Chemical and physical analysis of phaco handpiece tip surfaces before and after cataract surgery

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Purpose: To evaluate the surface chemical composition and roughness of different phaco tips before and after their use during cataract surgery.

Setting: Eye Clinic, University of Trieste, Trieste, Italy.

Design: Experimental study.

Methods: Of the 66 tips studied, 33 (15 new, 15 after single use, and 3 after multiple uses) were studied with X-ray photoemission spectroscopy and 33 (15 new, 15 after single use, and 3 after multiple uses) were examined using scanning electron microscopy with energy dispersive X-ray spectroscopy analysis and contact profilometry. All analyses were performed on the far end of the tip.

Results: Used phaco tips showed signs of wear at the end of the tip, with the deposition of debris. The cutting edge appeared to be rounded and irregular. After surgery, an increase in the surface roughness was detected. The chemical analyses showed modification of the superficial alloy composition and the biological origin of some debris deposited after surgery. The deterioration and wear observed were more remarkable after multiple surgical procedures.

Conclusions: Used phaco tips showed relevant signs of deterioration and deposition of biological material, mostly involving the cutting edge. Reusable tips might release remnants of previous procedures. The adoption of single-use disposable phaco tips seems to be highly advisable.

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Modern cataract surgery requires up-to-date phacoemulsification technology. Most studies have focused on the performance of the different phaco machines[1,2] that have improved the safety and efficiency of the surgery. Fluidics and ultrasound (US) delivery have been enhanced, and alternative removal modalities such as torsional and transversal phaco technologies have been appreciated worldwide.[2,3]

Less is known about the material and characteristics of phaco tips. Many types are available. Tips can be straight or bent (15 to 30 degrees) with different calipers and can be flared or not. Recent studies[4–6] analyzed the efficiency of the new phaco machines combined with different tips. In particular, torsional and transversal phacoemulsification modalities proved to be very efficient when used in combination with bent tips.[7]

The design of phaco tips has been well studied; however, there are few studies of the composition, manufacturing finishing, and possible deterioration after use.[8] According to manufacturers, phaco tips are made of a titanium (Ti) alloy. To our knowledge, only 1 recently published 2-part experimental study analyzed the chemical properties of new and resterilized phaco tips.[9,10] The authors did not consider phaco tips used in vivo after single or multiple cataract procedures. The tip's edge geometry and finishing might be important to improve lens fragmentation. Although most phaco tips are disposable, some are reusable for multiple procedures. No studies have analyzed the possible deterioration of the tips after 1 or multiple phaco cycles.

In the present study, we evaluated the surface chemical composition, the surface roughness profile, and the topographic/morphologic properties of different phaco tips before and after use.

MATERIALS AND METHODS

The following 3 phacoemulsification machines were used to perform cataract surgery: Whitestar Signature operated in elliptical mode (Abbott Medical Optics, Inc.), Infiniti (Alcon Laboratories, Inc.) operated in torsional or longitudinal removal modality according to the tip used, and Stellaris (Bausch & Lomb, Inc.) operated in longitudinal mode. An ophthalmic viscosurgical device (OVD) was used during the capsulorhexis and phacoemulsification (hyaluronic acid 1.6%–chondroitin sulfate 4% [Discovisc]) and during IOL insertion (sodium hyaluronate 0.3%–lidocaine 2.0% [Visthesia]).

The chemical composition of different models of phaco tips was accessed using X-ray photoelectron spectroscopy (XPS) and energy-dispersive X-ray spectroscopy (EDS) techniques. Their surface morphology and topography were also analyzed using scanning electron microscopy (SEM) and profilometry.

Phacoemulsification Tips

The following tips were studied: Laminar Flow 19-gauge 15-degree straight tip and Laminar Flow 20-gauge 30-degree curved tip (both Abbott Medical Optics, Inc.), turbosonics miniflared aspiration bypass system (ABS) tip 30-degree round 1.1 mm and turbosonics miniflared ABS tip 30-degree Kelman 0.9 mm (both Alcon Laboratories, Inc.), and microincision cataract surgery (MICS) phaco tip (Bausch & Lomb, Inc.). Six new tips and 6 single-used tips for each model were analyzed. In the case of the Laminar Flow 19-gauge 15-degree straight tip, approved for multiple surgeries (up to 20), 6 more samples were studied after 20 surgical cases. A total of 66 tips were studied; 33 tips (15 new, 15 after single use, and 3 after multiple uses) were studied with XPS, and 33 tips (15 new, 15 after single use, and 3 after multiple uses) were examined with EDS analysis. All the tips were evaluated using profilometry and SEM imaging.

All analyses were performed at the extremity of the tip, approximately 1.0 mm from the cutting edge, taking into consideration the entire circumference of the tip. The part close to the cutting edge is of crucial importance for phaco efficiency and represents the area where deterioration and wear are to be expected. This study focused on the evaluation of this small section of new and used phaco tips.

The new tips were analyzed immediately after the sterile package was opened; care was taken to avoid contact with the end of the tip. Before analysis, used tips were submerged into an enzymatic solution (Esozim, Esoform SpA), rinsed with sterile water, cleaned with compressed air, and sterilized in an autoclave at 120°C before being stored in sterile envelopes.

In addition, 2 groups of control tips (6 Laminar Flow 20-gauge 30-degree curved tip and 6 turbosonics mini-flared ABS tip 30-degree Kelman 0.9 mm) were studied. New tips were submerged in the enzymatic solution, rinsed with sterile water, cleaned with compressed air, and sterilized in an autoclave at 120°C before being stored in sterile envelopes. Six tips (3 Alcon and 3 Abbott Medical Optics) were analyzed with XPS and 6 (3 Alcon and 3 Abbott Medical Optics) with SEM coupled with EDS.

Morphologic Surface Analysis

Scanning Electron Microscopy Specimens were mounted on aluminum stubs covered with 2-sided conductive carbon adhesive tape. Samples were analyzed using SEM (Quanta 250, FEI) operated in secondary electron detection mode. Increasing enlargement magnifications from 50× to 1000× were used. The working distance was 10.0 mm, and the accelerating voltage was 30 kV.

Profilometry The quantitative analyses were performed with a 3-dimensional optical profilometer (Talysurf CLI 1000, Taylor Hobson). The scanning analyses were performed in contact mode with an inductive gauge that can achieve 300 nm in lateral resolution. The acquisition speed was 50 μm/s, and the measured area was 0.9 mm^2; the resolution in the x-plane and y-plane was 0.5 μm. All parameters were referred to an 80 μm cutoff. The roughness parameter considered in the analysis was the surface average roughness. Mean surface roughness describes the vertical deviation of a surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. The roughness analysis was taken along the main longitudinal axis of the shaft at the end of the tip (0.5 mm), considering an area of 300 μm × 300 μm. Four measurements were acquired every 90 degrees of clockwise rotation. Mean surface roughness was expressed in microns as the mean value of the 4 measurements.

Chemical Surface Analysis

X-ray Photoelectron Spectroscopy X-ray photoelectron spectroscopy is a quantitative spectroscopic technique sensitive to the elemental composition, chemical state, and electronic structure of the materials. X-ray photoelectron spectroscopy is performed measuring the kinetic energy and amount of electrons that escape from the top layers after the material has been irradiated with x-rays. For soft x-rays, the probing depth ranges from less than 1 nm to approximately 10 nm. Each element produces a unique set of XPS peaks at characteristic binding energy values corresponding to the electron shell and subshell of the electrons within the atoms (eg, 1s, 2s, 2p, 3s) that univocally identify the element and its chemical state. The intensity of XPS peaks is directly related to the amount of element within the irradiated area.

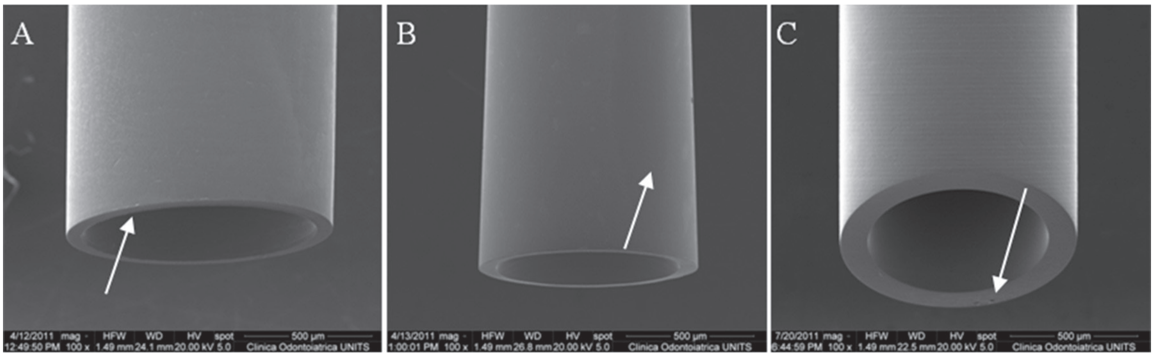

Figure 1. Scanning electron microscope images of new tips. *A*: Laminar Flow 19-gauge 15-degree straight tip. *B*: Turbosonics miniflared ABS tip 30-degree Kelman 0.9 mm tip. *C*: MICS tip. White arrows indicate the minimal production superficial irregularities.

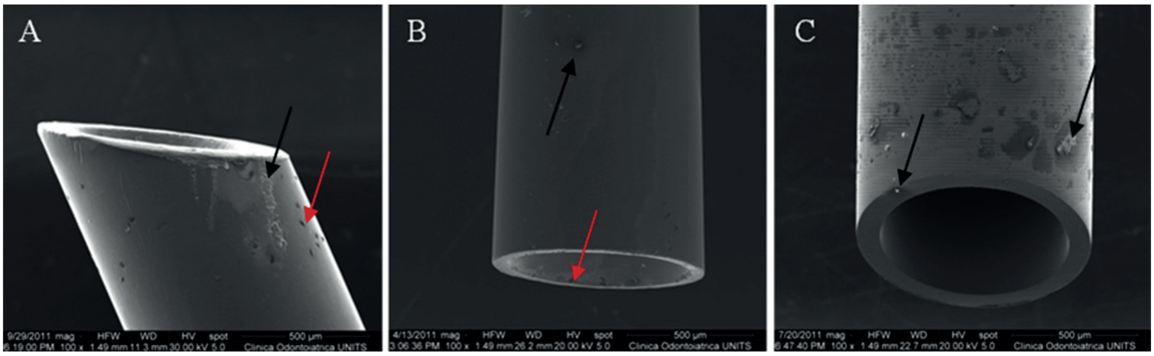

Figure 2. Scanning electron microscope images of tips after a single cataract procedure. *A*: Laminar Flow 20 gauge 30-degree curved tip. *B*: Turbosonics miniflared ABS tip 30-degree Kelman 0.9 mm tip. *C*: MICS tip. Black arrows indicate possible metallic debris and the red arrows, possible organic debris.

X-ray photoelectron spectroscopy was performed using a synchrotron-based light source combined with a VSW 150 mm hemispherical electron analyzer. This part of the study was performed at the National Research Council (Consiglio Nazionale delle Ricerche) Beamline for Advanced diCHroism at Elettra, 2-2.4 GeV third-generation synchrotron light source in Trieste, Italy.[A] The measurements were performed in 2 geometries and at different photon energies to identify the composition at different surface depths.

Energy Dispersive X-Ray Spectroscopy Energy-dispersive x-ray spectroscopy is an analytic technique associated with SEM that allows for the analysis of elements and chemical characterization of a sample. A beam of primary electrons of the SEM is focused on a sample so that it excites the electrons in the inner shell, forcing them to be ejected. The electron vacancy is filled by a higher energy electron from the outer shell. The difference in energy between the 2 electrons can be released as x-rays, which are detected by a spectrometer. The peculiar energy difference between electronic shells of each element allows for the chemical identification of the element itself. Compared with XPS, the probe depth of EDS is much higher (1 to 3 μm).

Phaco tips were analyzed in different positions by aiming the beam on parts of the shaft that, on SEM imaging, appeared to be clean after surgery and on others where possible debris after the surgical procedures were noticeable.

For surface chemical composition determination, a scanning electron microscope equipped with an EDS probe (Quanta 250 FEI with EDAX probe) was used to analyze 3 specimens per each group. The accelerating voltage varied between 10 kV and 30 kV; both spot-size and full-frame acquisitions were made at scanning times varying from 5 to 15 minutes.

Statistical Analysis

The primary quantitative variable evaluated (surface roughness) was expressed as the mean and standard error of the measurements. For each type of phaco tip, the differences in roughness for a different number of surgical cases were tested by 1-way analysis of variance or the t test for unpaired data, when appropriate. A P value less than 0.05 was considered statistically significant. All statistical analyses were performed using SPSS software (version 11.0, SPSS, Inc.).

RESULTS

Morphologic Surface Analysis

The SEM images showed all new tips were of good quality. The surface was smooth, and the end of the phaco tip presented a sharp, squared cutting edge (Figure 1). Rare and minor production defects consisting of superficial scratches and material flaws were observed (Figure 1).

After cataract surgery, all tips showed superficial deterioration (Figure 2). Debris was found on the surface, mainly at the end of the tip. The nature of most of the debris appeared to be metallic, while others could have been organic in origin. The profile of the edge, previously squared, tended to be circumferentially rounded and irregular. The main area of alloy wear did not extend for more than 0.5 mm from the end of the tip. This region of deterioration was not homogeneous in shape, and the debris had collected in small clusters (Figure 2).

After 20 cataract cases, the decay in the quality of the tip was even more evident and the amount of superficial metallic rubble and irregularities was impressive (Figure 3).

Table 1 shows the profilometer analysis. After surgery, an increase in the mean surface roughness was observed for all types of phaco tips. With the exception of the MICS phaco

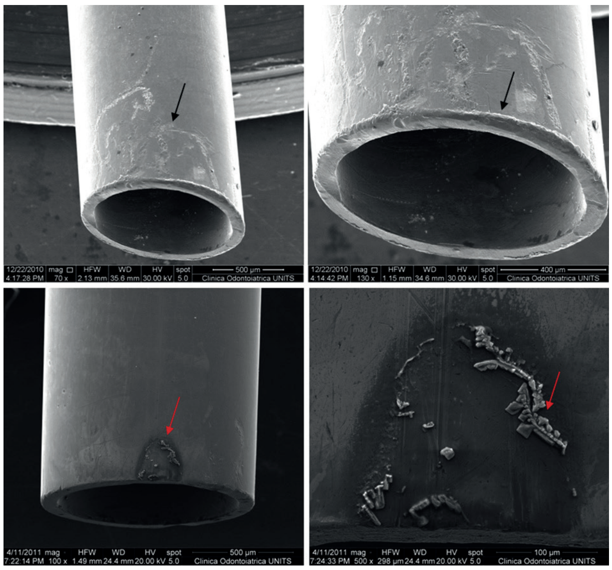

Figure 3. Scanning electron microscope images of tips after 20 cataract cases (Laminar Flow 19-gauge 15-degree straight tip). Black arrows point to the irregular and rounded edge and surface scratches and the red arrows, to the superficial debris.

Table 1. Mean and standard error of superficial roughness of new and used phaco tips.	
Tip	Mean Sa (μm) ± SE
AMO S	
New	0.443 ± 0.017
Used	0.523 ± 0.003
20 Surgeries	0.856 ± 0.078
P value	.002
AMO C	
New	0.542 ± 0.011
Used	0.872 ± 0.013
P value	.001
Alcon C	
New	0.655 ± 0.024
Used	0.838 ± 0.057
P value	.042
Bausch & Lomb	
New	0.967 ± 0.078
Used	1.153 ± 0.181
P value	.398
Alcon S	
New	0.456 ± 0.009
Used	0.867 ± 0.151
P value	.049

Alcon C = turbosonics miniflared aspiration bypass system tip 30-degree Kelman 0.9 mm; Alcon S = turbosonics miniflared aspiration bypass system tip 30-degree round 1.1 mm; AMO C = American Medical Optics Laminar Flow 20-gauge 30-degree curved tip; AMO S = American Medical Optics Laminar Flow 19-gauge 15-degree straight tip; Sa = superficial roughness; SE = standard error

tip, this difference was statistically significant. The surface average roughness value after 20 surgeries (Laminar Flow 19-gauge 15-degree straight tip) was almost twice the value of the new samples.

Chemical Surface Analysis

X-Ray Photoelectron Spectroscopy The metal elements found on the surface of the tips were Ti, aluminum (Al), zinc (Zn), silicon (Si), and lead (Pb). In addition, metals, oxygen (O) and traces of sulfur (S), carbon (C), nitrogen (N), phosphorus (P), chlorine (Cl), and fluorine (F) were found in most samples.

Figure 4 shows a sample comparison of the photoemission spectra recorded on the 2 Abbott Medical Optics tips, 1 Alcon tip, and 1 Bausch & Lomb tip. The surface chemical composition of the alloy between the 3 brands was similar, with minor differences, such as the presence of iron (Fe), Zn, sodium (Na), potassium (K), and calcium (Ca) in some tips and a relative amount of Al, Si, P, Pb, Cl, and F. This partially confirms the manufacturers' data regarding the construction materials used, which is a Ti–Al–vanadium (V) alloy.

The main outcome was the increase in Na, Si, S, Cl, N, K, and C on the surface of the tip after surgery. As an example, Figure 5 shows a comparison between the photoemission spectra (collected at 900 eV) measured on 1 tip before use (new) and after use. The Ti peak is strongly reduced, while the Si and Na peaks show a significant increase. The tips after use appeared to be covered by a layer mainly composed of Na and Si.

To determine whether the increase of the Si on the surface was the result of surgery or of the sterilization process,

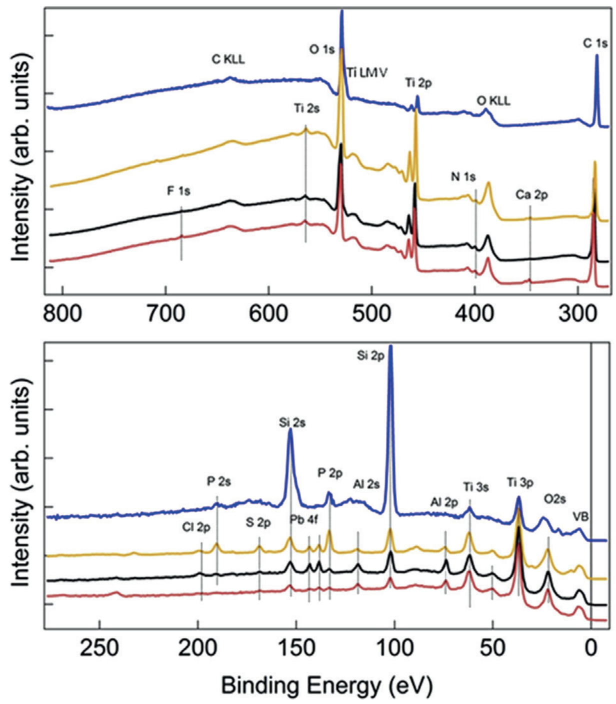

Figure 4. Photoemission spectra measured using a photon energy of 900 eV on 4 new phaco tips. The red line represents the turbosonics mini-flared ABS tip 30-degree Kelman 0.9 mm tip; the black line, the Laminar Flow 19-gauge 15-degree straight tip; the yellow line, the Laminar Flow 20-gauge 30-degree curved tip; and the blue line, the MICS phaco tip. The elements that were identified in the spectrum are indicated. The numbers (eg, 1s, 2s, 3s, 2p) indicate the electron shell (identified by the principal quantum number; eg, 1, 2, 3) and the subshell (identified by s, p, d, f labels) within the atoms for each element. In these spectra, for the used photon energy (900 eV), the Ti LMV Auger peak superimposes to the V 2p core level region (Al = aluminum; arb. = arbitrary; C = carbon; Ca = calcium; Cl = chlorine; F = fluorine; N = nitrogen; O = oxygen; P = phosphorus; Pb = lead; S = sulfur; Si = silicon; Ti = titanium; VB = valence band).

3 new phaco tips of each model were washed and sterilized as previously described for the used tips. The sterilization process did not increase the Si concentration on the surface of the new tips (Figure 6).

Energy Dispersive X-Ray Spectroscopy Energy dispersive x-ray spectroscopy showed that all the tips were made of a Ti alloy. The principal element detected was Ti followed by V and bromine, both in new tips and used tips. Minor elements, such as Na, K, Cl, C, and Ca were detectable, especially on used tips (Figure 7).

The debris on used phaco tips contained a high level of C, while on new phaco tips the presence of C was almost absent (Figure 7). Moreover the presence of C was low even on used tips when the analysis focused on the tip in an area free of debris. (Scanning electron microscopy images were used to guide the EDS analysis.)

The C peak was surprisingly high and equaled that of the Ti. The presence of C was constant in all used tips for which the debris areas were analyzed. The SEM imaging in the control group of new tips submerged in the enzymatic solution and resterilized did not show debris on the tips,

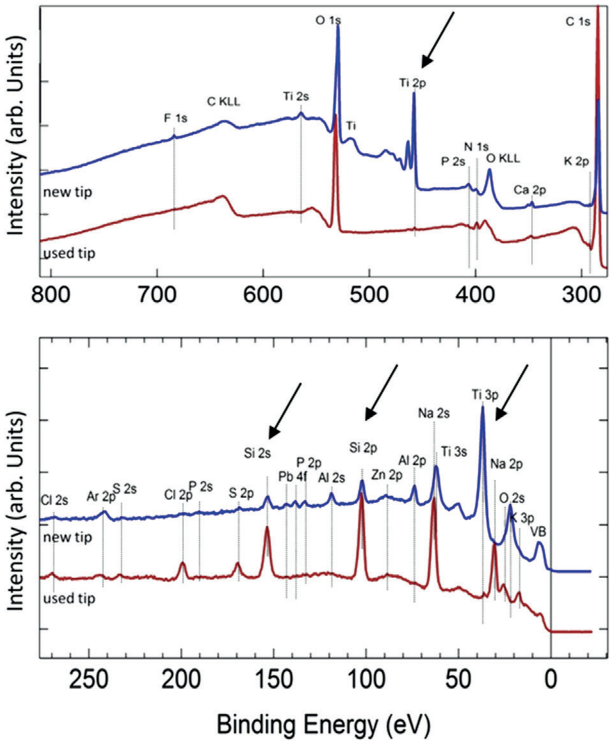

Figure 5. Photoemission spectra, measured using a photon energy of 900 eV on a new and a used turbosonics mini-flared ABS tip 30-degree Kelman 0.9 mm. Note the difference in the Ti and Si peaks between the new tips and used tips (*black arrows*) (Al = aluminum; Ar = argon; arb. = arbitrary; C = carbon; Ca = calcium; Cl = chlorine; F = fluorine; K = potassium; N = nitrogen; Na = sodium; O = oxygen; P = phosphorus; Pb = lead; S = sulfur; Si = silicon; Ti = titanium; VB = valence band; Zn = zinc).

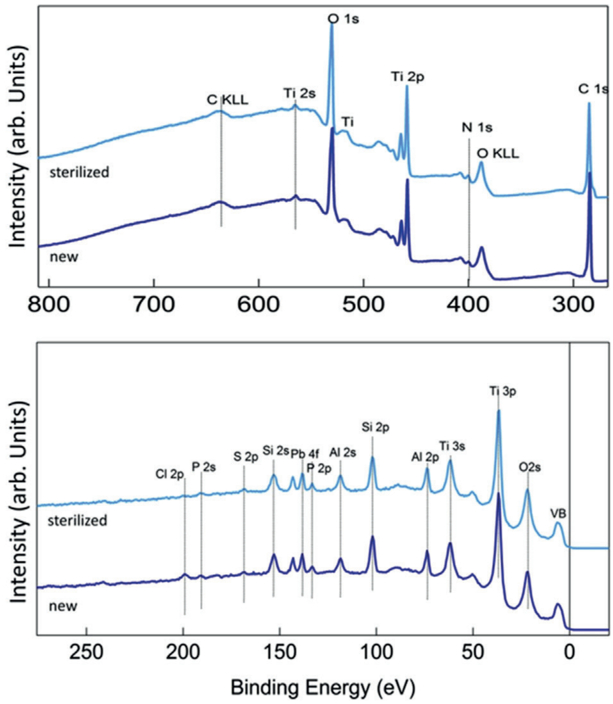

Figure 6. Photoemission spectra measured using a photon energy of 900 eV on a new phaco tip and a resterilized new phaco tip. No changes in the chemical composition or in the relative intensity of the peaks occurred (Al = aluminum; arb. = arbitrary; C = carbon; Cl = chlorine; N = nitrogen; O = oxygen; P = phosphorus; Pb = lead; S = sulfur; Si = silicon; Ti = titanium; VB = valence band).

and the EDS analysis did not detect a C peak on their surface (Figure 8 and Figure 9, respectively). These data strongly suggest that the origin of the debris was related to biological material contamination after use.

DISCUSSION

The trend in modern cataract surgery is to use disposable materials and tools. The aim is to prevent infections and provide patients with new and flawless surgical instruments and appliances. Although the cost of disposable tools is relatively high, it may be worth it in terms of efficiency and safety. This study addressed this problem in relation to phacoemulsification tips.

The main outcome of this study was that used tips deteriorate after a single use. This result was confirmed by all analyses we performed using different techniques. The SEM images showed that all new tips had a smooth and

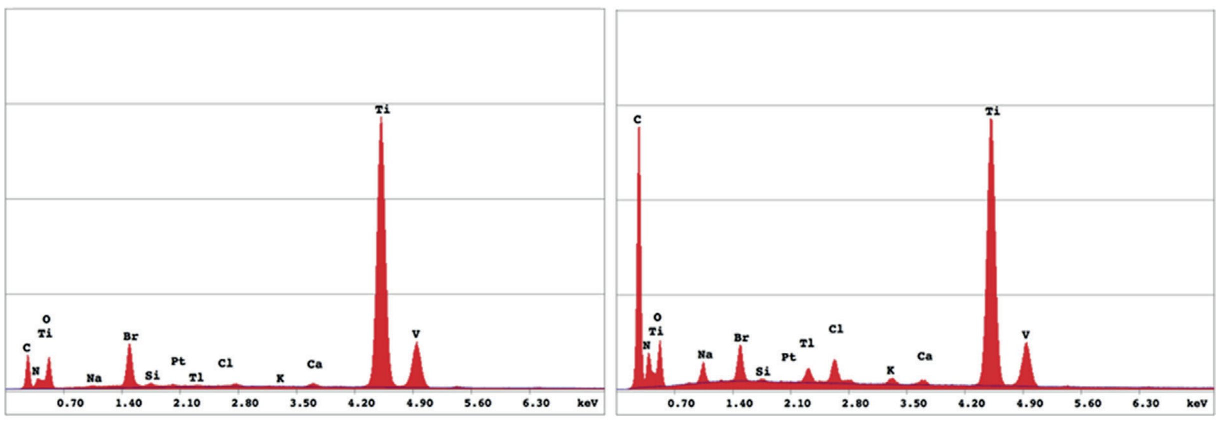

Figure 7. Example of EDS analysis of a new (*left*) and a used (*right*) phaco tip (turbosonics miniflared ABS tip 30-degree Kelman 0.9 mm). Analysis of the debris showed a high peak of C, which was almost completely absent on the bare shaft of the tip (Br = bromine; C = carbon; Ca = calcium; Cl = chlorine; K = potassium; kev = kilo electron volt; N = nitrogen; Na = sodium; O = oxygen; Pt = platinum; Si = silicon; Ti = titanium; Tl = thallium; V = vanadium).

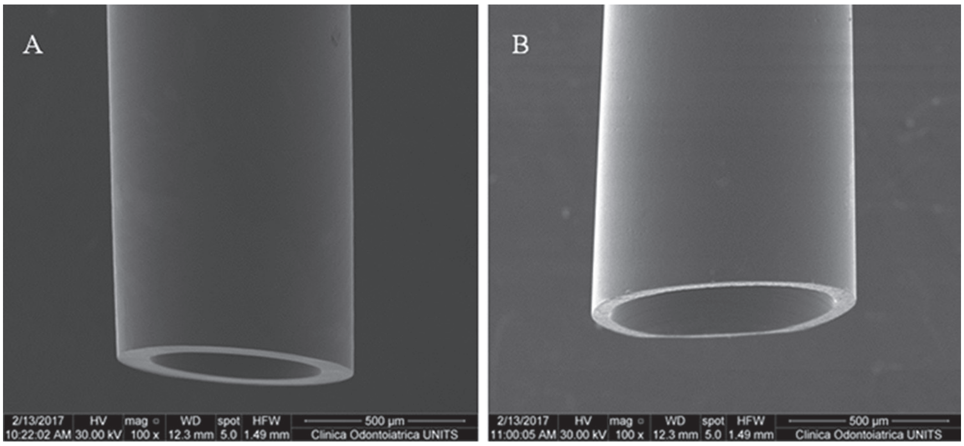

Figure 8. Scanning electron microscope images of new resterilized tips. *A*: Laminar Flow 20-gauge 30-degree curved tip. *B*: Turbosonics miniflared ABS tip 30-degree Kelman 0.9 mm. No debris was visible on the tip surfaces.

polished surface, while used tips had damage to the profile of the surface. Dents, debris, and a loss of sharpness were detected. The end of the tips appeared to be rounded. These signs of deteriorations were significantly higher in cases of reusable tips (20 surgical procedures). The profilometry confirmed the wear and tear of the tips that caused an increase in surface roughness of all used tips. This decay in the quality of the surface was more evident after multiple uses of the Laminar Flow 19-gauge 15-degree straight tip. The surface average roughness doubled in value, indicating extreme deterioration of the tip. In part I of their study, Tsaousis et al.[9] compared the profilometry of 7 new phaco tip models, concluding that the results might be affected by defective areas of phaco tips. The authors added that a smooth tip surface could be gentler to ocular tissue. Our study specifically compared the surface roughness of used phaco tips with that of new tips rather than to that of new tips of different brands.

Zacharias[11] found that cavitation does not have a relevant role in phacoemulsification. He clearly showed that the efficiency of phacoemulsification remains unaffected when cavitation is completely suppressed. The cutting effect is therefore the result of the mechanical movement of the tip that ruptures the lens material. The stroke can be longitudinal (jackhammer effect), torsional, or transversal–elliptical. More studies are needed to determine whether the loss of sharpness of and the presence of irregularities on used phaco tips decrease cutting efficiency, regardless of the removal modality (torsional, longitudinal, or transversal–elliptical). Demircan et al.[12] found that the total US time and cumulative dissipated energy increased when reused tips were used to perform phacoemulsification procedures using a torsional system, especially in eyes with hard cataract. Conversely, no difference was found in total phacoemulsification time and effective phacoemulsification time when reused phaco tips were used in a transversal phacoemulsification system. The authors suggested using a new phaco tip for each procedure.

All tips studied in our study work were made of a Ti-6Al-4V (6% Al, 4% V) alloy, which is a material widely used in biomedical applications. The chemical analysis with XPS and EDS confirmed that all tips were made of a titanium alloy. Often, treatments are applied to the surface; these include ASTM F86/B600 passivation in nitric acid, electropolishing in a perchloric acid–based electrolyte, anodization in sulfuric acid and phosphoric acid, and glow discharge plasma oxidation. These treatments provide a controlled and uniformly oxidized surface and improve corrosion resistance, decreasing the possibility of ion release.

For this reason, the survey spectra measured on the tips of different brands were slightly different quantitatively and in the detected elements, depending on the surface treatment performed on the Ti alloy used for the specific

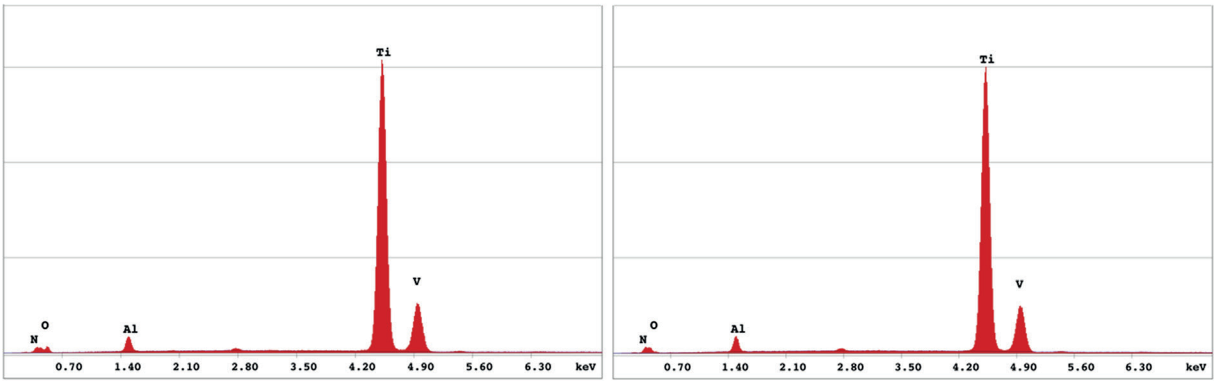

Figure 9. Example of EDS analysis of a new resterilized tip. *Left*: Laminar Flow 20-gauge 30-degree curved tip. *Right*: Turbosonics miniflared ABS tip 30-degree Kelman 0.9 mm. No carbon peak was detected (Al = aluminum; kev = kilo electron volt; N = nitrogen; O = oxygen; Ti = titanium; V = vanadium).

tip. X-ray photoelectron spectroscopy and EDS have different sensitivity in the sample depth. The probe sensitivity of XPS is in the range of nanometers, while the range of EDS is in the range of micrometers. This implies that XPS performs a very superficial analysis, while EDS can reach the core of the sample. This difference in depth analysis can explain the different chemical elements detected by XPS and EDS. Tsaousis et al.[9,10] obtained similar results, ascribing the difference in elemental composition to the difference in the depth of analysis between EDS and XPS. The main outcome of XPS analysis in the present study was the detection of a superficial silicon layer of the surface of used tips compared with new tips. In addition, the titanium peak decreased and some other elements that previously had low peak intensity became detectable. These results suggest a chemical modification of the phaco tips, even after a single cataract procedure. The presence of the superficial layer of silicon might be the result of rearrangement of the alloy elements, possibly induced by the US frequency movement of the tip during phacoemulsification. The silicon in the alloy appears to undergo a superficialization process during the US power delivery only because the sterilization process does not induce modifications of the superficial chemistry of the tips. It is not possible to speculate whether this chemical alteration has an effect on phaco efficiency when reusable tips are used.

The XPS analysis was extended diffusely on the end of the tip as a whole, allowing for a general chemical study, while with EDS we were able to focus the analysis on different spots under the guidance of SEM imaging. The EDS spectroscopy of debris showed a relevant presence of carbon after the use of the tip. It is likely that the carbon was biological in origin because it was not present in new tips, nor was it detectable on used tips outside the debris area. The amount of the biological debris found on used tips was significant. Theoretically, the debris could be derived from lens proteins, cellular remnants, OVD residue, or a combination. Because of the high oscillating frequency of modern phaco tips, these substances might be released into the eye during subsequent cataract procedures.

Toxic anterior segment syndrome (TASS) is described as an acute postoperative sterile inflammation characterized by corneal swelling, increased cells and flare with associated fibrin, and possible hypopyon formation. The main causes of TASS are believed to be OVD remnants, metals, irrigating solutions with unbalanced pH and/or osmolarity, or intraocular drugs.[13–17] Other studies[9,10,16–18] suggest that inadequate surgical instrument washing and the use of rinsing and enzymatic detergents might be factors in the development of TASS. Kim[19] reported 3 cases of TASS caused by OVD debris and residue on ophthalmic instruments from previous procedures.

We found a significant increase in the carbon peak on used tips in areas where material deposits were detected on SEM imaging. Even though sterile, the debris could promote inflammation and eventually TASS. Conversely, Nuyts et al.[20] did not detect lens protein residue on new or reused phaco tips after routine cleaning procedures. The authors suggested that the accumulation of lens proteins inside used tips is very unlikely. Our study found the presence of carbon on used tips. Undoubtedly, this deposit of carbon derives from the previous surgical case and/or cleaning system. After detergent use, Tsaousis et al.[9,10] found detergent residues on phaco tips even after performing meticulous rinsing.

As controls, new phaco tips were resterilized and subsequently analyzed with XPS to assess the effect of sterilization on the chemical surface composition. The photoemission spectra were not affected by the procedure, according to XPS analysis. Analysis by EDS of a second control group of new resterilized tips after submersion in enzymatic solution and rinsing process with sterile water did not show evident debris or signs of carbon remnants.

Our data suggest that the sterilization process, even with the use of enzymatic solution, does not significantly affect the surface and the chemical composition of the phaco tips. Because we assessed a portion of the phaco tip surface with EDS, mainly at the end of the tip, we cannot exclude the presence of detergent debris on the whole phaco tip. Whatever the origin of debris found on the used tips, it would be advisable to avoid any contamination to increase surgical safety.

In conclusion, this study found that used phaco tips had deterioration of the surface with a variable quantity of superficial debris. The cutting edge lost its original sharpness and appeared to be rounded. Those findings were more evident on reusable tips. Questions might arise regarding the residual cutting efficiency of multiple-use tips.

Even if single-use tips increase the total cost per procedure, their use might be advisable. Further studies are needed to determine whether multiple-use tips may have clinical disadvantages in terms of efficiency and safety.

WHAT WAS KNOWN

- Phaco tips are made of a titanium alloy.
- The surface of new tips are smooth and regular.

WHAT THIS PAPER ADDS

- Used phaco tips lost the sharpness of the cutting edge, which appeared rounded. Metallic and organic debris were present on the tip surface after the surgical procedures.
- Reusable tips appeared even more damaged and ruined, suggesting that single-use phaco tip should be used.

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