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ORIGINAL ARTICLE

Evaluating the diameter of eyedropper tips using a computer vision system

Avaliação do diâmetro de bicos de conta-gotas de colírios por visão computacional

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ABSTRACT | **Purpose:** This study aimed to determine the variation in diameters of outer and inner apertures of eyedropper tips using a computer vision system. Standardizing the size of eye drop nozzles is crucial to reduce the treatment cost of chronic eye diseases and to ensure a continued use of medication. An eyedropper volume of >20 µL (maximum storage of the conjunctival sac) causes medication wastage and increases treatment costs. **Methods:** We measured the diameters of the outer and inner apertures of eyedropper tips and evaluated variations in diameters using a computerized visual inspection system. **Results:** The computer visual inspection system identified anomalies in the apertures of eyedropper tips that resulted in diameter variations. **Conclusions:** The results of the present study show discrepancies in diameters of eyedropper tips, suggesting a variation in eyedropper size and medication wastage.

Keywords: Lubricant eye drops; Drug packaging; Eyedropp size; Diameter variation; Health care costs; Computer vision system

RESUMO | **Objetivo:** Este estudo teve como objetivo determinar a variação dos diâmetros das aberturas externa e interna dos bicos conta-gotas utilizando sistema de visão computacional. A padronização do tamanho dos colírios conta-gotas é importante para reduzir o custo do tratamento de doenças crônicas e garantir o uso contínuo de medicamentos. O volume da gota maior do que 20 µl (volume de armazenamento máximo do saco conjuntival) gera desperdício da medicação e aumenta o custo do tratamento. **Métodos:** Medimos os diâmetros das aberturas externa e interna das pontas dos conta-gotas e avaliamos as variações no diâmetro usando um sistema de inspeção visual computadorizado. **Resultados:** O sistema de inspeção visual por computador identificou anomalias nas aberturas dos bicos dos frascos conta-gotas que resultaram em variações de diâmetro. **Conclusões:** Os resultados do presente estudo mostram discrepâncias nos diâmetros dos bicos dos frascos dos conta-gotas, sugerindo uma variação no tamanho das gotas e no desperdício de remédios.

Descritores: Colírio lubrificante; Embalagem de medicamentos; Tamanho da gota; Variação do diâmetro; Custos de cuidados de saúde; Sistema de visão computacional

INTRODUCTION

Some chronic eye diseases decrease visual acuity, possibly resulting in vision loss. The World Health Organization reported that in 2002 >161 million people worldwide have some form of visual impairment, 37 million of whom are blind. In addition, >82% of all blind people were of ≥50 years of age[1]. Increasing costs associated with public health care has become a serious problem as visual impairment and blindness significantly impact the socioeconomic development of individuals and society[2].

Dry eye syndrome is a multifactorial disease affecting the tear film and consequently the ocular surface[3-9], with epidemiological studies indicating an increasing global incidence of dry eye disease[10,11]. The use of treatment method depends on the severity of the disease and includes patient education and use of topical (eye drops) and systemic medications. Topical medications include artificial tears, anti-inflammatory drugs (nonsteroidal, corticosteroids, and cyclosporine A), and autologous serum[12-14].

Moreover, glaucoma has a significant financial impact on the health care system owing to the frequent use of

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drugs, surgical procedures, consultations, and complementary tests involved in glaucoma treatment[15,16].

Most drugs used to treat eye diseases are aqueous solutions containing active ingredients (eye drops). These medications are applied using a wide range of eyedroppers with different types of tips that allow slow dropwise administration of the drug[17]. Studies suggest that the lack of uniformity in dropper size results in medication wastage[18,19] because the dropper size should be determined based on the maximum capacity of the conjunctival sac (20 µL)[20]. Here, we aimed to evaluate variations in the diameters of the outer and inner apertures of eyedropper tips using a computer vision system.

METHODS

All of the experimental protocols were approved by the Institutional Research Ethics Committee (nº 1092211014) at Federal University of São Paulo, and all experiments were performed in accordance with the approved guidelines and regulations.

A computerized visual inspection system was used to measure the dimensions of the outer and inner apertures. Tests were conducted on lubricating eye drops available in the Brazilian market, which were designated as "brand A" and "brand B" and chosen on the basis of the lowest price. We inspected ten 15-mL bottles from two different brands, five bottles from each brand and from different batches. Figure 1 illustrates the cross-section of the eyedropper tip; the external opening is in the upper portion of the tip, which is easily visualized by the user, and the inner aperture is in the lower portion of the tip, inside the eyedropper.

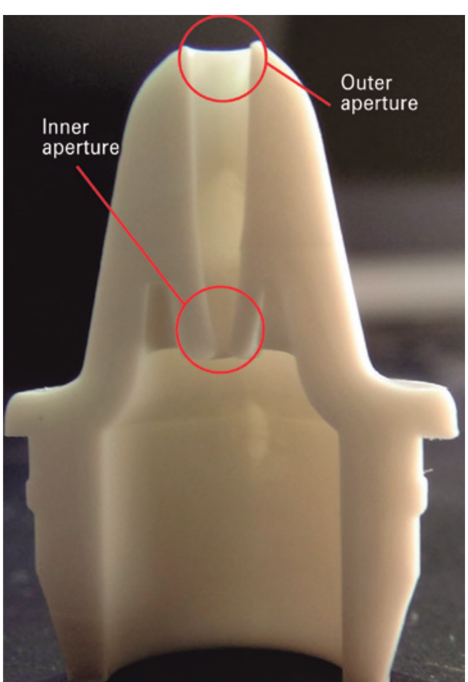

Figure 1. Photograph of the cross-section of an eyedropper tip (Source: author).

Computer visual inspection

An artificial vision system (Omron, Kyoto, Japan) was used to conduct the inspection using the following configuration: FZ5-L355 controller, dedicated software, camera resolution of 2 million pixels, 25 mm/1:14 lens, 30-mm spacer, and backlight (Figure 2).

In the present study, we used a backlight, 25-mm lens optical system, and 30-mm spacer to enhance and magnify the diameter of the openings 10 times. Digital images of the eyedropper tips were obtained in pixels.

We inspected the eyedroppers in two stages because the openings have different nominal dimensions and relative positions at the tips: inspection of the outer and inner apertures of the tips, with different distance ratios between the camera and the object, which generated different inspection images.

Statistical analysis

Descriptive analysis was performed to obtain means ($\bar{x}$) and standard deviations (SD). Data were analyzed using one-way analysis of variance using the SigmaStat software (Systat Software, San Jose, CA, USA). The study groups were subsequently compared, and p-values <0.05 were considered statistically significant.

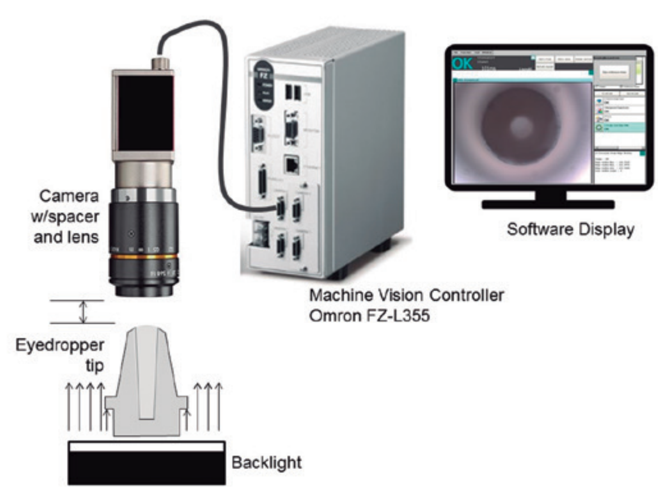

Figure 2. Installation of the computerized visual inspection system (Source: author).

RESULTS

The results of inspecting the dimensions of the outer and inner apertures of the eyedropper tips are separately shown.

Inner aperture

The inner aperture of bottles from brand A indicated variations in the measurements, with an average of 125.9 ± 5.31 pixels, corresponding to a difference of 8.6% (Table 1).

Figure 3 shows deficiencies in the dimensions and variation in the diameters of the openings of the eyedropper tips.

Figure 3 shows an examination of the inner aperture of different bottles from brand A using a computerized vision inspection system. Figure 3A shows an opening that is considered adequate (because it has no internal obstructions). Figure 3B demonstrates internal burrs, and Figure 3C exhibits the undefined shape of the opening. These results demonstrate the non-uniformity of the tips made by the same eyedropper brand.

Due to their small size, we could not measure the inner apertures of eyedropper tips of bottles from brand B, which limited inspection with the optical system.

Outer aperture

Outer aperture measurements of bottles (n=5) from brands A and B varied by 3.7% and 2.1%, respectively. In addition, a significant difference was noted in the outer aperture measurements (p=0.025) between brands A and B (Table 2).

Table 1. Measurements of the inner apertures of eyedropper tips

Bottle	Brand A (pixels)	±SD (pixels)
1	125.1	125.92 ± 5.3
2	120.4	
3	121.3	
4	131.1	
5	131.7	

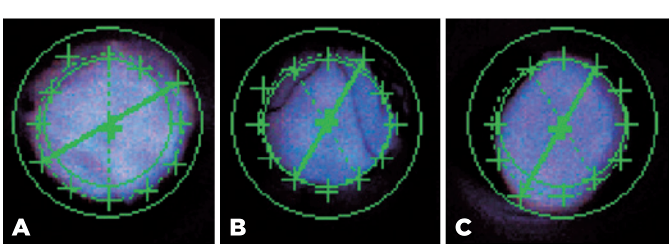

Figure 3. Inner aperture of the eyedropper tip (Source: author). (A) adequate (no internal obstructions), (B) internal burrs and (C) undefined shape of the opening.

The outer apertures exhibited no burrs or anomalies. Figure 4 shows an image of a tip captured by the computerized vision inspection system via diameter inspection.

DISCUSSION

Considering the increase in the number of elderly people in Brazil, who now represent 7.9% of the population and are estimated to account for 13.44% by 2030[21], and that the prevalence of eye problems is higher in this population, it is essential to implement solutions to reduce the financial impact of eye treatments on family income within this population.

Optical inspection systems, such as computerized vision inspection systems and laser measurement sensors, are effective strategies for increasing repeatability and reliability and obtaining more relevant information about the processes that can assist in production management[22]. Artificial vision system technology is a computational tool for obtaining relevant information for decision making in production lines involving ex-

Table 2. Measurements of the outer apertures of eyedropper tips (Source: author)

Bottle	Brand A (pixels)	±SD (pixels)	Brand B (pixels)	$\bar{x}$ ±SD (pixels)
1	890.3	901.4 ± 16.0	920.0	923.4 ± 8.1
2	895.4		929.9	
3	917.9		910.8	
4	884.4		930.1	
5	918.8		926.1	

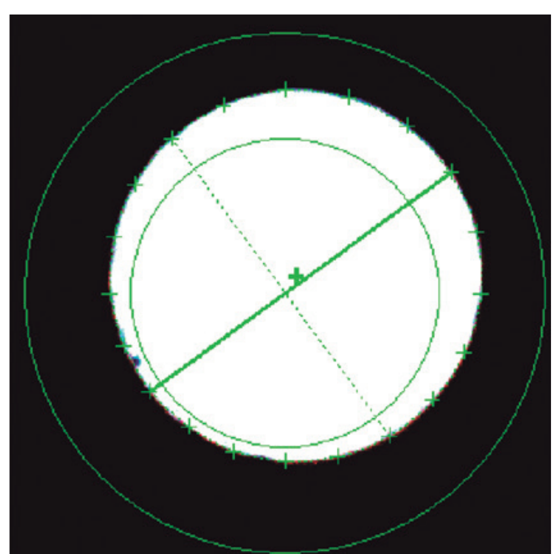

Figure 4. Inspection of the outer aperture of the eyedropper tip (Source: author)

traction, manipulation, analysis, and automated classification of images or image sequences using a specific computer system[23].

In the field of ophthalmology, vision systems provide automated inspection of processes related to quality assessment, selection, classification, character reading, and object orientation[24]. This technology is essential in the manufacturing industry due to the increased demand for traceability and documentation to certify product quality[25].

The number of drops in each bottle determines its yield and is a critical factor in consumer choice[18]. Therefore, a drop volume exceeding the recommended value decreases the yield, increases the annual cost of treatment and waste, and can significantly harm the consumer[16,26]. A previous study demonstrated that the financial impact on family income is an important factor involved in treatment adherence[26]. Reports indicate that in addition to financial issues, a higher drop volume than recommended may cause health problems via systemic absorption through the mucosa in adults and children. The larger instilled volume could be more rapidly drained through the naso-lacrimal duct system. Systemic absorption occurs more easily in children due to their smaller body size and lower systemic metabolizing capacity[27,28]. Factors influencing the size of the drops administered using a plastic eyedropper bottle include physicochemical properties of the solution, patient handling of the bottle, and design and characteristics of the eyedropper and bottle[29].

The mass of the dispensed drop is strongly affected by the solution's physicochemical properties, including viscosity and surface tension. Nascimento et al. compared 20 μL volumes of the drop mass of five different brands of lubricant eye drops used in ophthalmology. They obtained five 20 μL samples of each drug using a micropipette (Eppendorf 20 μL) and weighed the samples on a calibrated Precision Scale (Bioprecisa Electronic Balance FA2104N). Their results suggested the absence of a reference standard for the drop mass of lubricant eye drops considering a 20 μL volume[30].

Another factor is drug application and bottle handling, i.e., the way the patient applies the drug. For example, drop formation is influenced by the angle of application (45° or 90°) and the amount of pressure applied on the bottle[31]. Nascimento et al. found that the mean volume per drop exceeded 200% of the optimum 20 μL volume reported in the literature[30]. They collected samples of five lubricant drugs used in ophthalmology from four volunteers aged 21-29 years, and each volunteer collected one sample drop 10 times (applied at 90°) of each drug.

With respect to the design and physical characteristics of eyedropper tips, the internal shape of the tips directly influences drop size[29]. Moreover, these characteristics are determined during the design phase and may suffer variations in the production process. According to the manufacturer, the tips are thermoplastic injection-molded pieces of low-density polyethylene (LDPE), which is softened in a heated cylinder and injected into a mold, hardening and taking the final shape of the mold once cooled. The pieces are subsequently extracted from the mold[32].

Standardization of eyedropper size is necessary in reducing treatment costs of eye diseases and ensuring continuous use of medications without interruptions due to financial reasons, thus benefiting patients as well as society.

The presence of anomalies and lack of standardization of eyedropper tips indicate variations in dropper size and medication wastage. Therefore, standardizing the tip production process is necessary to prevent drug wastage and avoid eye damage due to excessive use of these drugs.

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