3D printing techniques in making custom eyeglasses frames

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Abstract. *The spectacles (or eyeglasses) are optical instruments that have the role of protecting the eye or correcting certain vision defects. A pair of glasses consists of the actual frame and two lenses. The main role of the frames is to position the lens as correctly as possible on the optical axis of the eyes. The basic dimensions of the glasses are: the line of the glasses, the optical centres of the two lenses; the length of the lens, measured from the line of the spectacle; the distance between the two optical centres; the minimum distance between the lens and the width of the bridge. Starting from these parameters, the shape of the frames can be customized according to the wearer's physiognomy and his preferences, so that the glasses correspond from the aesthetic point of view and to the fashion trends. Based on this information, this paper aims to present a method of making custom frames using 3D printing techniques. These techniques offer the possibility of dimensional choice of the frame, colour, shape and appearance, so as to match the wishes of the user from all points of view.*

Keywords: 3D Printing, Spectacles, Eyeglasses Frames.

Introduction

Eyeglasses are optical instruments that have the role of protecting the eye or correcting certain vision defects. They consist of the frame itself and two lenses. The main role of the frames role is to position the lens as correctly as possible on the optical axis of the eyes. Glasses frames must be comfortable, but at the same time medically appropriate (Barbu, 2003). The spectacle frame consists of two boxed lens, the arms for attaching the spectacle to the ear, and the nasal bridge (Figure no. 1). It is generally recommended that the lens be attached to its entire circumference, but there may be cases where it may be in contact with the frame only in certain areas (Brooks& Borish, 2006).

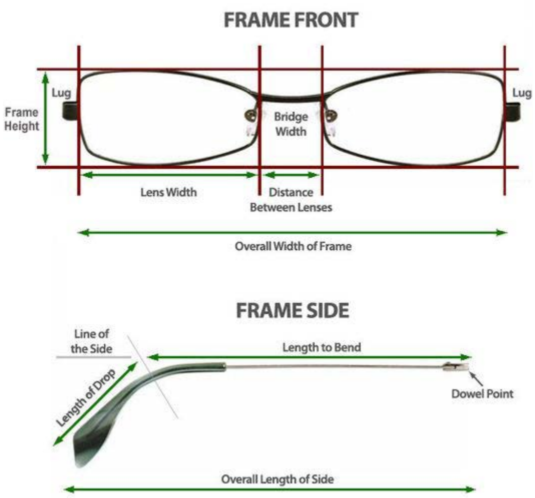

Figure no. 1. The main parameters of the frames
Source: https://www.selectspecs.com/.

Although visual acuity may seem better with custom glasses, it has been shown in a group of school-age children in Nigeria that there was

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no significant difference between the use of ready-made glasses and custom glasses (Ekpenyong et al., 2017).They demonstrated that prefabricated eyeglasses can be recommended for correcting refractive errors with ≤ 1.00D for anisometropia and ≤ 2.00D for astigmatism (Ekpenyong et al., 2017).Therefore, for small refractive errors, standard glasses can be used, which are more affordable and, in this way, can also be used by people who do not have the financial means to make custom glasses. Similar results were presented in (Angell et al., 2018), in which it was shown that "the relative cost-effectiveness of offering ready-made spectacles relative to no intervention as well as the relative cost-effectiveness of custom-made spectacles relative to ready-made spectacles to treat uncorrected refractive error".
The personalized frames have the role of ensuring first of all the quality of the vision. They are designed in such a way as to be optimally adapted according to the wearer's physiognomy, but also to his desires from an aesthetic point of view. Frames that have a certain shape or colour can be made, or they can be modelled when there are malformations or various deformities of the head.
According (Adams et al., 2015), 3D printing plays an important role in eye care, as it has been shown to be a valid method of manufacturing ophthalmic models, devices and instruments such as the intraocular pupil, prostheses and orthoses, and in process modelling and simulation of the ophthalmic processes. For example, (Ruiters et al., 2016) presents a method in the manufacturing of a customised ocular prosthesis based on computer-aided design and computer-aided manufacturing: an ocular prosthesis, based on a three-dimensional (3D) printed "impression-free mould of the anophthalmic cavity". Or (Ayyıldız, 2018) presents a study, where 3-D printing technology was used to design, prototype and manufacture a pair of spectacles for a child with Goldenhar syndrome.

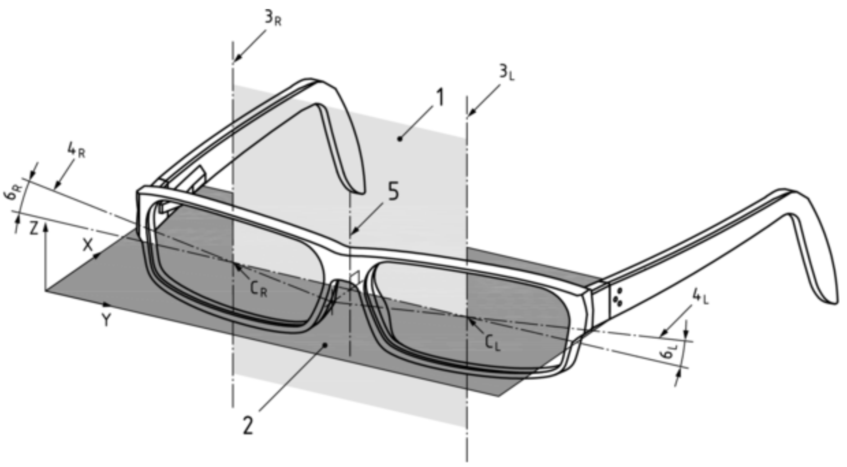
Methodology

Making personalized glasses involves the following steps: sketching the necessary model, measuring the necessary parameters, making the CAD model using one of the assisted design software, the actual printing, model optimization, 3D printing and system assembly. In the following we will present only the stages that are involved in 3D printing, which is the subject of this paper.

Establishing the shape and parameters of the spectacle frame

According to (Barbu, 2003), the line of the spectacle is the straight line joining the optical centres of the two lenses. The optical centre of a lens is the point through which the optical axis passes, a point which has the property that any ray of light passing through it will not be deflected (Brooks& Borish, 2006). The optical axis of a lens is the straight line joining the two centres of curvature of the lens surface.
The position of the optical centre, defined theoretically, cannot be practically realized in the ideal position, but with small deviations (Brooks& Borish, 2006). These deviations give rise to decentralization, which can be vertical, horizontal or diagonal. The importance of the spectacle line results from the fact that it defines the line of the centres of the two lenses, but in turn these centres must be at a certain distance from each other on this line.
The distance between the two optical centres must correspond to the distance between the pupils of the eyes (interpupillary distance) (Barbu, 2003). Therefore, with glasses, the distance between the two optical centres can be determined by measuring the length of the lens and the distance between the lenses in the same direction (Brooks & Borish, 2006).

The width of the nasal bridge is the distance between the corners of the frame to the nasal septum and can be measured along the line of the spectacle.
The front frame represents the front of the spectacle frame. Its main role is to fix the lenses. Care must be taken that this does not affect the field of view (Brooks& Borish, 2006). It is very important that the frame is suitable so that the pupil of the resting eye corresponds to the optical centre of the lens (Barbu, 2003).
The connecting part of the frame is used to attach the arms. Its length and width depend on the size of the arms. It can be processed in several forms: straight; curved; curved and cut; semi-curved; chamfered; semi-sharp or sharp. The arm helps to secure the glasses to the wearer's head (Barbu, 2003). Many types of arms are known, but their manufacturing technology is the same (Costan, et al., 2020).With a properly executed spectacle, the arm does not touch the temple, and the correct position of the spectacle is ensured by means of the bones behind the ears. The width of the arms depends on the width of the connecting part of the frame (the place where the arm is assembled to the frame by means of hinges) (Brooks & Borish, 2006).The distance from the arm to the top and bottom of the frame can also be indicated for the frame of the glasses. Given these dimensions, the diameter of the lens required to cover these distances is chosen dimensionally (Brooks & Borish, 2006).Usually, metal reinforcements are inserted inside the celluloid arms to increase their strength (Costan, et al., 2020).
The hinges are used to assemble the arms of the front frame. They can be made of alpaca or brass and can vary in shape and size (Brooks & Borish, 2006). The hinge consists of a right side and a left side, and screws are needed for assembly
Usually, the bridge is made of plastic and can have several shapes: normal, angled and arched (corrugated) bridge. As a position relative to the frame, the bridge can be placed in the middle (in the direction of the spectacle line) or at the top. The nasal bridge is characterized by three parameters: the peak radius, the arrow (distance from the spectacle line to the lower edge of the bridge) and the base (bridge width) (Barbu, 2003). The nasal bridge has two fins. They are plastic pills of different shapes depending on the physiognomy of the nose. The fins support the weight of the frame.
ISO 8624:2020 specifies a measuring system for spectacle frames with fronts that are intended to be symmetrical (Figure no. 2).



CR, CL - right, left boxed centre
1 - plane of the spectacle front
2 - XY plane, perpendicular to plane 1
3R, 3L - right, left vertical centreline
4R, 4L - right, left horizontal centreline
5 - vertical axis of symmetry
6R, 6L - right, left face form angle, measured in plane 2

Figure no. 2. Measuring system for spectacle frames
Source: https://www.iso.org/

Designing and developing custom frames

The design of the spectacle frame can be done in CATIA, SolidWorks or any 3D design software (Figure no. 3). In the version used by us, we started from the design of one of the boxed lens and, using the "Mirror" function, the front part of the frame was created. On the back face in the area of the connecting parts, support brackets were made. Subsequently, the arms were designed according to the chosen size and shape.

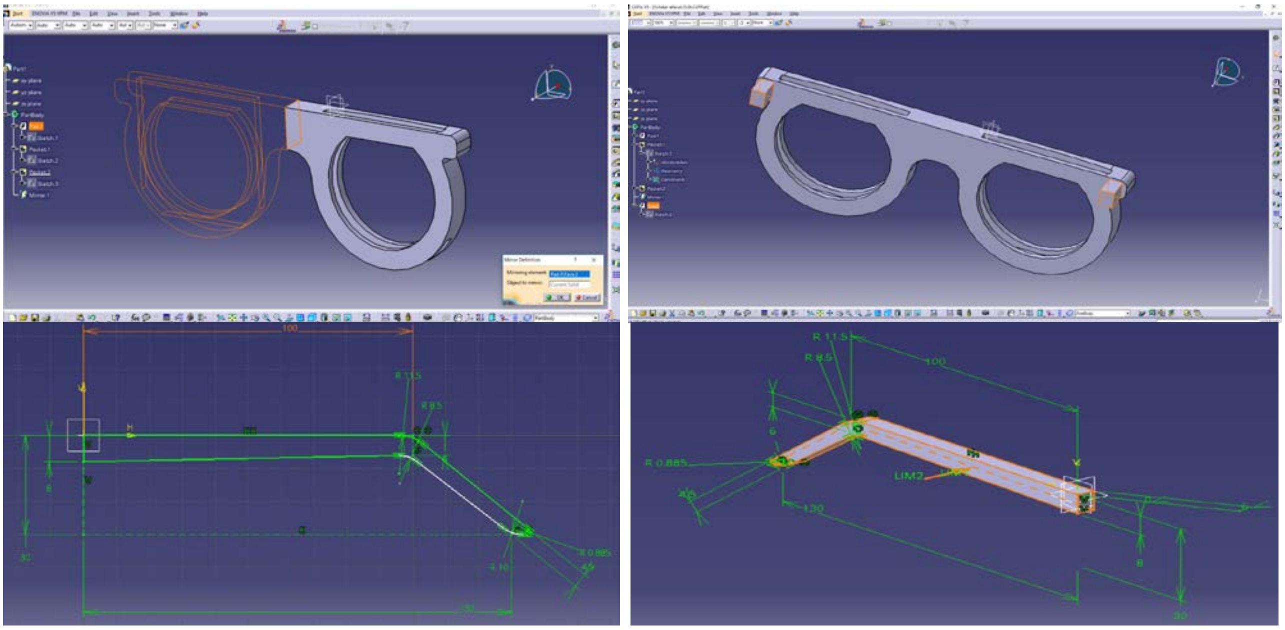


Figure no. 3. CAD models of the frame's parts

Source: Authors' own research.

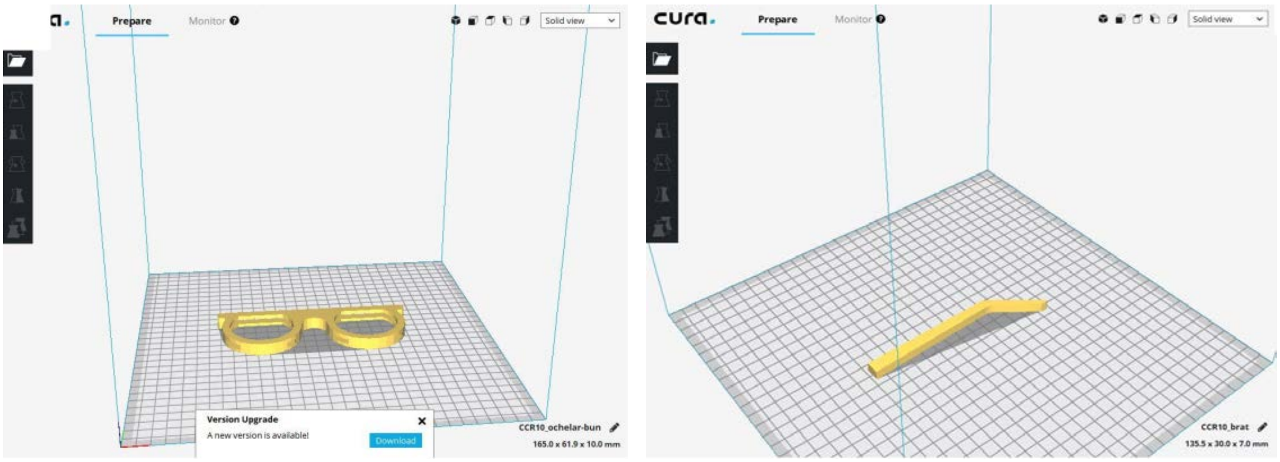


Figure no. 4. Ultimaker Cure 4.3 processes

Source: Authors' own research.

Once the CAD design was done, the project was saved in STL format to be introduced into the Ultimaker Cure 4.3 software, where it was previewed and ready for printing (Figure no. 4). At this stage, the printing area of the part on the work table and the printing material were established. The materials available were PLA and PLC, both leading to very good results.

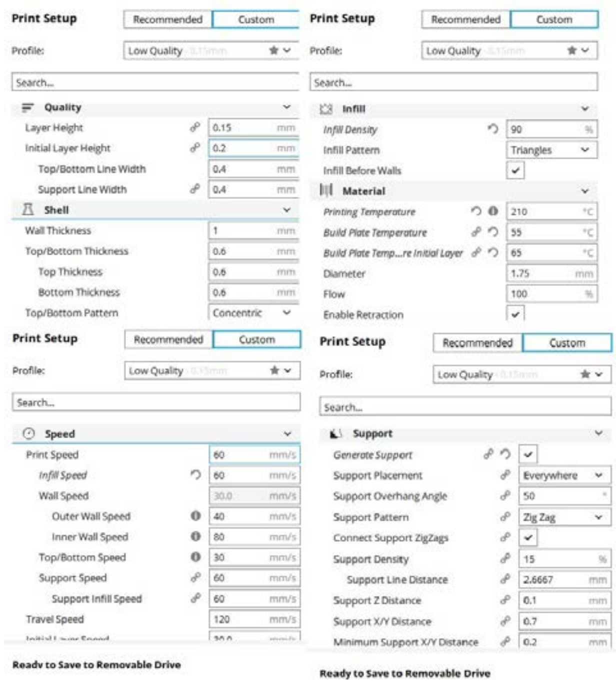


Figure no. 5. Printer settings
Source: Authors' own research.

The actual printing process was done on a Creality CR10 printer with open table, which allows a printing area of 30x30x40 cm (L x W x H).

The materials used for these frames are some biodegradable, namely PLA and ABS with a diameter of 1.75 mm. Thus, a series of special printing settings were used for these materials: 210°C printing temperature, 55-65°C printing table temperature and 60mm / sec printing speed. The size of each layer was set to 0.15 mm, which gives a print resolution and a high quality of the piece. Also, to prevent the workpiece from slipping off the table during the printing process, a substrate set at a much lower quality than the workpiece itself was used.

Once the settings have been made (Figure no. 5), the file must be saved in gcode format, which commands the movement performed by the extruder in coordinates on the three axes (x, y, z).

For the settings presented above, the actual printing time for such a spectacle frame was about 5 hours, the arms being printed in about 40 minutes each, and the front of the frame in about 3 hours (Figure no. 6).

Figure no. 6. Frame parts printing
Source: Authors' own research.

Conclusion

This paper wants to highlight the importance of custom frame 3D printing and their usefulness. It is a cheap and effective technology in many situations. A first category of beneficiaries is those whose asymmetries, deformities or malformations of the head make them unable to use standard frames. These could not ensure the coincidence of the optical centres of the lenses with respect to the ocular pupils or the positioning of the frames by means of the arms on the wearer's head. Also, the standard size of the bridge may not be sufficient in certain features of the nose. In addition, there is a category of people who want to customize the frame of glasses. They want the glasses they wear to be unique and extraordinary. 3D printing technology can meet these special requirements. This technology allows modelling and simulation of frame wear, so that the wearer has the opportunity to make changes before printing the final model. There is a cheap and flexible technology that has proven to be a good option in making custom glasses.

References

Adams, J.W., et al. (2015). “3D printed reproductions of orbital dissections: a novel mode of visualising anatomy for trainees in ophthalmology or optometry”. Br J Ophthalmol; 99: 1162–1167.

Angell, B. et al. (2018). “Ready-made and custom-made eyeglasses in India: a cost-effectiveness analysis of a randomised controlled trial”, BMJ Open Ophthalmology; 3: e000123, doi: 10.1136/bmjophth-2017-000123.

Ayyıldız, Ö. (2018). “Customised spectacles using 3-D printing technology”, Clinical and Experimental Optometry, 101. 10.1111/cxo.12795.

Barbu, D.M. (2003). “Spectacles assembly and adaptation technologies”,Transilvania University of Brasov Publishing House, Romania.

Brooks, C.W., Borish, I.M. (2006). “System for ophthalmic dispensing”, Butterworth-Heinemann,Elsevier Publishing, United Kingdom.

Costan, V.V., Forna, N.C., Ciurcanu, O.E., Sulea, D.,Doscas, A., Surlari, Z., Bosinceanu, D., Beznea, A., Popa, G.V., Fotea, S., Ciofu, M.L., Buduru, S. (2020) Improvements to Biomaterials Structure Used in Acrylic Prostheses, Materiale Plastice, Volume 57, Issue 3, pp. 271-278.

Ekpenyong, B. et al. (2017). “Comparative Analysis of Satisfaction with the Use of Ready-Made Spectacles and Custom-Made Spectacles among School Children in Nigeria: A Randomised Controlled Trial”, Journal of Health, Medicine and Nursing. 35.

Gradinaru, I., Ignat, L., Giurgiu, L., Dascalu, C.G., Hurjui, L.L., Ignat, M.E., Doroftei, F. Surlari, Z., Fotea, S., Gurau, G., Beznea, A., Antohe, M.E., (2020) Study on the Surface Condition of Composite Biomaterials Related to Saliva pH, Materiale Plastice, Volume 57, Issue 3, pp. 174-179.

Ruiters, S. et al. (2016). “Computer-aided design and three-dimensional printing in the manufacturing of an ocular prosthesis”, Br J Ophthalmol; 100: 879–881.