Dynamometric Analysis of Normative Auricular Stiffness and Comparison With Operated Prominent Ears

Orhan Ozturan, MD, Remzi Dogan, MD, Berke Ozucer, MD, Yavuz Selim Yildirim, MD, and Aysenur Meric, MD

Aim: Stiffness of the auricular cartilage is the main determining factor for the choice of operative technique of the prominent ear deformity. The aim of this study is to evaluate the stiffness of normal appearing ears objectively and quantitatively, compare the results with the operated prominent ear patients, and present prospective short-term dynamometric evaluation of the operated prominent ear patients.

Patients and Methods: A total of 190 volunteers without ear deformities were recruited and 9 age groups were formed: group (5–9), group (10–14), group (15–19), group (20–24), group (25–29), group (30–34), group (35–39), group (40–49), and group (50+). Total 28 ears (14 patients) with otoplasty were included in the study as group (operated 5–9) and group (operated 10–14). In addition, 3 patients with prominent ear deformity were prospectively followed for dynamometric changes that occur with otoplasty operation. The auriculocephalic angle (ACA) was measured once and auricle to scalp distance was measured at 4 different standardized levels. Ear stiffness was measured on each ear individually at 4 different points over the antihelix using digital computer-aided dynamometry. Each ear was compared in terms of ACA, distance, and dynamometric values.

Findings: Dynamometric values tend to increase with age, which increase and peak around 35 years of age and declines after 40 years of age. Measurements of the first 2 age groups were statistically different compared with the other groups. Postoperative dynamometric measurements (DNM) of group (operated 5–9) were similar with normative values of group (5–9) and postoperative satisfaction visual analogue scale (VAS) score was 92.8%. Postoperative DNM of group (operated 10–14) were higher compared with normative values of group (10–14) for each different measuring level and the postoperative satisfaction VAS score was 75.3. A total of 3 patients with prominent ears had lower dynamometric values preoperatively; these values approached closer to normative values of their age group postoperatively.

Conclusions: Results show that auricular cartilage stiffens and malleability decreases with increased age. This stiffness peaks in the 35–39 age group and declines after 40 years of age. Dynamometric values increase, at all levels, suggesting increased cartilage stiffness is related to age. In the scope of these results, cartilage sparing techniques are more suitable for 5 to 14 years of age and cartilage-cutting techniques are more suitable for older patients.

Key Words: Auriculocephalic angle, auriculocephalic distance, otoplasty, prominent ear, recurrence, stiffness

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From the Department of Otorhinolaryngology, Medical Faculty, Bezmialem Vakif University, Fatih, Istanbul, Turkey.

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Address correspondence and reprint requests to Berke Ozucer, MD, Bezmialem Vakif University, Medical Faculty, Department of Otorhinolaryngology, Fatih, Istanbul, Turkey;
E-mail: berkeozucer@gmail.com

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Prominent ear is a common congenital deformity with an incidence of 1% of the population.[1] More than 200 operative techniques have been described for correction of prominent ear deformity.[2] All techniques have drawbacks and shortcomings; therefore, newer techniques and modifications continue to be developed.[3] At the time of this writing, otoplasty surgery uses either cartilage-cutting, cartilage-sparing or minimal invasive techniques, or combinations of them according to the stiffness of the cartilage to achieve natural and symmetrical-looking ears.[1] The aim of all the techniques is to reduce the stiffness of the ear caused mainly by the fibroelastic cartilage.[4,5] The major problem associated with otoplasty is recurrence of the deformity,[4] because sutures tend to untie or slip at high-tension sites.[6] Strong-cartilage sites require scoring and cartilage-cutting techniques for emasculation of the cartilage memory and to obtain permanent results.[7] Therefore, cartilage stiffness is one of the main determining factors on choice of operative technique. Preoperative planning and analysis of ear deformities are crucial for long-term satisfactory results.[1,8,9]

Assessment of auricular cartilage stiffness has been performed with tactile examination and with cotton applicators.[10] The auricle is full of twist and turns, stiffness varies, and subjective assessment may mislead and yield increased rates of recurrence. No information in the literature regarding deals with objective assessment of stiffness of the auricular cartilage.

The dynamometer (force meter) is a device used to measure applied force to push or pull a mass. The aim of this study is to objectively and quantitatively evaluate the stiffness of normal-appearing ears, compare the results with the operated prominent ear patients and present 3 patients with prospective short-term dynamometric evaluation of operated prominent ears.

MATERIALS AND METHODS

The current study was performed at Bezmialem Vakif University, Medical Faculty, Department of Otorhinolaryngology. All participants were tested with the dynamometer with the approval of University Ethics Committee and in accordance with the guidelines of the National Health and Medical Research. All volunteers were provided with information about the procedures and each gave written informed consents before study. Volunteers younger than 5 years and older than 60 years of age were not included in the study. Ear examination was carried out individually for each volunteer: presence of congenital or acquired auricular pathologies was among criteria of exclusion.

Patient Groups

This study consists of 3 groups of data: normal patients without ear deformity—recruited into the study were 190 ears (91 women, 99 men) of volunteers qualifying normal measurements without deformities. Total 9 groups were formed according to their ages and operative history: group (5–9), group (10–14), group (15–19), group (20–24), group (25–29), group (30–34), group (35–39), group (40–49), and group (50+); ears undergone otoplasty operation evaluated retrospectively—patients who have undergone otoplasty operation at least 6 months ago were included in the study as group (operated 5–9) and group (operated 10–14); ears with prominent ear deformity followed prospectively—3 patients (6, 12, and 15 years old) with prominent ears were preoperatively evaluated and compared with normative measurements of group (5–9), (10–14), and (15–19), respectively. These patients were prospectively followed for 3 months after otoplasty operation.

Measurements

Auriculocephalic Angle

The auriculocephalic angle (ACA) of all volunteers was measured to the nearest degree (°). Ears that were within normal limits were included in the study and otherwise it was a criterion for exclusion from the study.[11]

Auriculocephalic Distance

Each patient was also evaluated via auriculocephalic distance (ACD) at 4 previously defined reference points:[6] Level 1 (the most superior point on the auricle), level 2 (the point of insertion of the helix crus to the scalp), level 3 (the most superior point of the tragus), and level 4 (the level of the antitragus).[11] All distances were measured with a ruler to the nearest millimeter.

Dynamometric Measurement

Each ear was marked with a surgical marker and each volunteer was laid in a supine position. Measurements were conducted with a computerized Sundoo SH-10 digital dynamometer (Wenzhou Sundoo Instruments Co. Wenzhou, China) assembled with Sundoo SPJ Stand (Fig. 1). Dynamometer used in this study measured the amount of force required (in millinewtons) to compress/move the ear 2 mL and force exerted was measured with 5 mN of accuracy (±5 mN margin of error). Measurements were analyzed with the SH Test Version V1.01 (Wenzhou Sundoo Instruments Co.) software program (Fig. 2).

Ear stiffness was measured on each ear individually at 4 different levels of antihelix by means of digital computer-aided dynamometry. These points were located at the antihelix superior crus level, crus helix level, tragus level, and antitragus level. Each measurement was repeated 3 times, averaged and recorded in millinewtons (mN) (Fig. 2).

Visual Analogue Scale

Parent satisfaction was assessed for group (operated 5–9) and (operated 10–14) at the sixth postoperative month via visual analogue scale (VAS). Parent satisfaction was assessed with a 100-mm VAS (0 = worst, 100 = best). Ears were evaluated using a horizontal 100-mm VAS marked as "worst possible result" at the left end and "best possible result" at the right end. The scale was unmarked except for the 2 verbal anchors at each of its ends. The parent was asked to make a "X" mark along the horizontal scale that indicated the overall aesthetic appearance of the ear. Numeric scores were then obtained by measuring the horizontal distance from the left end of the scale to the marking and rounded to the nearest millimeter.

FIGURE 1. Dynamometry measurement points over the antihelix.

FINDINGS

Auriculocephalic distance of all volunteers was within normal limits at 4 levels (8–10 mm, 10–12 mm, 16–18 mm, and 20–22 mm, respectively).[11–13] The ACA of all volunteers was similar and within normal limits (21–30°) ($P = 0.303$).[12,13] Range of mean ACA of all normative age groups was within 20.7 to 21.5°. The mean age of the women was similar to the mean age of the men ($P = 0.377$). Dynamometric measurements (DNM) of women were similar with DNM of men ($P = 0.081$).

Mean ACD and DNM were calculated for each group and each reference point. These findings were graphically compared and represented in detail in Figure 3A and B, respectively.

Level 1 measurements yielded the lowest DNM values, whereas level 2 had the highest DNM values. Measurements of levels 3 and

FIGURE 2. Sundoo SH-10 Digital Dynamometer assembled to Sundoo SPJ stand.

4 were between these 2 levels for all age groups (Figs. 3-4). Dynamometric measurements of the first 2 age groups were statistically different compared with the other groups. Dynamometric measurements values tend to increase with age and this increase peaks around 35 years of age and declines after 40 years of age. Measurements of the first 2 age groups are statistically different compared with the older age groups (Fig. 3B).

Measurements of groups (5–9) and (10–14) were compared with postoperative values of groups (operated 5–9) and (operated 10–14), respectively (Fig. 5). Postoperative measurements (ACD and DNM) of group (operated 5–9) (8 patients) were similar with normative values of the similar age group (5–9) for each different measuring level (Fig. 5). The postoperative satisfaction VAS score was 92.8%. Postoperative ACD measurements of group (operated 10–14) (6 patients) were slightly higher compared with normative values of the similar age group (10–14) (Fig. 5A). Dynamometric measurements measurement also revealed significant difference in DNM-4 (Fig. 5B). Postoperative satisfaction VAS score was 75.3.

Preoperative DNM of all 3 patients with prominent ears were lower compared with their age groups (Fig. 6). Following otoplasty operation, ACD as well as the DNM approached to "normative" values. Dynamometric measurements and ACD measurements are graphically represented in Figure 6.

DISCUSSION

Patient dissatisfaction because of recurrences and residual deformity is a common result of otoplasty.[10] Studies have shown that recurrences are related to inadequate surgical planning and to poor choice of operative technique.[13] Objective and quantitative evaluation of auricular cartilage rigidity/stiffness can guide the surgeon in his choice of operative technique and lead to permanent and successful results.

Although quantitative and objective evaluation of nasal deformities before rhinoplasty have been used to aid surgical planning,[14–16] a Pubmed search with "otoplasty, ear, stiffness, rigidity, elasticity, resistance" individual and combined keywords yielded no results. Evidently, this is the first study in the English language literature evaluating auricular stiffness/rigidity quantitatively. Auricular stiffness is lowest in the age 5 to 9 group, increases with age, and peaks in the 35 to 39 age group. Stiffness declines after 40 years. At all levels, rigidity increases with age suggesting that cartilage elasticity and malleability is related to histologic changes of the cartilage that occurs with age.

Dynamometric measurements of the 20 to 39 age groups resulted in higher rigidity scores compared with those of the younger age groups. In light of these results, in these age groups, cartilage-cutting techniques can be preferred for more satisfactory and permanent results. These individuals had similar DNM values at every measurement level. Similar surgical techniques can be used for this age group.

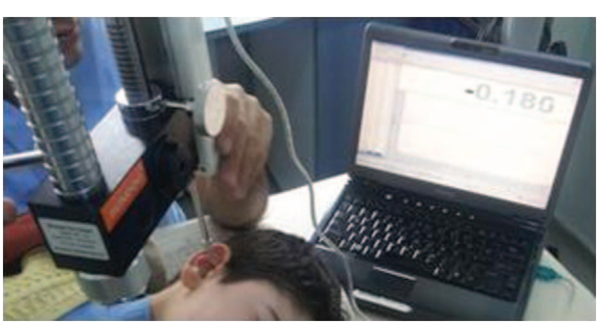

FIGURE 3. Digital computerized dynamometric evaluation (miliNewtons).

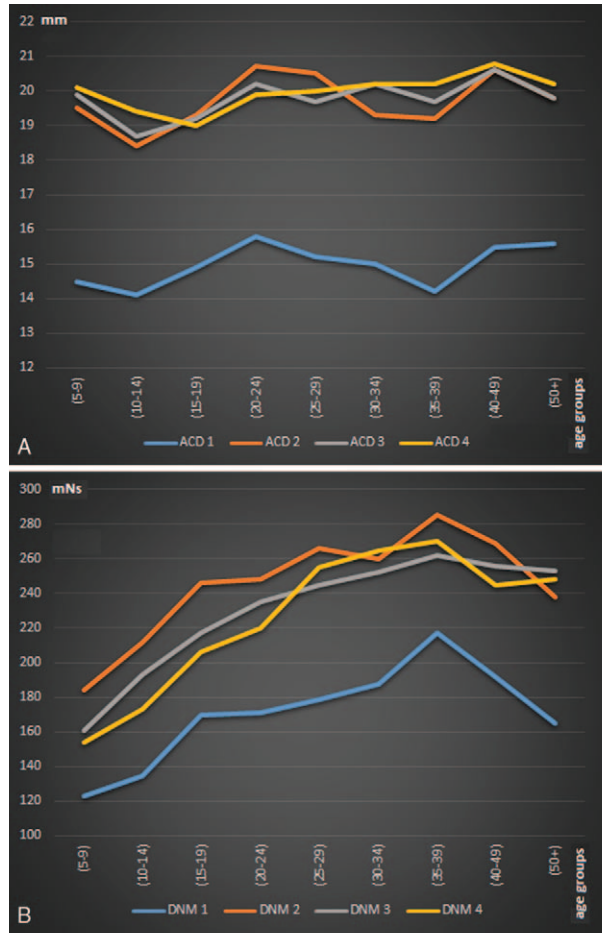

FIGURE 4. Data of normative ears. A, Auriculocephalic distance of normative ears. ACD (1) the most superior point on the auricle, (2) the point of insertion of the helix crus to the scalp, (3) the most superior point of the tragus, and (4) the level of the antitragus) axis (age groups). B, Dynamometric measurements of normative ears. Mm, millimeters; ACD, auriculocephalic distance; DNM, dynamometry (mN) (superior crus level, crus helix level, tragus level, and antitragus level).

Although in the 40+ age group, DNMs are lower compared with 20 to 39 age groups, difference is not significant. Dynamometric measurements of 40+ are significantly higher compared with groups 1 and 2; therefore, cartilage-cutting techniques are more appropriate. These strategies may vary for each patient individually, but DNM can guide operational strategy for successful results.

Dynamometric measurements of group (operated 5–9) are very similar to their representative normative age group (5–9), whereas group (operated 10–14) DNMs are slightly higher than group (10–14) (Fig. 5). Auriculocephalic distance of group (operated 10–14), although within normal range, are slightly higher compared with normative group, hence the parent VAS satisfaction was lower compared with group 1 (operated). This difference reflected to the DNMs as well as the VAS score. Auricular stiffness is maximum at level 2, where the antihelical crura congregate to form a protrusion superior to cymba conchae (Fig. 3B). Auricular stiffness is minimum at level 1 for all age groups, which suggests suture techniques will be adequate for correction of deformity at this level. Although the auricle can be medialized with minimal resistance, postoperative recurrences are most commonly seen at this level.[13] This unexpected localization of recurrence most probably arises as

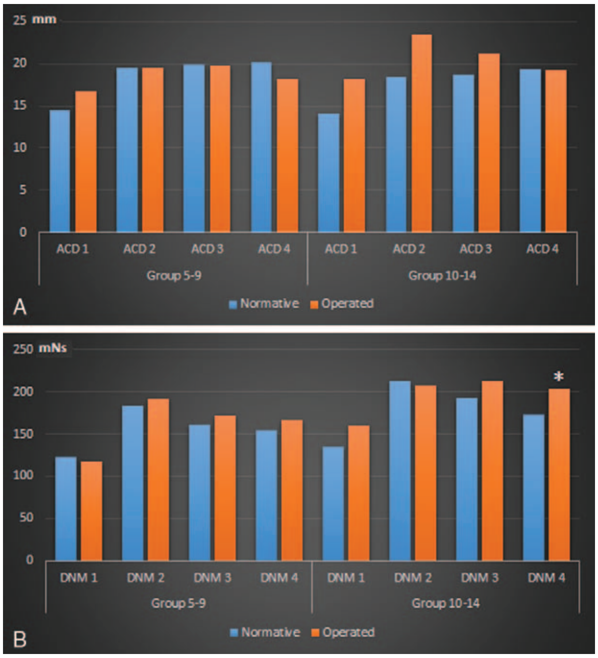

FIGURE 5. Data of normative ears versus operated ears. A, Auriculocephalic distance of normative ears. ACD (1) the most superior point on the auricle, (2) the point of insertion of the helix crus to the scalp, (3) the most superior point of the tragus, and (4) the level of the antitragus) axis (age groups). B, Dynamometric measurements of normative ears. Mm, millimeters; ACD, auriculocephalic distance; DNM, dynamometry (mN) (superior crus level, crus helix level, tragus level, and antitragus level).

the result of inadequate correction in lower levels where the cymba conchae and the cavum chonchae increase rigidity during medialization. With use of adequate techniques in this region, recurrences at level 1 can be prevented.

Preoperative evaluation of 3 patients with prominent ear deformity revealed increased ACD and lower DNMs compared with their representative age group. Following otoplasty, DNMs along with the ACDs approached "normative" values of their age group. Although further follow-up and larger study population is essential for a solid conclusion, otoplasty seems to "normalize" the ear in terms of stiffness as well as the ACD.

Otoplasty surgery focuses on effective and adequate medialization of the auricle. Understanding biomechanical properties of the auricle is essential to choose the surgical technique from the armamentarium.[7] Successful surgery requires thorough understanding of each surgical technique.[7] Residual postoperative auricular deformity remains when inadequate correction of cartilage stiffness (cartilage memory) counteracts medialization of the auricle.[17,18] Scoring, cutting, and suturing techniques are used in combination

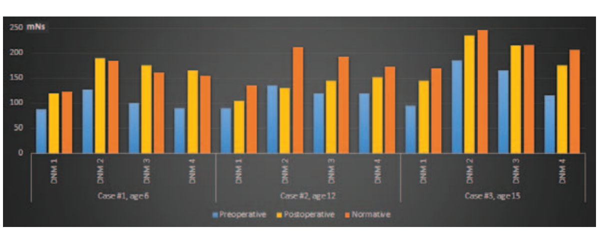

FIGURE 6. Prospective dynamometric measurements of operated ears. DNM, dynamometry (mN) (superior crus level, crus helix level, tragus level, and antitragus level). Patient 1, A total of 6 years, normative values of group 5 to 9 included; patient 2, a total of 12 years, normative values of group 10 to 15 included; patient 3, a total of 15 years, normative values of group 15 to 19 included.

during surgery and tactile examination subjectively evaluates how "relaxed" cartilage is for medialization. Dynamometric measurements can easily be used for objective quantitative intraoperative analysis of applied techniques.

Suture extrusion can be prevented with accurately positioned sutures and tension-free wound margins.[8] Suture extrusion rates vary from 0% to 22.2% for otoplasty patients.[19–21] Dynamometric measurements of auricular stiffness can guide the placing of sutures, indicate the need of additional scoring or cartilage excision techniques to stiffer regions for tension-free wound margins, and the placing of extra sutures for stability.

CONCLUSIONS

Auricular cartilage elasticity has been evaluated quantitatively for the first time in the literature. Dynamometric measurements were lowest at level 1 and highest at level 2. Results show that auricular cartilage stiffens and malleability decreases with increased age. Stiffness peaks in 35 to 39 age group and declines after 40 years. Increased rigidity, at all levels, with increased age suggests cartilage elasticity is related to age. In the light of these findings, cartilage sparing techniques are more appropriate for patients 5 to 14 years of age, and cartilage-cutting techniques can be added for older patients. Suturing techniques will be sufficient for correcting the level 1 region whereas level 2 requires reliable cartilage weakening for efficient correcting of deformities. Although further follow-up and larger study population is essential for a solid conclusion, otoplasty seems to "normalize" the ear in terms of stiffness as well as the ACD.

Quantitative and objective evaluation of auricular cartilage strength and stiffness will yield valuable information for definitive correction of ear deformity and cosmetically happy patient. Because of these positive outcomes, we suggest the utilization of the dynamometer for objective and quantitative preoperative assessment of prominent ears.

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