BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 21, Issue 1

DOI: 10.58240/1829006X-2025.1-19

RESEARCH ARTICLE

ANALYSIS OF RESISTANCE OF ORTHODONTIC COMPONENTS TO MOUTHWASHES, DISINFECTANTS AND STERILIZER: AN IN VITRO STUDY

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Received: *Dec 06, 2024;* ***Accepted:*** *Dec 26, 2024;* ***Published:*** *Jan 10, 2025*

Abstract

Background: The application of fixed orthodontic appliances plays a crucial role in altering the oral biofilm, exposing patients to an increased risk of caries and periodontal diseases. For this reason, the literature consistently recommends the use of chlorhexidine and fluoride containing mouthwashes as adjuncts to routine oral hygiene practices. Furthermore, it is known that orthodontic appliance components are not sterile when removed from their packaging and should therefore undergo disinfection and sterilization before use.

Aim: To evaluate whether commercially available mouthwashes, disinfectants and sterilizers can damage orthodontic components through analysis using scanning electron microscopy (SEM).

Materials and Methods: Four commonly used components of fixed appliances were examined: brackets, Ni-Ti arch, metal ligatures and elastic ligatures. The substances tested for their effects on these components included two mouthwashes, two disinfectants, and one sterilizer. Each component was analyzed via SEM at two time points: T0, when untreated, and T2, after immersion in the respective solution for its designated action time, depending on intraoral and extraoral use.

Results: The correlation analysis revealed no dependence of the KM width on the age and gender of patients and the type of teeth and jaws.

The results indicated that the tested mouthwashes did not cause surface damage to the orthodontic components. Regarding the disinfectant and sterilizer, no surface damage was observed on brackets, arch, or metal ligatures; however, one disinfectant and the sterilizer caused noticeable surface deterioration of the elastic ligatures.

During the year of follow-up, there were no dental implant failures in both groups, and the survival rate of implants one year after their installation was 100%.

Conclusion: Metal alloy components (stainless steel and nickel – titanium) were not affected in vitro by either the disinfectants/sterilizers or the mouthwashes. Therefore, these substances can be used safely and comply with the healthcare professional's obligation to maintain patient health. However, caution should be exercised in disinfecting elastic ligatures. Mouthwashes and chlorhexidine-based disinfectants were shown to have no damaging effects on elastic ligatures and can thus be safely employed for these components.

Keywords: *Orthodontic components, Mouthwashes, Disinfectant, Sterilizer, Scanning electron microscopy.*

INTRODUCTION

As known in the literature, four hundred to seven hundred different types of bacteria can be found within the oral cavity.[1-5] Undergoing orthodontic treatment, particularly the application of a fixed orthodontic appliance plays a crucial role in bringing changes of the oral biofilm. In fact, various studies testify that fixed braces alter the physicochemical conditions of bacterial growth and cause both qualitative and quantitative changes in bacterial colonies[6-9] and furthermore due to its shape characterization this promotes the accumulation and retention of food and debris, and this exposes patients to an increased risk of developing carious and periodontal pathologies with greater ease. For this reason, the literature agrees that orthodontic patients should use specific mouthwashes containing active ingredients such as chlorhexidine and fluoride that act as adjuvants to common oral hygiene maneuvers. Chlorhexidine is a synthetic substance with disinfectant action that possesses a broad spectrum of action against Gram-positive and Gram-negative bacteria and is also effective against some viruses and fungi.[10-13] In the medical-pharmaceutical field the gluconate ion is used as this, being a cationic biguanide is poorly soluble in water and that is why it must be combined with suitable negative ions in fact, in the majority of drugs this is found in the form of chlorhexidine digluconate and its use has been recommended for the control of plaque and gingivitis since 1970 and to date it is considered the gold standard for chemical control of biofilm; rinsing with chlorhexidine has been shown to provide better oral hygiene in orthodontic patients resulting in reduced biofilm retention, reduced gingival bleeding, less inflammation, and shallower periodontal probing.[14-17] In addition, it is well known that orthodontic patients are more susceptible to the development of caries processes because of the difficulty in ensuring adequate oral hygiene, and this is why the use of a fluoride-based mouthwash may therefore be found to be beneficial; topical administration, which is the mode of fluoride supplementation on which this study focused, is intended to promote enamel remineralization processes and to counteract bacterial growth and acid production. It is also important to note that orthodontic components related to fixed braces are not sterile when they are taken out of the packaging and therefore contaminated by different bacterial species as evidenced by several studies in the literature;[18-23] in particular, the species that, due to skin contact during processing and packaging, is most frequently involved in contamination is Staphylococcus,[24] followed by Streptococcus, Bacillus cereus and Bacillus licheniformis[25-27] and Klebsiella.[28] Therefore, these components should be subjected to chemical sterilization or aggressive disinfection processes before use.[29-33]

The purpose of the present work is to clarify whether some of the commercially available mouthwashes, disinfectants, and sterilizers can damage the components of fixed orthodontic appliances. Specifically, Ni-Ti (nickel titanium) arches, steel brackets, and metal and elastic ligatures were examined as orthodontic components.[34-37]

To analyze and identify possible alterations, the above components were exposed to the action of chemicals and observed by light microscopy and SEM (scanning electron microscope).[38-40]

MATERIALS AND METHODS

The study focused on the analysis of fixed appliance components, specifically: 0.022" Mini Roth attachments made by the IMD medical company, whose alloy steel components are iron, nickel, and chromium; Ni-Ti arch. 018 made by the company Henry Schein Orthodontics, composed of a nickel-titanium alloy; 010" closed preformed metal ligatures made by the company Leone, with alloy composed of iron, chromium, nickel and traces of molybdenum; and elastic ligatures made by the company Dental World composed of a polymer, specifically it is an elastomer.

As for the substances used to act on orthodontic components, these are: Broxo Din 200mg/100g from SIT pharma, a mouthwash based on chlorhexidine digluconate. It contains chlorhexidine digluconate 0.2%; the other components are: xylitol, trirectified mint essence, saccharin sodium, ethanol, macrogolglycerol hydroxystearate, and purified water; BioXtra from Biopharm, a mouthwash containing sodium monofluorophosphate 1500 ppm and whose other components are: lysozyme, lactoferrin, lactoperoxidase, colostrum extract, water, propylene glycol, xylitol, polyoxamer 407, sodium benzoate, hydroxyethyl cellulose, aloe barbadensis, flavor and ethylenediaminetetraacetic acid (EDTA).

Regarding disinfectants, the following were used: Gioclorex 0.5% from the company Giochemical, a disinfectant solution based on ethyl alcohol; chlorhexidine digluconate 0.5%; co- formulants; antioxidant; and purified water. It has a pH close to neutrality, which allows the cationic bis- biguanides to achieve maximum microbicidal power, and Farmecol 70, produced by the company Farmec, an alcoholic solution based on 70% with denatured ethyl alcohol; the denaturants are acetone and isopropyl alcohol; also contains purified water. It is a broad-spectrum product, active against Gram-

positive, Gram-negative vegetative bacteria, fungi, viruses, and Mycobacterium tuberculosis.

EC ster, produced by the company Rident innovation, was used as a sterilizer. It is a free radical-generating sterilizer composed of sulfate peroxides and sodium bromide buffered with alkaline carbonates.

For each type of orthodontic component (arch, attachment, metal ligature, and elastic ligature), 11 samples were considered, for a total of 44 samples. Specifically, one specimen for time "0" (T0), not immersed in any substance; one specimen for each substance, kept in immersion for half of the expected time of use for the specific substance (T1); and one specimen for each substance to be analyzed when immersion was finished (T2).

The metal attachments were analyzed exactly as produced by the company while the other components were cut to obtain samples of appropriate size for examination by SEM (scanning electron microscope). Specifically, the Ni-Ti arch and metal ligatures were dissected using an orthodontic cutter, while the elastic ligatures were removed from the main body using a scalpel.

Immersion times were established for each substance by making an average calculation of their time of action and use, taking into consideration the time of action of each of the prescriptions stated by the manufacturer and the average time each component stays in the oral cavity of an orthodontic patient.

There is a difference between mouthwashes, which are used daily inside the oral cavity, and disinfectants and sterilizers whose use is extra oral for only once.

For mouthwashes, an average duration of about 15 seconds was considered: generally, two rinses per day are performed and the duration of each rinse should be approximately 30 seconds but considering the average age of orthodontic patients and their reduced compliance, an average duration of a single rinse of 15 seconds was considered therefore in one day the mouthwash encounters the natural teeth and the components of the fixed appliance for about 30 seconds.[41-43]

The average contact time between the substance (the mouthwash) and each type of component under consideration was then calculated. For brackets, these generally remain in the oral cavity for the duration of orthodontic treatment. We therefore consider a total time of one year. Accordingly, in one year, the average contact time between the substance (30 seconds per day for 365 days) and the attachment is about 10,950 seconds, or about 3 hours.[44-46]

For components such as arch and metal ligatures, one month was taken as the total residence time in the oral cavity. Thus, in one month such components encounter the mouthwash for 900 seconds, which is equivalent to 15 minutes (while the intermediate time is 7.5 minutes).

For elastic ligatures, a dwell time equal to half that of metal bows and ligatures was considered, thus equal to 7.5 minutes (so the intermediate time is 3.75 minutes).

Disinfectants/sterilizers, on the other hand, have an extra oral use, therefore, a very limited time of action, in particular: EC ster has an action time of 1 minute; Gioclorex 0.5% acts in 5 minutes while Farmecol 70 exerts its action in 10 minutes.

Then the various components were immersed in the substances and the times were timed; the samples were then removed from the solution, washed with distilled water, and placed on a sheet of absorbent paper.

At this point, the samples are ready for SEM analysis. The microscope used in this study is a Zeiss FE SEM Leo 1525 with an EDX probe of the Bruker Quantax EDX type, which allows for semiquantitative microanalysis and mapping of samples by energy dispersive X-ray analysis. Prior to SEM examination, samples were bonded onto aluminum stubs using carbon adhesive.[47]

For the nonmetallic specimens, thus the elastic ligatures, it was necessary to arrange for their metallization prior to SEM study. The metallizer used in this study was the Quorum Q150T ES and resulted in the samples being covered with a thin layer (10 nm) of chromium. It is noteworthy that the metallizer used covered the samples not only with chromium, but to a small extent also with aluminum and bromine, and this was considered when the microanalysis was carried out.[48,49]

For the exposition of the results, they will be divided based on the various orthodontic components and their analysis at times T0 and T2; observation and SEM microanalysis was performed for each of them, eventual light microscope analysis was conducted later to avoid contamination that could have distorted the SEM analysis results.

Analysis of the attachments was carried out at 1000 X magnification, and examination was performed on several points of the attachment, particularly fins, slots, and central scaling. Significant surface irregularities were noted on all the attachments (figure 1), and by microanalysis the presence of iron, chromium, nickel but also carbon, silicon, and manganese were revealed (figure 2).

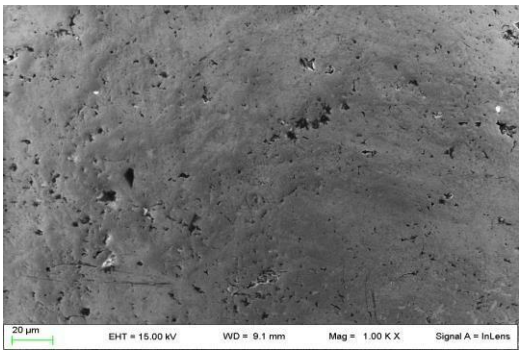

Figure 1. *Attachment wing, time 0, 1000X, AsB*

Element	At. No.	Netto	Mass[%]	Mass Norm.[%]	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma)
Carbon	6	9140	3,50624549	3,98673202	15,75291332	0,186850874	5,329087046
Silicon	14	7950	0,490582938	0,557811116	0,942601247	0,021557786	4,394320318
Calcium	20	741	0,059554109	0,067715246	0,080186	0,010704473	17,97436536
Chromium	24	124128	15,03695476	17,09757897	15,60585935	0,259125647	1,723258802
Manganese	25	5569	0,914022765	1,039278009	0,897804749	0,041294512	4,517886642
Iron	26	280699	60,95212701	69,30484407	58,89612846	1,125566994	1,846641044
Nickel	28	17865	6,418010203	7,297517218	5,900772424	0,160237328	2,496682356
Oxygen	8	4515	0,570362396	0,648523339	1,923733555	0,047244651	8,283268974
		Sum	87,94785968	100	100		

Figure 2. *Chemical elements found upon microanalysis of the attachment wings, time 0*

Specifically, at T2 for the three components under analysis, immersed within solutions containing chlorhexidine and fluoride, deposition of organic material was noted. The same components, immersed in the disinfectant solutions and treated with sterilizer at T2 appear to have less anfractuosity than at T0 (figure 3).

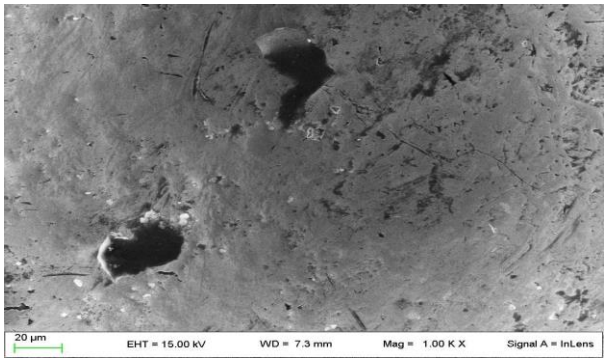

Figure 3. *EC ster treated attachment, Wing, 1000 X, InLen*

It should also be noted that for the "central scaling" portion, SEM analysis of the samples treated with Gioclorex 0.5% and Farmecol 70 could not be performed, probably due to the non-planar conformation of this component, which cannot be reached by the SEM-emitted beam.

Analysis of the arches was obtained by grading at 1000X, magnification at which microanalysis was also performed. Observation of the sample at T0 revealed the irregular surface of the orthodontic arch due to the fabrication process (figure 4).

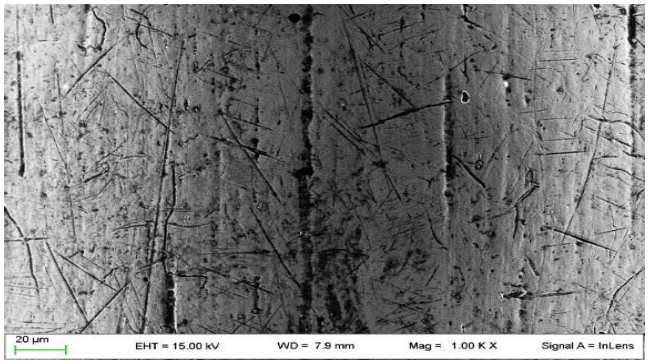

Figure 4. *Orthodontic arch, time 0, zone 1, 1000 X, InLens*

The microanalysis detected the presence of nickel and titanium characterizing the alloy and traces of aluminum as well as organic material (carbon) accumulating within the scaling of the arch and oxygen (figure 5).

Element	At. No.	Netto	Mass[%]	Mass Norm.[%]	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma)
Carbon	6	13928	5,351262327	5,695387968	19,68923709	0,278535558	5,20504398
Aluminium	13	1818	0,134672897	0,143333357	0,220579568	0,014480732	10,7525215
Titanium	22	354297	38,9967568	41,50453592	35,99367265	0,644941102	1,653832665
Nickel	28	138032	46,06855638	49,03110437	34,68703267	0,987006561	2,14247339
Oxygen	8	9361	3,406570758	3,625638386	9,40947802	0,187721562	5,51057281
		Sum	93,95781916	100	100		

Figure 5. *Chemical elements found at microanalysis of orthodontic arch, zone 1, time 0*

In addition, an area with visible mitotic formation was identified within this sample (figure 6), and again a microanalysis was performed that showed a large amount of carbon.

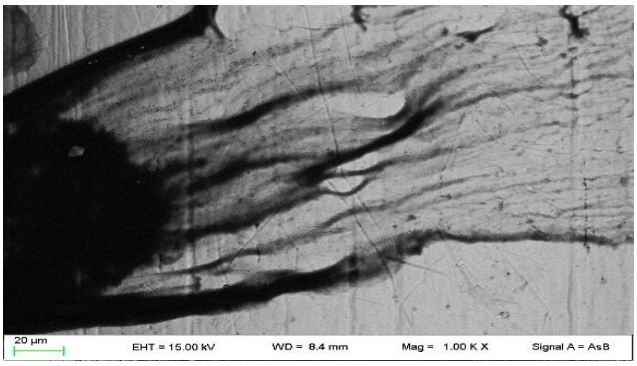

Figure 6. *Orthodontic arch, time 0, zone 2, 1000 X, AsB*

At T2, the arch immersed in solution containing chlorhexidine digluconate showed on observation presence of crystals, resulting from the mouthwash

used in the test and taking on a dark coloration at backscatter (figure 7).

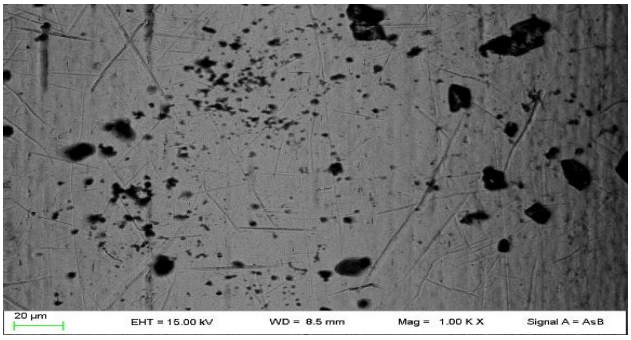

Figure 7. *Orthodontic arch treated with chlorhexidine digluconate mouthwash, 1000 X, AsB*

Microanalysis for both samples immersed in solution containing fluoride and chlorhexidine mouthwash proved to be compatible with the above at T0. Microanalysis at T2 of arches treated with the disinfectants (figure 8 and figure 9) and sterilizer (figure 10) detected the presence of nickel, titanium, aluminum, oxygen, and carbon.

Element	At. No.	Netto	Mass[%]	Mass Norm.[%]	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma
Carbon	6	14819	5,496058481	5,93996984	20,34281174	0,286093282	5,205426461
Oxygen	8	9823	3,452270517	3,731107087	9,592679285	0,199669812	5,783724395
Sodium	11	1532	0,200093972	0,216255365	0,386935147	0,023575213	11,78207066
Aluminium	13	866	0,059426062	0,064225848	0,097914954	0,010978401	18,47405057
Titanium	22	358185	37,73826227	40,78634544	35,04019857	0,618644369	1,639302744
Nickel	28	139518	45,56267739	49,24273104	34,51109747	0,971721748	2,132714325
Silicon	14	306	0,017918142	0,019365373	0,028362833	0,008546321	47,69647167
		Sum	92,52670684	100	100		

Figure 8. *chemical elements found upon microanalysis of the orthodontic arch treated with Gioclorex 0.5%*

Element	At. No.	Netto	Mass[%]	Mass Norm.[%	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma)
Carbon	6	14198	5,41338443	5,800252932	20,07142132	0,281759289	5,204863852
Oxygen	8	9054	3,270046432	3,503740895	9,102038075	0,181213235	5,541610464
Aluminium	13	1050	0,078532798	0,084145158	0,129620222	0,012039859	15,33099421
Titanium	22	353838	38,11145603	40,83509816	35,44784387	0,625993021	1,642532415
Nickel	28	138520	46,45672458	49,77676285	35,24907651	0,995850764	2,143609506
		Sum	93,33014427	100	100		

Figure 9. *Chemical elements found upon microanalysis of the orthodontic arch treated with Farmecol 70*

Element	At. No.	Netto	Mass[%]	Mass Norm.[%]	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma)
Carbon	6	15734	5,888376094	6,218029853	21,02232251	0,307080383	5,215026658
Oxygen	8	10854	3,877232357	4,094294617	10,39160075	0,208309343	5,372629844
Aluminium	13	716	0,047661188	0,050329443	0,075746479	0,010497928	22,02615603
Titanium	22	360246	39,35702514	41,56038156	35,24783469	0,655733205	1,666114761
Nickel	28	139661	45,52812631	48,07696452	33,26249558	0,971448171	2,133731936
		Sum	94,69842109	100	100		

Figure 10. *Chemical elements found upon microanalysis of the orthodontic arch treated with EC ster*

The study of the metal ligatures was conducted by magnification at 5000X since these components compared to the previous ones are considerably smaller in size. At time zero, observational analysis showed an irregular surface (Figure 11), and from the microanalysis conducted, the presence of iron, chromium, nickel, manganese, oxygen, silicon and molybdenum is noted (figure 12).

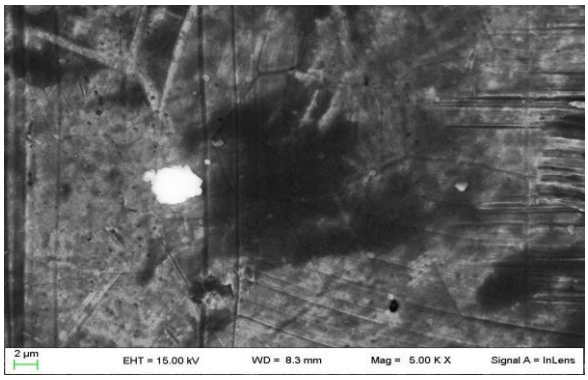

Figure 11. *Metal ligatures at time 0, 5000 X, InLens*

Element	At. No.	Netto	Mass[%]	Mass Norm.[%	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma
Carbon	6	15117	6,877681721	7,418093827	26,36483543	0,358600696	5,213976309
Oxygen	8	5322	0,877423448	0,946366774	2,525036717	0,058095783	6,621179705
Aluminium	13	689	0,059711747	0,064403582	0,101895546	0,012129838	20,31398967
Silicon	14	6826	0,496996285	0,536047643	0,814766456	0,022634747	4,554309131
Phosphorus	15	0	0	0	0	0	1,787392021
Chromium	24	103332	15,66333131	16,89407361	13,86999667	0,286754788	1,830739469
Manganese	25	4577	0,928054056	1,000975677	0,777790413	0,045423846	4,894525916
Iron	26	227817	60,47531604	65,22714875	49,85864319	1,184092892	1,957977187
Nickel	28	15854	6,807949889	7,342882834	5,340590021	0,178288763	2,618831894
Molybdenum	42	3427	0,389720215	0,420342382	0,187031767	0,026324696	6,754767983
Calcium	20	1495	0,138761759	0,149664929	0,1594138	0,013750702	9,909575869
		Sum	92,71494647	100	100		

Figure 12. *Chemical elements found at the microanalysis of metal ligation at time 0*

At T2 these components persist both from the observational point of view and from the microanalysis, it is reported that samples treated with ECster (figure 13) Gioclorex 0.5% (figure 14) and Farmecol 70 (figure 15) residual organic matter remains but in smaller amounts than those observed on the sample at T0.

Element	At. No.	Netto	Mass[%]	Mass Norm.[%	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma)
Carbon	6	11134	4,09657432	4,591079242	17,71426955	0,216354905	5,28136164
Oxygen	8	5668	0,694601617	0,778448239	2,254829308	0,046811377	6,739312977
Aluminium	13	964	0,069011586	0,077342099	0,132842442	0,011396227	16,51349874
Silicon	14	9443	0,581517612	0,651713658	1,075380829	0,023914047	4,112351252
Sulfur	16	2728	0,150586203	0,168763737	0,243905713	0,011248356	7,469711927
Calcium	20	853	0,064501021	0,072287056	0,083587651	0,010410506	16,14006428
Chromium	24	131860	15,51413753	17,38687723	15,49670192	0,265265058	1,709827937
Manganese	25	5841	0,923048447	1,034471	0,872636206	0,040872255	4,427964244
Iron	26	290332	60,27151159	67,54699515	56,05234838	1,102471871	1,829175746
Nickel	28	20281	6,863514945	7,692022292	6,073498004	0,166858285	2,431090869
		Sum	89,22900486	100	100		

Figure 13. *Chemical elements found upon microanalysis of EC ster-treated metal ligature*

Element	At. No.	Netto	Mass[%]	Mass Norm.[%]	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma)
Carbon	6	15194	6,776795643	7,511073656	26,51972122	0,353467978	5,215857122
Oxygen	8	5408	0,865156016	0,958897229	2,541642522	0,056665432	6,549735679
Sodium	11	661	0,106015202	0,11750214	0,216749075	0,020188367	19,04289779
Aluminium	13	361	0,029990557	0,033240088	0,052244615	0,010678994	35,60785435
Silicon	14	7730	0,550350447	0,609981909	0,921045098	0,023723029	4,310531502
Sulfur	16	2325	0,155763478	0,172640731	0,228320327	0,012177061	7,817661143
Chlorine	17	620	0,044086092	0,048862899	0,058448856	0,009587539	21,74731107
Calcium	20	1033	0,095779632	0,106157528	0,112328731	0,01178707	12,30644762
Chromium	24	102670	15,05940385	16,69111739	13,61324237	0,274037653	1,819711163
Manganese	25	4688	0,923697317	1,023781585	0,790279232	0,044307355	4,796739621
Iron	26	226946	58,76635852	65,13379931	49,45983504	1,144497141	1,947537962
Nickel	28	16221	6,850663776	7,592945535	5,486142916	0,178318526	2,602937936
		Sum	90,22406054	100	100		

Figure 14. *chemical elements found upon microanalysis of the metal ligature treated with Gioclorex 0.5%*

Element	At. No.	Netto	Mass[%]	Mass Norm.[%	Atom[%]	abs. error [%](1 sigma)	rel. error [%](1 sigma
Carbon	6	11889	4,360996147	4,787643763	18,48190966	0,231663683	5,312173527
Oxygen	8	3847	0,470734996	0,516788227	1,49765954	0,046390517	9,854911459
Aluminium	13	304	0,018856399	0,02070117	0,03557397	0,009276053	49,19312835
Silicon	14	10278	0,552361503	0,606400468	1,001109425	0,022435859	4,06180712
Sulfur	16	2756	0,139033194	0,152635174	0,220705939	0,010704166	7,699000223
Chromium	24	135482	16,07917148	17,65223872	15,74106234	0,280921641	1,747115148
Manganese	25	5947	0,9422378	1,034419379	0,873027623	0,04145379	4,399504073
Iron	26	297474	61,52523812	67,54441248	56,07816083	1,125382934	1,829140314
Nickel	28	21043	6,999938406	7,684760619	6,070790665	0,171420538	2,448886374
		Sum	91,08856805	100	100		

Figure 15. *Chemical elements detected upon microanalysis of metal ligature treated with Farmecol 70*

Elastic ligatures were analyzed at magnifications 5000 X, because of their small size (0 3mm). Also, please note that these samples were subjected to chromium metallization process by SEM microanalysis therefore the presence of Chromium, Aluminum and Bromine within these samples could result from the process described above. Observational analysis at times T0 and T2 revealed an irregular surface morphology with a "scale-like" appearance (figure 16 and figure 17) while the microanalysis conducted shows that elements such as carbon, oxygen, bromine, sodium, and potassium are present in the samples at both times.

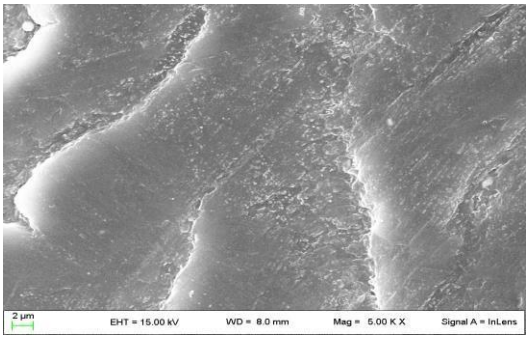

Figure 16. *Elastic binding at time 0, 5000 X, InLens*

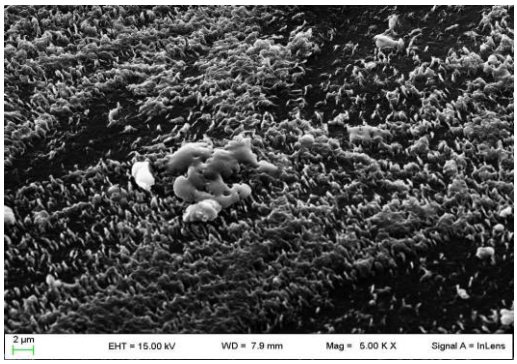

Figure 17. *EC ster treated elastic ligation, 5000 X, InLens*

It is also observed that the surface of the sample treated with Farmecol 70 during T2 is particularly damaged by direct examination, and this phenomenon is due to the acetone contained within the solution, which frequently degrades the elastomer of which the elastic binding is composed, and the same process was also observed, although to a lesser extent, for the sample treated with ECster.

DISCUSSION

Summary of the main findings: The results of this study show how the mouthwashes do not cause surface damage to the orthodontic components examined but generate Carbon deposits on the surface of the various components due to the excipients contained in the solutions, particularly for the carbohydrate-based substances used as sweeteners to improve the organoleptic characters.

Regarding the use of sterilizer and disinfectants, it should be noted that these do not cause surface damage on bows, attachments, and metal ligatures, but the use of Farmecol 70 and ECster results in noticeable surface deterioration of elastic ligatures as exhibited in Table 1.

Table 1. *Farmecol 70 and ECster results*

SURFACE DAMAGE AT THE END OF THE EXPERIMENTS					
	Chlorhexidine digluconate mouthwash	Fluoride-based mouthwash[2]	EC ster[3]	Gioclorex[4]	Farmecol[5]
Arch	- C	- C	-	-	-
Attachment	- C	- C	-	-	-
Metal ligature	- C	- C	-	-	-
Elastic ligature	- C	- C	+ *	-	++ **

LEGEND
1: action time: for attachments 3 hours; for arch and metal ligatures: 15 minutes; for elastic ligatures: 7.5 minutes.
2: action time: for attachments 3 hours; for arch and metal ligatures: 15 minutes; for elastic ligatures: 7.5 minutes.
3: action time: 1 minute.
4: action time: 5 minutes.
5: action time: 10 minutes.
+++: very noticeable surface damage ++:moderate surface damage. +: minor surface damage. -: no surface damage is visible.
C: Carbon deposition following immersion, probably due to excipients.
*: dubious case **: probable cause: presence of acetone.

Limitations of this study: in the SEM analysis, some samples of internal components of the bindings (the so-called "central scaling") were not reachable by the beam emitted by the scanning electron microscope due to the non-planar conformation of these components therefore it was not possible to proceed with the microanalysis. In addition, this study does not consider the environmental conditions existing in the oral cavity; in fact, mechanisms are present there that go some way to neutralize the possible danger posed by carbon deposits generated on the surfaces of the various components by the mouthwashes used in the present study.

The results obtained from this work offer insights for further study and future investigations such as: further in vitro studies with the addition of salivary specimens; in vivo studies, in particular culture of any microorganisms present on the surface of the specimens just taken from the packages and following treatment with disinfectants/sterilizers to evaluate their actual efficacy compared to disinfection and sterilization processes but paying attention to a possible negative effect on the oral cavity; and study on the fabrication of the components of the fixed orthodontic appliance by using a 3D printer.

CONCLUSION

Given the premise of this study, the need for aggressive sterilization or disinfection of orthodontic components prior to placement in the oral cavity, as these extracts from the manufacturers' packaging do not appear to be sterile, it was seen that metal-alloy based components (steel, nickel-titanium) are not attacked in vitro by either disinfectant/sterilizing solutions or mouthwashes. Therefore, such medical supplies can be used and enable compliance with the health care professional's obligation to work while ensuring that the health status of patients is maintained.

Attention, on the other hand, should be paid to the disinfection of elastic ligatures, on which mouthwashes and chlorhexidine-based disinfectant alone did not show surface damage effects and therefore they can be safely used on this type of component, whereas EC ster and disinfectant containing acetone damaged elastic ligatures.

In addition, our work showed that the surface morphology of fixed orthodontic appliance components is irregular. Brackets, in particular, exhibit greater roughness, especially at the slot and central groove areas that are not easily accessible to be properly cleaned.

Consequently, this facilitates oral biofilm accumulation, which is why it is essential for the operator to engage in the activity of instruction in oral hygiene maneuvers and to consider the possibility of intervening with chemical adjuvants if necessary.

ABBREVIATIONS

Ni-Ti: nichel titanium;
T0: time 0;
T1: time 1;
T2: time 2;

DECLARATIONS

Conflicts of interest and financial disclosures

The author declares that he has no conflict percent and there was no external source of funding for the research in question.

Ethical approval

The study was approved by the Institutional Ethics Committee and was conducted in accordance with the Declaration of the World Medical Association.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Source of funding

The work was not funded.

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