121 °C for 15-20 min (gravity type) or 134-135 °C for shorter cycles (pre-vacuum) [5].	Reliable, fast, relatively inexpensive; good penetration; compatible with many metals and heat-licensed plastics.	Can damage heat-sensitive materials (some plastics, elastics). May corrode some metals if maintenance is poor. Certain arch-wires may lose elasticity or surface finish if repeatedly autoclaved.
Dry Heat Sterilization	Oxidation of cell components via hot air	Typical: 160-180°C for 1-2 hours; or higher temp shorter time in some instruments [6].	Good for materials damaged by moisture; no corrosion from steam; less risk of rust.	Slower cycles; poor penetration compared to moist heat; high temp may deform or affect physical properties of some wires/plastics.
Chemical Vapor Sterilization (also called chemical steam or chemiclave)	Heated chemical vapor (commonly formaldehyde + alcohol + other chemicals) under pressure; kills by denaturing	~270°F (~132 °C), pressure ~25 lb, for ~20 minutes for many systems [7]	Less corrosion; good for some metal pliers; shorter cycles than dry heat.	Some chemicals are pungent, toxic, may require proper ventilation; residues may remain; not suitable for all materials, especially those reacting with chemicals.
Ethylene Oxide (ETO) Gas Sterilization	Alkylation of DNA/RNA and proteins.	Low temperature (e.g. 37-55 °C), long exposure (varies: many hours) and aeration required afterward [8]	Good for heat- and moisture-sensitive items (e.g. certain plastics, wires with coatings, elastics).	Slow process; expensive; requires specialized equipment and handling; possible chemical residues; aeration time needed to remove ETO.

Method	Principle/Mechanism	Typical Parameters	Advantages	Limitations / Effects on Ort. Materials
Chemical Disinfectants / Cold Sterilization	Immersion in chemical agents like glutaraldehyde, peracetic acid, hydrogen peroxide, orthophthalaldehyde etc.	Often 2% glutaraldehyde for 6-10 hours or per manufacturer's instructions; or shorter high-level disinfection cycles for semi-critical items[2,9.]	For heat-sensitive items; relatively easy to implement.	Not always full sterilization (may not kill all spores); chemicals may irritate tissues if residues remain; frequent replacement required; safety issues for staff (toxicity, ventilation).
Ultraviolet (UV) Light / UV-C	DNA damage via UV radiation; kills many microorganisms.	Exposure time depends on intensity and distance; often used as adjunct rather than primary sterilization method [4].	Quick; no heat; useful for surfaces or small items.	Poor penetration; shadowing issues; no effect on spores reliably; may damage plastics; needs maintenance; safety precautions for eyes/skin.
Microwave Sterilization	Heated chemical vapor (commonly formaldehyde + alcohol + other chemicals) under pressure; kills by denaturing proteins	~270°F (~132 °C), pressure ~25 lb, for ~20 minutes for many systems [7]	Rapid; accessible equipment; sometimes effective	Not standardized; uneven heating; may damage certain materials; safety issues; efficacy variable depending on load; not widely adopted in many jurisdictions.

Material-Specific Effects: Orthodontic Wires, Elastomerics, Bands, Appliances

Material-Specific Effects: Orthodontic Wires, Elastomerics, Bands, Appliances

Orthodontic materials are diverse, and sterilization/disinfection alter their mechanical and surface properties to varying degrees. Key studies:

- Archwires: Stainless steel, NiTi, β-Ti are frequently used. In one study, used vs new arch-wires that had been exposed to different sterilization/disinfection protocols (steam autoclave, dry heat, cold solution etc.) showed no clinically significant differences in force delivery for many types of wires 11. However, repeated sterilization cycles may gradually degrade surface finish (increase friction), cause discoloration, or affect superelastic properties especially of NiTi after many cycles.
- Elastomeric chains and ties: These plastics can be sensitive to heat and chemical exposure. A study found that UV, autoclave, dry heat, ethanol, glutaraldehyde all effectively sterilized e-chains and ties, but repeated exposure to harsh chemicals or high heat may reduce their elasticity or color stability 4.
- Bands and Appliances: Molar bands, brackets etc., made of metal are more robust. Studies show that molar bands can be sterilized using microwaving in water; bands can also be heat-sterilized in cassettes along with instruments 10,7. Care in cleaning and pre-treatment (removal of debris, adhesives) is important.

Protocols / Best Practices for Orthodontic Instrument Sterilization

Below is a recommended workflow, combining literature evidence and standard infection control guidance.

1. **Universal Precautions and Staff Training**
   - o All staff must treat all patients and materials as potentially infectious. Use PPE (gloves, masks, protective eyewear, gowns) 8.
   - o Regular training for assistants in proper cleaning, handling, sterilization, and storage.
2. **Pre-Cleaning / Cleaning Stage**
   - o Immediately after use, instruments should be wiped or rinsed to remove gross debris. Saliva, blood, adhesives.

- o Use ultrasonic cleaners for hinged and non-hinged instruments to reach joints or crevices 7.
- o Use enzymatic detergents to aid removal of organic matter.

3. Inspection

- o After cleaning, inspect for damage, wear, corrosion. Hinges and joints should move freely. Damaged instruments should be repaired or discarded.

4. Packaging / Instrument Cassettes

- o Use sterilization pouches, wraps, or cassettes. Instruments should be arranged so sterilizing agent (e.g. steam) can penetrate all surfaces.
- o For hinged instruments (pliers, cutters), open the instrument where possible during sterilization to allow exposure of all surfaces.12

o Use cassettes for efficiency and safety (less handling) .7

5. Selection of Sterilization Method

o For heat-tolerant instruments: steam autoclave is preferred. Dry heat or chemical vapor can be alternatives.

o For heat- or moisture-sensitive instruments and components: chemical sterilants, or if available, ETO gas sterilization.

o Avoid overuse of cold sterilization where heat methods are feasible, due to residue issues and lower guarantee of spore kill.

6. Sterilization Cycle Parameters

o Follow manufacturer's recommended cycles. Typical standard: 121-134 °C steam under pressure for specified time (e.g. 15-30 min) depending on load and type of autoclave.

o Dry heat: 160-180 °C for 1-2 hours or appropriate settings.

o Chemical sterilants: concentration and exposure time per product specs (e.g. 2% glutaraldehyde for 6-10 hours).2

7. Monitoring / Validation

o Use biological indicators (spore tests) to ensure sterilizer is performing as expected. A study comparing hot air oven, steam autoclave and ETO using biological indicators showed that all methods achieved sterilization when monitored biologically 4.

o Use chemical indicator strips/tape to indicate sterilization exposure in every load.

o Swab tests of instruments (after sterilization) may reveal failures in some methods (e.g. heavy loads in hot air oven showing sterilization failure under swab test although biological indicator passed) 4.

8. Post-Sterilization Handling & Storage

o After sterilization, let instruments cool (especially steam autoclave) before handling.

o Store in sterile packaging in closed cabinets. Avoid wet or torn packaging. Package integrity is crucial for sterility maintenance .

o Use "first in, first out" system or event-based shelf life: sterile until packaging is compromised 10

2. Maintenance of Equipment

o Regular servicing of autoclaves, dry heat ovens, chemical vapor sterilizers.

o Periodic calibration.

o Cleaning of sterilizer chambers, drains, furnaces, gas lines etc.

o Ensuring that vacuum cycles, pressure, temperature gauges etc. are working properly.

3. Documentation and Traceability

o Keep logs of sterilization cycles: date, load contents, operator, result of biological indicator, chemical indicator etc.

o Maintain inventory of instrument sets, tracking number of sterilization cycles—especially for wires, elastics etc. where repeated cycles might degrade function.

Specific Considerations in Orthodontics

Orthodontics imposes some special challenges and issues:

- Frequent use of small instruments and many parts: pincers, cutters, ligature ties, springs, arch wires. Some small parts are difficult to clean, may get stuck residue (adhesives, composite).
- Heat or moisture sensitive components: plastic modules, esthetic arch wires (coated, composite), elastomeric ties and chains. Sterilization methods must preserve their mechanical and aesthetic properties.
- Potential for repeated sterilization cycles: wires or archwires may be "tried in" multiple times; or reused ties etc. Each sterilization/disinfection cycle may accumulate changes.
- Cross-contamination risk through bands and brackets: bands may contain crevices; brackets may be partly exposed

to adhesives, gross debris. Reusing tried-in bands or brackets without proper sterilization is risky 12.

- Instrument sets & cassettes: using instrument cassettes helps reduce handling, decreases risk of cross-contamination, more efficient for sterilization. Studies show that instruments and bands in wrapped cassettes can be effectively sterilized by steam, chemical vapor, or dry heat sterilizers 7.
- COVID-19 and airborne infection precautions: Additional guidelines recommend flushing dental unit waterlines, use of more rigorous disinfection, proper PPE, pre-screening, and more frequent cleaning of environmental surfaces 12.

Evidence from Studies

Some of the key findings from literature:

1. Evaluation of Various Sterilization Processes A comparative study tested steam autoclave, hot air oven, and ETO sterilization of orthodontic instruments (medium and heavy loads). Monitored via biological indicators (spore tests) and swab tests. Conclusion: all methods achieved sterilization when properly done; however, heavy loads or insufficient exposure may lead to failure under the conventional swab test, despite biological indicators passing. 4
2. Effectiveness of Different Sterilization Methods on Clinical Orthodontic Materials(Actually this refers more to the orthodontic supplies study 5) The study found that autoclave, dry heat, UV, 70% ethanol, 2% glutaraldehyde each prevented microbial growth on wires, e-chains, ties etc. UV was found to be as effective as other methods in eliminating contamination in the materials tested. 4
3. **Arch Wire Mechanical Properties After Sterilization** Archwire types when subjected to various sterilization/disinfection cycles did not show clinically significant loss of force or change in performance, though subtle changes in surface or finish might occur.11
4. **Microwave Sterilization**

Instruments, bands, and mirrors immersed in water, with or without pre-treatment, microwaved for 5-10 min, were studied. Effectiveness was generally good, but parameters (exposure time, presence of pre-soak, load) affected outcomes.10

5. Surveys of Current Practices / Biosafety Conduct In one survey of orthodontists/biosafety in orthodontic practice, about 95-96% of instruments were sterilized with autoclave; for pliers ~33%; for elastics and accessories, percentages were lower; a sizeable fraction still used 70% alcohol or did nothing for some non-critical items 11. This indicates gaps in practice.

Emerging / Alternative Methods

As dentistry progresses, new or less common methods have been explored:

- Plasma Sterilization: Low-temperature, low-pressure plasma discharge has been shown (in recent non-orthodontic instrument contexts) to inactivate spores using oxygen plasma, microwave discharge plasma, etc. Could be promising for heat-sensitive items. (Recent research outside orthodontics indicates this possibility) 13.
- Microwave Irradiation: As mentioned above; may serve as adjunct method where traditional options are not available.
- Ultraviolet (UV-C) sterilization / disinfection: For surfaces and small items; may be useful for accessories or interim items. However, UV has limitations in penetration and may not kill spores reliably.
- Improved sterilization packaging / indicator technology: Better wraps, self-sealing pouches, reliable chemical indicators, and faster biological indicator systems ("integrator strips", rapid spore tests) to reduce waiting times.
- Automated washer-disinfectors: For instruments and photographic retractors; reduce human handling.

Regulatory and Guideline Frameworks

Various national and international guidelines govern sterilization and infection control in dental and orthodontic practice:

- CDC (USA): Guidelines for Infection Prevention and Control in Dental Settings include recommendations on sterilization practices, packaging, storage, etc. 10.
- National Dental Associations (e.g. Indian Dental Association) provide guidance on chemical sterilants, autoclaves, instrument classifications, etc. 2.
- Standards (ISO, ADA, etc.) for materials, sterilization equipment (e.g. autoclave pressure, temperature accuracy, validation) apply.
- Occupational health & safety regulations concerning

handling of chemicals (e.g. glutaraldehyde, ETO), exposure to harmful fumes, disposal of biohazardous waste.

Challenges in Sterilization in Orthodontics

While the theory is well known, real-world practice often faces difficulties:

1. Heat/Material Compatibility

Many orthodontic components are sensitive (coated wires, elastomeric ties, plastics). Repeated exposure to steam or dry heat, or strong chemicals, may alter mechanical or aesthetic properties.

2. Time, Cost, and Workflow Issues

Running full cycles (autoclave, ETO) takes time. If instrument sets are limited, there can be pressure to shorten cycles or reuse items without proper sterilization. Using multiple sets or investing in enough sterilizers helps but increases cost.

3. Human Error and Compliance

Cleaning may be inadequate; packaging may be improper; instruments may be overloaded in sterilizer; operators may skip biological indicator testing; failure to properly store sterilized instruments; neglecting to open hinged instruments during sterilization.

4. Monitoring and Validation Gaps

Some practices rely only on chemical indicators or visual checks but neglect biological indicators, which are gold standard for verifying sterilization efficacy.

5. Availability of Suitable Equipment

In low-resource settings, proper autoclaves, chemical vapor sterilizers, plasma sterilizers may not be available. Cold sterilization or simple disinfection may be the only available methods.

6. Exposure to Chemical Hazards

ETO and other sterilants (e.g. formaldehyde, glutaraldehyde) are hazardous to staff; require proper ventilation, handling, personal protective equipment.

7. Regulatory Oversight and Auditing

Regular audits and inspections may be absent or lax in some regions, leading to variation in practice.

A Proposed Protocol for Orthodontic Sterilization (Step-by-Step)

Below is a suggested “best practice” protocol, which can be adapted depending on local regulations and resources. This can be used as a standard operating procedure (SOP) in an orthodontic clinic.

Pre-Clinical Preparations

- Staff should don appropriate PPE (gloves, mask, eye protection, gown/apron).
- Prepare instrument sets for expected procedures; segregate those which may contact blood/saliva heavily.
- Ensure sterilization and disinfection area is separated and organized.

After Use (Instrument Reprocessing)

1. Transport instruments to the sterilization area in a closed container (sharps covered).
2. Pre-soak or rinse in water immediately to prevent drying of debris; use enzymatic detergents if available.
3. Ultrasonic cleaning for instruments with joints or complex geometry.

Inspection

- Inspect instruments for residual debris; remove adhesives or composite residues using appropriate instrument cleaners.
- Inspect for corrosion, dullness, damage. Remove from use if beyond repair or safe standards.

Packaging / Loading

- Arrange instruments in sterilization pouches or cassettes, making sure hinged instruments are open.
- Avoid overloading sterilization chamber. Ensure packaging material is appropriate (steam permeable etc.).

Sterilization Stage

- Choose sterilization method depending on instrument heat sensitivity:
  - o Steam autoclave: primary method for heat-tolerant metal instruments.
  - o Dry heat/autoclave or chemical vapor: interchangeably when steam might damage items.
  - o ETO sterilization: for heat/moisture sensitive items.
  - o Cold sterilization / chemical immersion: only if no other method available, for a long exposure time, followed by thorough rinsing.
- Run the sterilizer for full cycle, including required time, temperature, pressure.

Validation and Monitoring

- Use chemical indicators in each load (e.g. indicator strips/paper).

- Weekly (or per guideline frequency) use biological indicators / spore tests for each sterilizer.
- Maintain sterilizer maintenance logs.

Post-Sterilization

- Allow cooling, drying before opening.
- Sterile storage: in closed cabinets, dry, with good airflow; avoid moisture.
- Check packaging integrity before use.

Specific Instruments / Materials

- Archwires: limit number of sterilization cycles; monitor for changes. Possibly use sterilization before first insertion (for "received from manufacturer") even if labeled as clean.
- Bands / Brackets: clean, sterilize prior to fitting; used bands may be acceptable after cleaning and sterilization 12.
- Plastic / Esthetic Materials: check manufacturer's recommendations; minimize exposure to harsh chemicals or high temperatures.

Environmental and Adjunct Controls

- Disinfect surfaces, dental chair, tray, equipment between patients.
- Use barrier covers for items that are difficult to sterilize.
- Flushing water lines; water quality control.

Case Scenarios and Examples

Case Example 1: Autoclaving in Instrument Cassettes A study evaluated instruments and bands contaminated with blood or saliva and bacterial spores, inside OMS-ASAPsys instrument & band cassettes. After ultrasonic cleaning and rinsing, instruments placed in wrapped cassettes and processed through steam autoclave, chemical vapor, and dry heat sterilizing cycles. The results: all three sterilization methods killed the spores in all cases. Instruments inside cassettes can thus be safely sterilized. 7

Case Example 2: Orthodontic Materials "as Received" As discussed above, orthodontic supplies (wires, e-chains, ties) showed microbial contamination on arrival ("as received") from manufacturers. After applying sterilization or disinfection, all methods tested (autoclave, dry heat, UV, ethanol, glutaraldehyde) prevented microbial growth. 5

Case Example 3: Cold Sterilization Efficacy In the comparative study that used hot air oven, steam autoclave, ETO, cold sterilization (glutaraldehyde) etc., biological indicator methods showed effectiveness for each when protocols were properly followed. However, in some groups with heavy load, swab tests failed, indicating that some surfaces may have remained contaminated under certain conditions. This underscores that monitoring and adequate exposure are critical. 4

Emerging Trends and Future Directions

- Development of more rapid biological indicators to reduce delays in confirming sterilization status.
- Use of plasma sterilization for delicate instruments or ones with coatings, perhaps reducing damage while maintaining sterility.
- More research into how sterilization affects orthodontic materials over long term, especially newer materials (coated wires, esthetic brackets, 3D-printed appliances).
- Enhanced automation in cleaning and sterilization; automated washer-disinfectors; reducing manual handling.
- Better disinfection of waterlines, air filtration in operatory, especially in light of airborne infections (e.g. COVID-19).
- Innovations in packaging materials to preserve sterility longer and be more user friendly.

Summary

Below is a summary checklist clinics should have to ensure sterilization in orthodontics is being managed well:

1. Universal precautions adhered to always.
2. Proper cleaning (immediate, enzymatic, ultrasonic where needed).
3. Instruments inspected and sorted (heat-sensitive vs not).
4. Use of instrument cassettes / packaging.
5. Choosing appropriate sterilization method for each item.
6. Full sterilization cycles, not abbreviated.
7. Monitoring sterilizers with chemical and biological indicators.
8. Proper storage of sterilized instruments.
9. Maintenance of sterilization equipment.
10. Clear documentation, periodic audits, staff training.

Conclusion

Sterilization in orthodontics is not optional—it is essential. When properly implemented, sterilization and disinfection protocols protect patients, staff, and the community from potentially serious infections. The balance is in using methods that effectively eliminate microorganisms while preserving the functionality, appearance, and mechanical properties of orthodontic materials. Adequate training, monitoring, use of appropriate technology, and adherence to guidelines make this practical and feasible.

References

1. Jankare S, Surani SS, Parchake P, Borkar E, Rathod A. Sterilization protocol in orthodontic practice: a review. Acta Sci Dent Sci. 2019;3(12):1–5.
2. Indian Dental Association. Sterilization and disinfection: IDA guidelines. Mumbai: Indian Dental Association; [year not available].
3. Musaddique SSY, Ajit K, Ashwith H, et al. Evaluating the sterility of orthodontic materials as received from the manufacturer and that exposed to the clinic environment – an in vitro study. South Eur J Orthod Dentofac Res.
4. Evaluation of various sterilization processes of orthodontic instruments using biological indicators and conventional swab test method: a comparative study. PubMed.
5. Effectiveness of different sterilization methods on clinical orthodontic materialsSAGE J;
6. Zarate AM, et al. Effectiveness of different disinfection/sterilization protocols for heat-sensitive orthodontic instruments. Rev FacOdontol UNC. [year not available];[volume(issue)]:[pages].
7. Sterilization of orthodontic instruments and bands in cassettes. PubMed
8. Precautions and recommendations for orthodontic settings during the COVID-19 outbreak: a review. [Internet]. PubMed Central (PMC);.
9. Aksoy A, Kılıç G, Hussein E, Aboukhalil D. Sterilization and disinfection in orthodontics. In: IntechOpen. London: IntechOpen; [year not available].
10. Orthodontic instrument sterilization with microwave irradiation. [Internet]. PubMed; [year not available].
11. The effect of clinical use and sterilization on selected orthodontic arch wires. Am J Orthod Dentofacial Orthop
12. Rohmetra A, Tandon R, Jaiswal A, Singh K, Chandra P. Derigueur protocol: sterilization in orthodontics. Int J Orofac Res. 2018;3(1):5–13.
13. Gonzalez-Lizardo A, Rondon J, et al. Sterilization of bacteria with low-pressure low-temperature plasma discharge.