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Visual facial perception of postsurgical cleft lip scarring assessed by laypeople via eye-tracking

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Abstract:

OBJECTIVES: This study aimed to evaluate the visual facial perception in response to scars associated with repaired cleft lip (CL) on a male adolescent model, as assessed by eye-tracking technology.

MATERIAL AND METHODS: Unilateral and bilateral facial images of repaired CL on the upper lip and nasal asymmetry were added to an image of a male adolescent model, using Photoshop CS5 software. 40 laypeople eye movements were tracked by an infrared sensor of the Eye Tribe hardware in conjunction with OGAMA software. An analysis of variance was used to identify differences in total fixation time for the added areas of interest. A visual analog scale of attractiveness with a questionnaire were also incorporated into the study. Statistical analysis was performed using a significance level of $P < 0.05$.

RESULTS: Significant differences were noted between the image with no scar and the image featuring a unilateral scar for total fixation time associated with the right eye ($p = 0.002$) and right nose area ($p = 0.003$), in addition to the numbers of fixations for the right eye ($p = 0.005$) and right nose area ($p = 0.007$). Comparing the image with no scar with the image featuring a bilateral scar showed a significant difference only for the number of fixations on the right eye ($p = 0.005$). The heatmaps and fixation point maps for both the unilateral and bilateral scar images indicated increased fixation for the scar areas. For the image with no scar, increased fixation was captured for the right eye area. Pearson's correlation coefficient test showed a moderate positive ($p = 0.692$) relationship when comparing to unilateral and bilateral cleft scars.

CONCLUSIONS: The participating laypeople perceived the cleft-repaired faces and did not perceive any difference in attractiveness between the images featuring the unilateral and bilateral postsurgical clefts and lip scarring.

Keywords:

Cleft lip and palate, cleft lip scarring, esthetics, eye-tracking, perception

Introduction

Cleft lip (CL), either with or without the involvement of a cleft palate, is the most common congenital malformation of the head and the third-most common birth defect.[1,2] CL is approximately twice as common in men,[3] and a higher prevalence of CL has been identified on the left side of the face.[4]

The clinical management of CL represents a continuous and unique challenge in the field of maxillofacial plastic surgery, which aims to repair CL and achieve a normal facial appearance and allow for normal feeding, phonation, and hearing abilities,

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without significantly affecting the child's final facial and psychosocial development.[2]

Children with cleft lip and palate (CLP) are often rejected by their peers, and any reference to the cleft during casual social gatherings can result in anxiety, anger, shame, and anguish.[5] Primary-school-aged children with CL often display shaky self-esteems, perceive themselves as being less-accepted by peers, and become sadder and more irritated than children with no cleft deficits.[6]

The facial appearances of patients with unilateral CLP can be seriously affected at two very important facial areas: the nose and the mouth. Even in situations in which a cleft repair can be completed during early childhood and is accompanied by interdisciplinary therapeutic rehabilitation, a residual scar on the upper lip and nose asymmetry often remains into adulthood.[7]

Hunt *et al*.[8] described the social consequences of facial asymmetries, suggesting that patients with CLP are socially disadvantaged, and the appearances of patients with unilateral CLP may be seriously affected in the nose and mouth areas.[7]

Facial symmetry has been strongly associated with attractiveness, and asymmetries in the esthetic facial subunits, such as those that occur in the nose and upper lip of CL patients and those observed for the lower third of the face in patients with Class III malocclusions, can negatively impact perceptions of the entire face.[9]

Shaw[10] was a pioneer in describing the effects of dental esthetic changes and their effects on how individuals are perceived. Although considerable evidence has suggested that individuals with CLP suffer from psychosocial consequences associated with their facial appearances, despite advanced cosmetic surgery,[11] data are lacking regarding how their faces are perceived by others and the eye movements made by individuals of different age groups when viewing the CLP faces.

Eye-tracking studies have been used to explore the need for orthodontic treatments and to assess treatment results from a lay perspective, and eye-tracking technology represents a new diagnostic tool, as an alternative to traditional assessments based on static photographs.[12]

Therefore, this study aimed to evaluate the visual perceptions and attractiveness assessments made by laypeople by utilizing eye-tracking technology and VAS in response to the presentation of images of an adolescent male model featuring unilateral CL, bilateral CL, postsurgical cleft with lip scarring, and no scar, as a positive control.

Materials and Methods

This study was approved by the ethics committee (No. 3,729,413) of the (name is omitted).

Data preparation

The image bank consisted of photographs taken with a digital camera (Rebel XTI; Canon, Tokyo, Japan). Images were standardized, featuring frontal facial photos in the portrait direction, with the head oriented with the Frankfurt plane, parallel to the ground, without lateral inclination or rotation.

The photos were calibrated using the ruler and protractor tools, linking height, width, and resolution. This effectively transformed pixels into centimeters, ensuring that the changes were made at real sizes and proportions, using a simple 3 rule in Photoshop CS5® software (Adobe®, San Jose, CA). Any existing imperfections on the face that could distract the viewer's attention and any other features that could attract the viewer's focus away from the study objective were removed (props, skin blemishes, facial tattoo, extreme facial hair or exotic hairstyle, asymmetry, or abnormal piercing). Initially, the left hemi-face was mirrored to generate a symmetrical face [Figure 1], and unilateral and bilateral cutaneous scars were digitally inserted on the upper lip, associated with the nasal asymmetry [Figure 1b].

Participants

Forty participants (60% women, n = 24; and 40% men, n = 16), between the ages of 18 and 45 years (mean age of 35.14 years) were invited to participate while shopping at two different clothing stores located in a countryside city in the state of (omitted), with no limits placed on educational history or profession. To measure differences between observers, Student's t-test was performed to compare the responses between the two sexes, and no significant differences were found.

Participation was voluntary, and participants signed informed consent. The observers did not present any neurological alterations, were not on medication

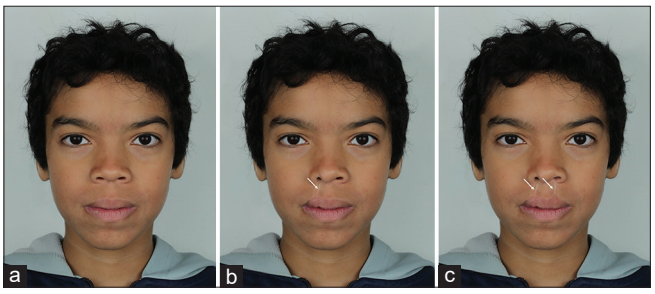

Figure 1: Front photographs. (a) Without scar. (b) Unilateral scar. (c) Bilateral scars (arrows)

associated with the interference of cognitive skills, had good vision, and the use of glasses was recommended, when necessary.

Each study image was presented to the observers on a 15-inch Dell P23 17 monitor for 7 sec in the vertical position, and images were presented at random, with a green slide inserted between each image, to minimize fatigue No specific instructions were given to the observers; they were simply asked to freely view the images. The eye tracking system (The EyeTribe) which captures infrared light reflected off the cornea with a binocular data tracking rate of 30 Hz, in conjunction with Ogama software.

For data collection with Ogama software, 5 areas of interest (AOIs) were delimited: 1, the right eye; 2, the left eye; 3, the right nose area; 4, the left nose area; and 5, the lower third of the face [Figure 2]. The heatmaps, fixation point maps, total fixation time, and direction transition values were all generated automatically.

The system was calibrated on a per subject basis at the beginning of the experiment. The eye tracking procedure started with a calibration/validation sequence in which participants were asked to follow a dot presented randomly at nine different locations on the screen. The participants were allowed to start the experiment when the software considered the results of the calibration to be "perfect."

Visual analog scale

Afterward, the VAS was administered applied as printed form who was allowed allowing to view the full-sized view of images, which were arranged in an album in the same order they were presented. The rater was then asked to score the perceived the attractiveness of each image. The VAS scores using the visual analogic SCALE ranged from 0 to 10, with 0 representing less attractive and 10 representing more attractive images.

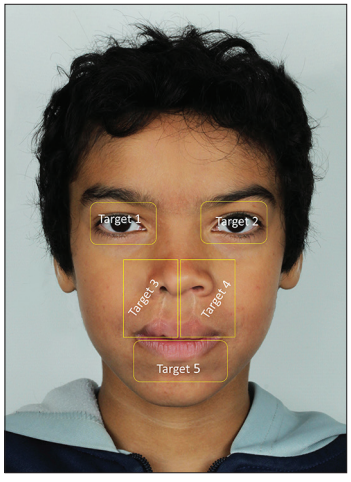

Figure 2: Areas of interest. Eyes, nose/upper lip, and lower lip

Statistical analysis

The results obtained from the eye-tracking experiment were tabulated in Microsoft Excel (Microsoft, Redmond, WA), before being exported to and analyzed by SPSS software, version 25 (SPSS Inc., Chicago, IL). The independent variable was the class of observers, and the dependent variables analyzed included the time to the first fixation, the number of fixations, and the total fixation time.

A one-way analysis of variance (ANOVA) was performed to identify differences in the mean values of the dependent variables among the presented images. The Levene homogeneity test of variance was performed. When heterogeneous variations were identified, comparisons were performed using the Games-Howell test ($p < 0.05$), and Tukey's honest significant difference (HSD) test was performed when homogeneous variations were assumed ($p > 0.05$). The level of significance adopted for this study was 0.05.

Pearson correlation test was carried between the VAS grades and raters population to find how the attractiveness correlate with the repaired CL scars.

Results

The eye-tracking experiment generated results in the form of descriptive statistics, heatmaps, fixation point maps, the total fixation time, and directional transition values.

Heatmaps analyzed the average visualization for certain areas of each image, and their representations are color-coded, on a scale ranging from cold colors (green) to warm colors (red), where Warmer colors indicate that more fixations occurred at this point. As the visualization of an area increases, warmer colors are used to represent the area [Figures 3a and 4a]. For the fixation point maps, the analyses were generated based on the eye-tracking order of the observers. When a specific AOI was identified by visualization, a point was registered on the fixation point map, until the eye-tracking period was completed [Figures 3b and 4b].

The total fixation time [Figure 5] was the sum of the total time and fixation numbers for all observers, which were represented by bubbles in the 2.00 proportion. The directions of transition values refer to the most common visualization pattern, from fixation in a given AOI to the next area of fixation, described as a percent.

The analysis indicated that significant differences among the images were only identified for total fixation time between the image without cleft-associated deficits and the image with a unilateral cleft-associated scar, for the total fixation times for the right eye ($p = 0.002$) and the nose and mouth area ($p = 0.003$) and the number of

fixations in the nose and mouth area (p = 0.007). However, the right eye AOI also showed significant differences when comparing the unilateral and bilateral cleft images with the image without cleft (p = 0.005, Table 1).

However, despite not displaying significant differences, shorter times until the first fixation were recorded for areas where the scar was present, suggesting that these areas represented the first areas of fixation by observers.

The heatmap and fixation point map for the image without a scar indicated a more reddish color, with a higher density of fixations observed the area of the right eye and a low density of points in the area of the upper lip, with the slight dispersion of fixations for the other areas of the face. [Figure 3a]. The fixation point map showed that although fixations were diversified across all AOIs, fixations were concentrated on the right eye and lip, confirming the heat maps [Figure 3b and c].

For the images with unilateral and bilateral scars, both the heatmaps [Figure 4a] and the fixation point maps [Figure 4b], which represented the average fixations among all observers, significant fixations were concentrated on the scars. In the heatmap for the image with a bilateral fissure, a higher concentration of fixations was observed in the region of the lip philtrum, as attention was divided between the two scars. For the unilateral image, a more reddish color was found above the scar area in the heatmap. On the fixation point maps, for images with both a unilateral scar and a bilateral scar, high point densities were observed for the upper lip, especially in the areas of the scars, the tracking occurred less frequently and less densely for either eye [Figure 4b and c].

The high degree of fixation in the regions containing the scars can be observed in the images showing total fixation time [Figure 5] and in the directions of transition [Figure 6]. For the image without a scar, a more equal distribution of time and transition values can be observed for all AOIs. In contrast, for images with scars, the uneven distribution of fixation time and the number of fixations can be observed for the nose and mouth AOIs compared with the other AOIs. Despite a less unequal division, the AOI with a scar on the right side drew more attention from observers in the scarred image showing bilateral scars than the scar on the left side.

The visualization pattern [Figure 6] varied for each image, as the directional transition values indicate which AOI was registered by the next visualization by the highest percentage of individuals after the visualization of any given AOI. For the image without a scar, higher values were found for transitions to the eye regions. In the image with a unilateral scar, the largest direction moves toward the area of the right nose, where the scar was located. In the analysis of the image with the bilateral scars, the greatest concentration of variation occurred between the right and left nose AOIs, where the two scars were located. These findings indicated that the attention of laypeople tends to be directed towards the scar.

The VAS results showed the image without scar scored higher attractiveness grades (mean 9.10) when comparing to unilateral (mean 7.21) and bilateral cleft scars (mean 6.43) in the laypeople × s perception. Pearson correlation test showed a moderate positive relationship [p = 0.692, Table 2].

Discussion

The present study evaluated the visual facial perceptions of scars resulting from unilateral and bilateral CL surgical procedures, and the analysis of the obtained data was relevant. Even with advances in surgical techniques and interdisciplinary care, residual scars due to bilateral CL repair could be perceived by adult lay individuals.

Cleft and lip is commonly corrected by surgical interventions, to allow normal phonation, psychosocial adjustment, and facial attractiveness. However, even with the application of various modern treatment strategies and techniques designed to improve the function and esthetics, the further minimization of the impacts of scars that result from surgical interventions remains a goal of the field.[13]

Clinicians must critically re-evaluate the results of reparative interceptions, even small residual

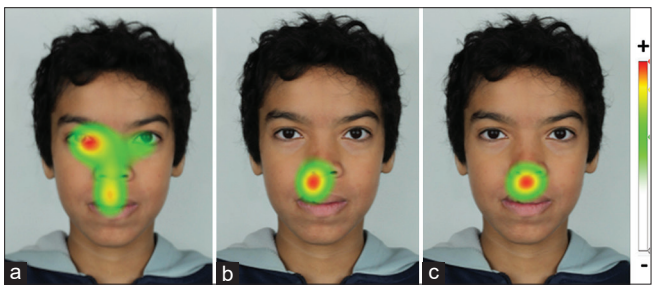

Figure 3: Color-coded, on a scale scanpath. Warmer colors indicate that more fixations occurred at this point. (a) Without scar. (b) Unilateral scar. (c) Bilateral scars

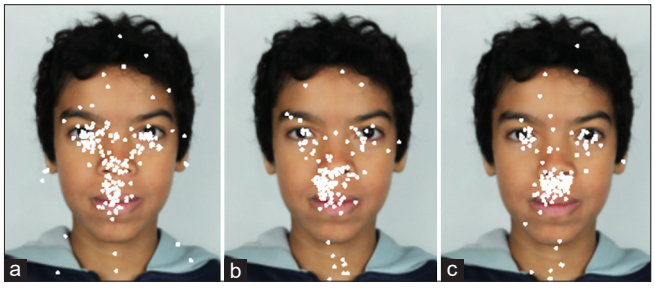

Figure 4: Fixation point maps. (a) Without scar. (b) Unilateral scar. (c) Bilateral scars

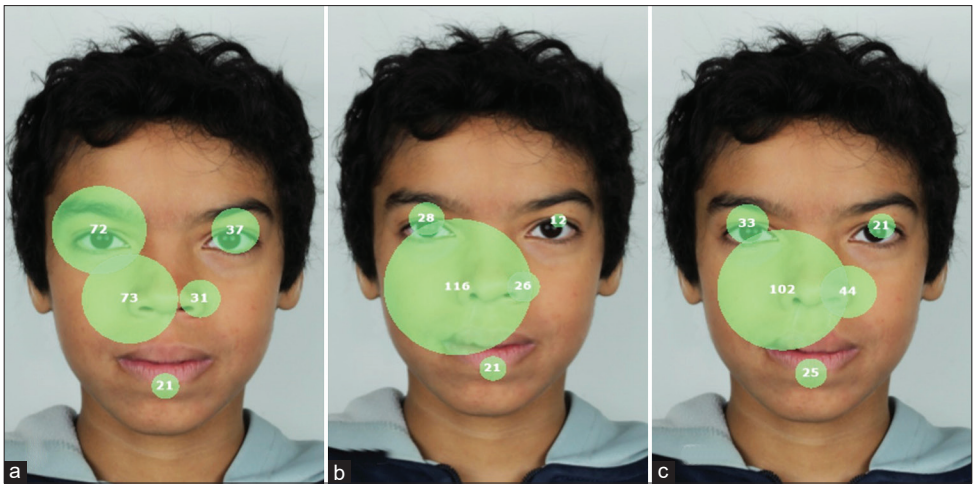

Figure 5: Total fixation time. (a) Without scar. (b) Unilateral scar. (c) Bilateral scars

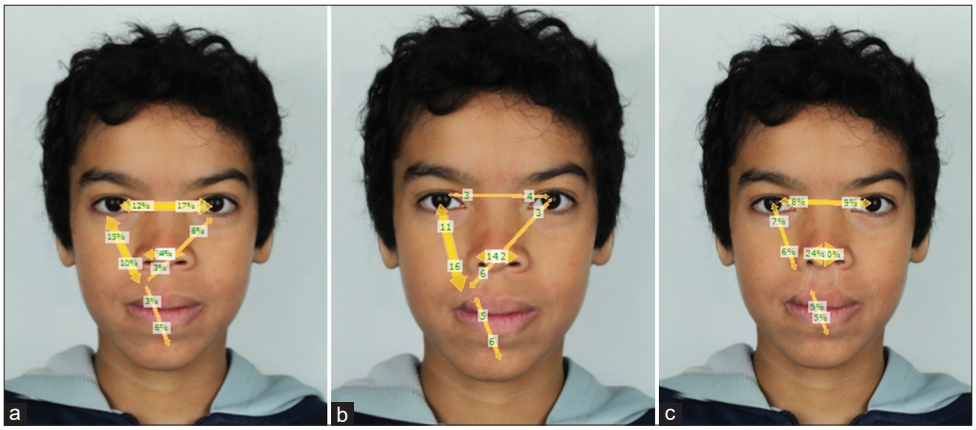

Figure 6: Directions of transition for the most common visualization patterns. (a) Without scar. (b) Unilateral scar. (c) Bilateral scars

Table 1: Comparison between the images using ANOVA

Variables	Mean (±SD)			*P*
	Without scar	Unilateral Cleft	Bilateral Cleft	
Time until first fixation at right eye (ms)	1555.27 (±1670.17)	1938.63 (±1999.10)	2677.90 (±1759.92)	0.117
Time until first fixation at left eye (ms)	3340.13 (±1662.99)	4007.00 (±884,59)	4951.71 (±1741,15)	0.131
Time until first fixation at right nose rectangle (ms)	1134.61 (±1378.19)	1099.13 (±1631.48)	1141.88 (±1503.02)	0.993
Time until first fixation at left nose rectangle (ms)	1447.59 (±2103.41)	3066.71 (±2473.87)	1818.86 (±1375.87)	0.064
Time until first fixation at lower third of face (ms)	3592.57 (±2066.61)	3649.92 (±2356.49)	2776.64 (±2222.63)	0.574
Complete fixation time at right eye (ms)	1194.23 (±921.29)[a]	440.11 (±291.93)[a]	747.20 (±614.29)	0.002*
Complete fixation time at left eye (ms)	1006.45 (±1362.81)	455.00 (±244.26)	524.00 (±339.27)	0.187
Complete fixation time at right nose rectangle (ms)	1199.94 (±1069.51)[a]	2390.38 (±1590.38)[a]	1873.62 (±1349.71)	0.003*
Complete fixation time at left nose rectangle (ms)	595.41 (±460.98)	794.43 (±832.86)	974.87 (±638.88)	0.196
Complete fixation time at lower third of face (ms)	487.64 (±293.95)	860.58 (±985.68)	910.73 (±826.93)	0.256
Number of fixations at right eye	2.88 (±2.00)[ab]	1.53 (±0,90)[a]	1.70 (±1.03) b	0.005*
Number of fixations at left eye	1.77 (±0.86)	1.33 (±0.50)	1.28 (±0.46)	0.061
Number of fixations at right nose rectangle	2.24 (±1.30)[a]	3.72 (±2.23)[a]	3.25 ((±2.03)	0.007*
Number of fixations at left nose rectangle	1.82 (±1.13)	1.86 (±1.02)	2.00 (±1.08)	0.862
Number of fixations at lower third of face	1.50 (±0.94)	1.75 (±1.13)	2.27 (±1.79)	0.345

Participants: 40 laypeople, *Statistical Difference *P*<0,05

asymmetries, and the patient's desire to eliminate any remaining scars must be considered.[11] Individuals with CLP did not settle in areas of interest more often or for longer than other participants. In addition, the area of the upper lip in images with bilateral CLP drew more voluntarily and involuntarily attention than the same region in images of unilateral CLP or control images,[14] similar to the results found in the current study.

Table 2: VAS grade

	VAS (Grade) Mean (±SD)	Pearson correlation
Withou Cleft	6.43 (±1.299)	*0.692
Unilateral Cleft	7.21 (±1.151)	
Bilateral Cleft	9.10 (±0.900)	

Participants: 40 laypeople

The upper lip captured more attention during smiles when images with unilateral CLP were viewed, and more fixations were counted in the nose area for images of bilateral CLP, but similar numbers of fixations were recorded between unilateral cleft and control images.[14] In the present study, only laypeople were evaluated, and the image of bilateral CLP was primordial and strongly captured.

The results reported by Meyer-Marcotty *et al*.[7] showed more fixations in the nose area for images of bilateral CLP, whereas similar numbers of fixations were recorded between unilateral and control CLP images. They also observed that the nose was fixated on for longer periods of time in patients with repaired unilateral CLP than in controls, due to deviations of the nose relative to the midline. Although nasal asymmetry is much more evident in patients with unilateral CLP before the primary surgery, obtaining ideal nasal anatomy in patients with bilateral CLP after surgery can be difficult.[15] In the present study, the nose area, although captured by perception, was secondary to the areas of the lips and eyes in images without fissures.

Our results also revealed that the observers fixed their attention more frequently on the upper lip than on the eyes, in bilateral CLP, when shown faces at rest. For Dindaroglu *et al*.[14] observers with unilateral and bilateral CLP fixed more on the upper lip area than on the eyes in an individual with CLP. More fixations and faster times to the first fixation, which were observed for images of smiling faces with unilateral CLP, may be due to midline deviations, compared with control images and smiling faces with bilateral CLP.[14]

Observers with CLP and observers without CLP viewed the faces of individuals with unilateral CLP differently, unlike how they viewed unaffected faces. Observers' eye fixations were more frequently drawn to the nose and mouth areas of faces with unilateral CLP, and observers with unilateral CLP focused more attention on different details than observers without CLP. When individuals with unilateral CLP viewed the faces of patients with and without unilateral CLP, they fixated on the nose for long periods of time and only spent a short period focused on the eyes.[7] In the present study, the nose was in a secondary plane.

The perceptions of laypeople observers were better when evaluating images of a teenager with CLP after orthognathic surgery and mentoring, followed by definitive nasal reconstruction compared to the condition before surgery.[16] However, when only the facial attractiveness of the nasolabial area of children treated for unilateral CLP was analyzed and in the images of complete faces the camouflaged facial image in the nose area for the evaluation of the nasolabial appearance with CLP seems to be unnecessary,[17] as applied in the present study.

CL had the most compromising effects on the quality of life, and males were more susceptible to the esthetic implications associated with CLP.[18] This result can be compared with those of the present study, in which images without scars were more likely to draw the attention of the observer to the eyes, instead of the upper lip.[18] This result can be compared with those of the present study in images without scarring, in which the capture was in the eye area and not in the upper lip.

The facial perceptions of adult medical school students, assessed by eye-tracking technology, in babies with CLP differed from perceptions of unaffected controls, regardless of whether the babies were using a naso-alveolar esthetic device.[19] However, the participants' involvement in the medical field and may have biased the results of this previous study, whereas, in the present study, observers were laypeople who were unfamiliar with CLP.

Eye-tracking technology has allowed for the assessment of human reactions to the presence of facial deformities,[20] and in the present study, it constitutes an important tool for investigating the perceptions of laypeople in response to images with scars, contributing to our understanding of involuntary perceptions. The finding that abnormal-looking faces attract our involuntary attention is not surprising, as similar findings have been reported in other studies,[21,22] with the observers have placed most of their attention on internal facial features, such as the eyes, nose, and mouth,[23] which converges with the present study whereas a triangular path pattern in heatmaps may be seen mostly in the image without scar.

One condition to be considered it that since the nose and lip was evaluated as a whole unit, eye fixation in this region may be mainly caused by nasal or lip deformity instead of the thin flat cutaneous scar, but the results of this study by using the eye-tracking can contribute to our understanding of the daily lives of individuals with repaired CL scars, based on the perceptions of laypeople, in a real context.

Despite the encouraging results, one limitation of this study was the relatively small number of observers,

who represented adults and residents from the same community. The ratings of these observers may reflect local esthetic preferences and may not be generalizable to other populations, even though the observers were not advised of the objectives underlying their evaluations.

Conclusions

The participating laypeople perceived the cleft-repaired faces and did not perceive any difference in attractiveness between the images featuring the unilateral and bilateral postsurgical clefts and lip scarring.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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