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Development and Optimization of Universal Bone Conduction Hearing Spectacles

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Abstract

Background: Non-implantable bone anchored hearing devices (BCHDs) are utilized for patients with conductive or mixed hearing loss who are unsuitable for conventional hearing aids or have unresolved middle ear issues. These devices can be surgically implanted or attached using adhesive plates, dental sticks, elastic headbands, or bone conduction spectacles. Optimal fitting of bone conduction spectacles requires appropriate frame selection and contact pressure in the temporal and mastoid areas. The ANSI S3.6 and DIN EN ISO 389-3 standards recommend a contact area of approximately 1.75 cm^2 and a maximum force of 5.4 N for effective sound transmission and comfort. **Methods:** This study aimed to evaluate the technical fit and mechanical stability of universal bone conduction hearing spectacles compared to established systems. A Sen-Pressure 02 thin-film sensor connected to an Arduino Uno R3 board measured contact force in the temporal and mastoid areas. Several BCHDs were tested, including the Bruckhoff la belle BC D50/70, Radioear B71 headset, Radioear B71 elastic headband, Cochlear Baha SoundArc M, and Cochlear Baha elastic headband, on a PVC artificial head, with data analyzed using ANOVA and LSD post hoc tests. **Results:** The la belle BC D50/70 spectacles showed comparable contact force to established BCHDs, ensuring adequate sound transmission and comfort. Significant differences were observed between the systems, with the Radioear B71 headset exhibiting the highest forces. The la belle BC D50/70 had similar forces to the Radioear B71 elastic headband. **Conclusion:** The la belle BC D50/70 universal bone conduction hearing spectacles are a technically equivalent alternative to established BCHDs, maintaining pressure below 5.4 N. Future research should explore the impact of different contact forces on performance and comfort, and the integration of force control in modified spectacles. This study indicates that the la belle BC D50/70 is a viable alternative that meets audiological practice requirements.

Keywords

Bone Conduction Hearing Devices (BCHD), Universal Bone Conduction Hearing Spec-Tacles, Non-Implantable Hearing Aids, Contact Pressure Optimization

1. Introduction

Non-implantable bone conduction hearing aids are often used for patients with conductive or mixed hearing losses who cannot benefit adequately from conventional air conduction hearing aids or for those whose conductive components cannot be corrected despite middle ear surgery. These hearing aids can be surgically implanted or, as a non-surgical, pressure-free alternative, reversibly attached with an adhesive plate [1], dental sticks, a rigid or elastic headband, or bone conduction hearing spectacles [2]. The frame of bone conduction hearing spectacles is initially selected based on the individual's anatomical features, including face shape, nose shape for bridge width, lens width dimensions, and personal style preferences such as lens height, temple length, and overall aesthetic preferences [3]. Optimal fitting of the bone conduction receiver requires correct contact pressure on the head [4]. According to ANSI S3.6 and DIN EN ISO 389-3, the contact area should be approximately 1.75 cm^2 [5] [6]. Lehnhardt and Laszig (2009) state that large-area bone conduction headphones facilitate sound transmission during in situ bone conduction threshold measurement by enabling the determination of the minimum audible signal through a single contact surface on the head [7]. Although calibration standards require relatively high contact forces on the mastoid, audiological practice often recommends a contact force that the patient can tolerate. This should not be exceeded to ensure a tight fit of the receiver and effective sound transmission. Accordingly, the contact force should be approximately 5.4 Newtons or, ideally, a maximum mass of 400 g [8] [9]. These recommendations, based on practical experience, aim to protect the wearer from discomfort and potential injury. Determining the most favorable contact surface of the head for bone conduction hearing aids can be challenging, as the position of the hearing aid plays a critical role depending on the individual's skull structure [7]. For some individuals, optimal bone conduction occurs when the receiver is positioned on the temporal bone just behind the auricle without touching it. For others, the best placement is at the tip of the mastoid process [7]. Probst *et al.* (2008) noted that the bone conduction probe could be located either on the mastoid or the forehead [10]. Additionally, Kachhadiya (2023) identified a placement on the cheekbones as ideal for outdoor activities, allowing users to stay aware of their surroundings. This is beneficial for military and professional communication systems, sports, outdoor activities, and individuals with normal hearing [3]. Before placing the bone conduction receiver on the patient, it is essential to identify any structural abnormalities or issues that may interfere with its proper placement. Common problems include hair under the receiver, oily skin, and unusually shaped or narrow mastoids that make it difficult for the receiver to stay in place. Less common but equally important are pathologies and surgically altered structures [9].

The audiologist takes the following procedures to adjust the hearing aids for the patient. The patient listens to an easily audible bone conduction tone at 500 Hz while moving the vibrating receiver over the mastoid to find the loudest spot [9]. Lehnhardt and Laszig (2009) also mention that the subject can help identify the best contact point for bone conduction by holding the receiver and making small tilting movements during sonication. This optimal contact point may vary with frequency, requiring multiple adjustments to achieve the best bone conduction at every frequency. Contact pressure also influences bone conduction, albeit to a relatively minor extent [7]. Bone conduction hearing aids typically offer up to 30 dB of amplification. Reports of skin complications and long-term bone loss (osteolysis) in users underline the importance of carefully monitoring and adjusting contact pressure to prevent such issues. Regular checks and individual adjustments are crucial for wearer comfort and safety [11] [12]. The contact pressure of bone conduction hearing spectacles depends on the size of the frame's front, which applies the force and form fit on the head and the temple length, enabling a snug fit against the base of the ear [13]. Once the spectacle frame is chosen, the bone conduction earpiece is mounted and precisely aligned on the head based on the contact pressure. It is crucial to properly center the spectacles in front of the wearer's eyes [14]. After performing the aforementioned steps, the audiologist may select lenses tailored to the individual visual needs of the wearer, including parameters such as sphere (distance vision), cylinder (astigmatism correction), axial position, pupil distance (PD), and addition for near vision. Trial spectacles, also known as refraction spectacles, are typically used to determine all spectacle measurements [14].

On the other hand, for patients without bone conduction temples, meaning the necessary contact pressure is not accounted for, it may lead to inaccuracies in measuring temple length and frame front size, ultimately reducing fit accuracy. To date, little is known about the use of modified refraction spectacles with bone conduction temples to estimate the required contact pressure on the temporal line and mastoid region, their practical use in clinical settings, their effect on hearing aid fitting, and their potential benefits for the patient's quality of life. In practice, the correct sequence of positioning, applying the appropriate contact pressure of the bone conduction hearing aid, and then centering the spectacles in front of the wearer's eyes are often overlooked. This leads to problems such as insufficient contact pressure on the head and improperly fitting temples, which compromise the optimal placement of the bone conduction receiver in the temporal line and mastoid process areas. This study is based on the following hypotheses: (H0) Universal bone conduction hearing spectacles can provide a technical fit comparable to established bone conduction hearing aids. (H1) The universal bone conduction hearing spectacles do not exceed the maximum contact force of 5.4 N (400 g), indicating similar mechanical stability to established bone conduction hearing devices. (H2) There are no significant differences in contact forces between the universal bone conduction hearing spectacles and various established bone conduction hearing devices. (H3) The variation of the contact force significantly influences the technical performance of bone conduction hearing devices.

2. Design and Method

2.1. Hardware and Software

2.1.1. Technology for Force Measurement

The Sen-Pressure 02 thin-film sensor, manufactured by Joy-IT Simac Electronics GmbH in Neukirchen-Vluyn, Germany, was used to measure the contact pressure at the temporal line and mastoid process. The sensor's contact area is circular and measures 0.56 cm^2. It was connected to an Arduino Uno R3 microcontroller board (serial number: 44231313430035130C0D1) programmed and controlled using the Arduino IDE software version 2.3.2. The resistance value (RC in kΩ) of the sensor was determined using its datasheet. The Arduino Uno R3 board's supply voltage (VCC) was 5 V, and the resistance on the sensor board was 510 kΩ. The sensor outputted voltage values (VOUT) in the millivolt range, which required conversion to volts for the subsequent Equation (1).

$$RC = \left(\frac{VCC \times 510}{VOUT}\right) - 510 \tag{1}$$

2.1.2. Bone Conduction Hearing Devices

The La Belle BC D50/70 bone conduction hearing device (BCHD) from Bruckhoff (Sömmerda, Germany) was developed to optimize universal bone conduction hearing spectacles. Unlike traditional bone conduction spectacles with a fixed design, the Bruckhoff La Belle BC D50/70 features a modular design, allowing it to be adapted to various spectacle frames, thereby increasing the flexibility and accuracy of fit to individual head anatomies. To demonstrate feasibility, we compared the contact pressure of the DIN EN ISO 389-3 and ANSI S3.6 standardized B71 bone conduction hearing aid from Radioear (Middelfart, Denmark), along with its headset and elastic headband, to the audiologically established Cochlear Baha SoundArc M bone conduction device and the Cochlear Baha elastic headband (Sydney, Australia). The elastic headband, or SoundArc, comes in sizes XS, S, M, L, XL, and is suitable for adults, infants, and children. In contrast, the size of the universal bone conduction hearing spectacles can be adjusted by the users to maintain appropriate contact pressure.

2.1.3. Refraction Spectacles

The measurements were taken using unbranded "Standard" model Universal Optical Measuring Spectacles from Shenzhen, China. These spectacles have a pupillary distance (PD) range of 48 to 80 mm and weigh 60 g. Their dimensions are 156 mm in width, 60 mm in height, and 38 mm in depth.

2.1.4. Artificial Head Model

In experimental audiology, artificial head models like Brüel & Kjær's Head and

Torso Simulator (HATS) or GRAS Sound & Vibration's G.R.A.S. KEMAR HATS are used to simulate human anatomy and auditory processing. Though these models can't perfectly replicate human anatomy and auditory processing, they enable the collection of head-related contact force data. In our research lab, we used a PVC artificial head that allowed for a more compact measurement setup than the previously mentioned models. While it doesn't simulate all aspects of human anatomy, it provides an accurate representation of head-related contact force data. We utilized a soft PVC artificial head model (D-HeadModel-Male-2pc) made by Dicunoy (China), with a height of 29 cm and a head circumference of 55.4 cm, matching the average adult head size. This model facilitated the testing of positioning and contact force of bone conduction hearing aids under controlled conditions. We selected a PVC head over the more rigid HATS or KEMAR models because the material shows slight compliance under pressure, mimicking how human skin yields to the pressure of a bone conduction hearing device. This characteristic makes the PVC head a more accurate representation of human tissue compared to the metal-constructed HATS and KEMAR simulators. Consequently, the PVC head provides a more realistic approximation of the contact forces experienced by the human head when using bone conduction hearing devices.

2.2. Development Phase—Modification of the Spectacles and the System for Regulating the Contact Pressure

2.2.1. Preparation and Calibration

To ensure accurate contact force measurements, the thin-film sensor was calibrated prior to testing. It measures the analog force applied and converts it into voltage values ranging from 0 mV to 1023 mV. The higher the voltage, the lower the resistance of the sensor and the greater the force measured. The following **Code Example (1)** demonstrates how to read the analog value of the sensor every 2 seconds and display it on the Arduino IDE's serial monitor (version 2.3.2):

Code Example 1

```
// Initialize the variable to store sensor value
int val;

void setup() {
// Configure pin A0 as an input
pinMode(A0, INPUT);
// Begin serial communication at a baud rate of 9600
Serial.begin(9600);
}

void loop() {
// Read the analog value from pin A0
val = analogRead(A0);
// Print the sensor value to the serial monitor
Serial.println(val);
// Wait for 2 seconds before taking the next reading
delay(2000);
}
```

For calibration, the mass was gradually increased in 20 g increments from 0 to 600 g. The Arduino Uno R3 platform was programmed to continuously record readings during the experiments. The arithmetic mean of 5 measurements was used for further analysis (see Figure 1).

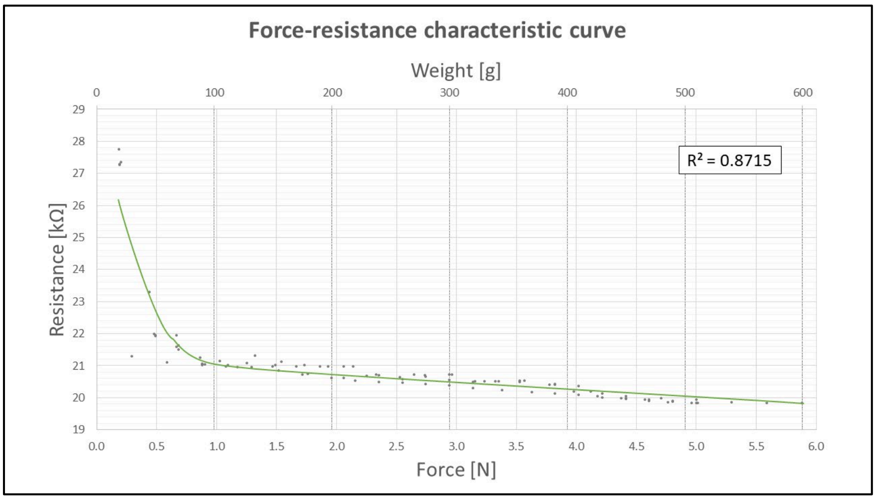

Figure 1. Force-resistance characteristic curve: Calibration was performed in 20 g increments from 0 to 600 g. Measurements were continuously recorded using the Arduino Uno R3 platform, and the arithmetic mean of 5 measurements was used for analysis.

The force-resistance characteristic calibrated the thin-film sensor, and the force-voltage characteristic curve (see Figure 2) was used to calculate the force (F in N) exerted by the bone conduction sensor from the voltage value.

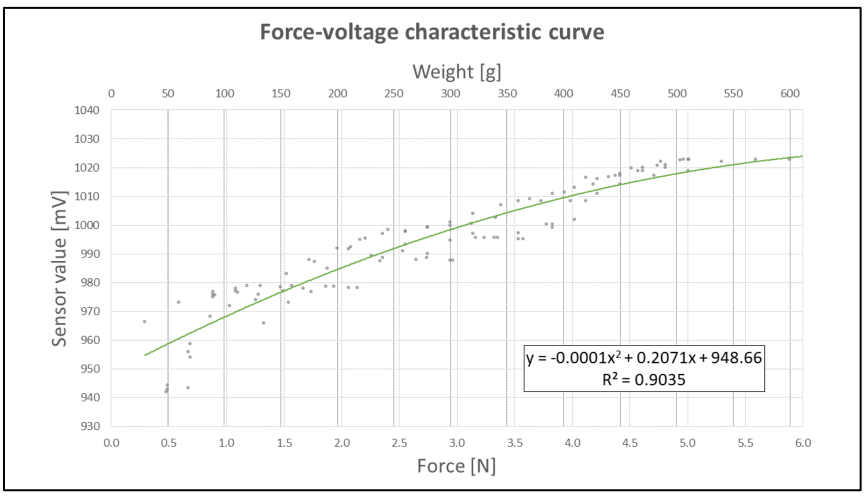

Figure 2. The literature suggests an optimal contact force range of 3.9 N (400 g) to 5.4 N (550 g). Thus, the thin-film sensor should ideally output a voltage between 1010 mV and 1020 mV, or less, to ensure the contact force remains within this range.

The sensor value (VOUT in mV) was first converted to weight in grams and then to force (F in N). Equation (2) for calculating the force is as follows:

$$m = \frac{-0.2071 + \sqrt{0.04289941 + 0.0004 * (948.66 - VOUT)}}{-0.0002} \quad (2)$$

2.2.2. Performing the Tests

Initially, the contact area of the bone conduction hearing devices was measured (see Table 1).

Table 1. Bone conduction hearing device characteristics.

Type		Surface [cm²]	Shape	Surface finish
(A)	Bruckhoff la belle BC D50/70	1.1	oblong	concave
(B)	Radioear B71 Headset	1.75	circular	plane
(C)	Radioear B71 elastic headband	1.75	circular	plane
(D)	Cochlear Baha SoundArc M	4.5	circular	plane
(E)	Cochlear Baha elastic headband	4.5	circular	plane

The contact surfaces were measured to ensure optimal force distribution, compare different systems, and maximize comfort. The head circumference of the PVC artificial head was 55.4 cm. These measurements ensured that the test conditions were realistic and that the bone conduction hearing devices (BCHD) were fitted under representative conditions. The end caps of the temples of the refractive spectacles were removed (see Figure 3), and the Bruckhoff la belle BC D50/70 bone conduction hearing device was attached to the exposed metal temples.

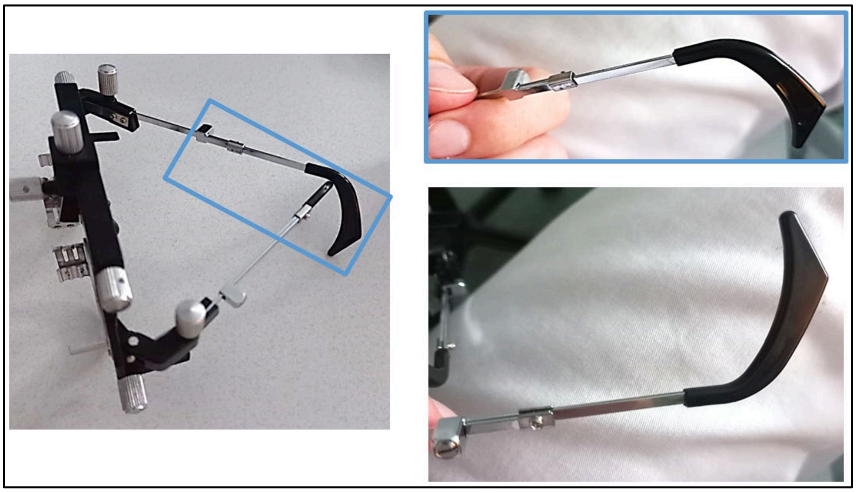

Figure 3. The illustration on the left depicts the universal refraction spectacle, highlighting the length-adjustable temple with a blue frame. The top right picture displays the temple end from the inside of the head, including the plastic end cap. The bottom right photo documentation reveals the temple end from the outside of the head, featuring the slide and locking mechanism for individual temple length adjustment.

The spring hinge of the refraction spectacles was adjusted to maintain a constant clamping force without affecting the contact pressure. The universal bone conduction hearing spectacles were tailored to the anatomical features of the PVC artificial head, and the thin-film sensor was secured to the contact surface. The contact force of these spectacles depended on how well they fit the head and the length of the temple, ensuring the temple end pressed snugly against the base of the ear. The contact surface was limited to the area around the temporal line, preventing measurements in other areas such as the tip of the mastoid process, across a larger section of the mastoid, or on the forehead or cheekbones. Contact force was continuously monitored, and adjustments were made to the bone conduction hearing spectacles to achieve the highest possible contact force for optimal positioning. Care was taken to ensure that the maximum contact force of approximately 5.4 N (about 400 g) was not exceeded to protect future wearers from discomfort and possible injury. Special attention was given to correctly centering the bone conduction hearing spectacles in front of the artificial head's eyes. Once the optimal fit and contact pressure were achieved, the spectacles were fitted ten times. To verify the mechanical stability and consistency of the contact pressure, the arithmetic mean of 5 measurements was calculated (see **Figure 4**).

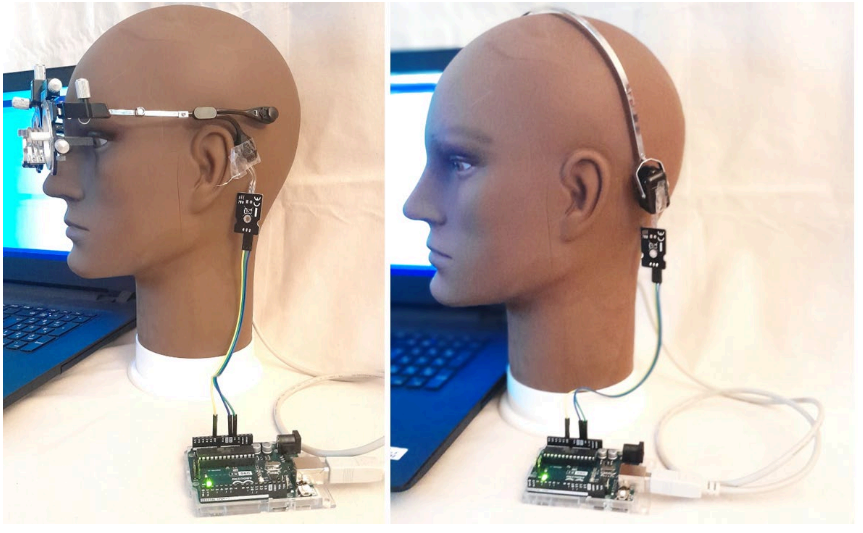

Figure 4. The figure on the left displays modified refractive spectacles equipped with the bone conduction spectacle module (A) Bruckhoff la belle BC D50/70. The spectacles were placed on the PVC artificial head ten times to measure contact pressure using the Sen-Pressure 02 thin-film sensor connected to an Arduino Uno R3 microcontroller board. The figure on the right illustrates the same measurement repetitions using the (B) Radioear B71 bone conduction headset attached to a headband.

The thin-film sensor was mounted on the contact surfaces of other bone conduction devices (B) to (E) from **Table 1** and placed on the PVC artificial head. The optimal fit was found, and measurements were repeated to determine the contact force using the thin-film sensor. The contact force data were transferred from the analog thin-film sensor to the computer in real time, and the results were recorded using Arduino IDE software. After completing the measurements, the sensor data were imported into Microsoft Excel for statistical analysis.

2.2.3. Statistics

Regarding the statistical analysis, the method chosen was one-way analysis of variance (ANOVA) with repeated measures. The selection of ANOVA was directly linked to the study's research objectives, enabling specific questions about the influence of contact force between different bone conduction hearing devices on the linea temporalis and mastoid process of the PVC artificial head to be answered. This approach allowed for the limiting of influencing factors to the different bone conduction hearing devices, with measurements consistently performed on the same PVC artificial head. A significant advantage of ANOVA is its ability to compare multiple groups simultaneously without increasing the error probability that multiple pairwise comparisons might introduce. Moreover, ANOVA facilitates the analysis of variance between groups, leading to more precise results. The significance level was set at 0.05. To compare differences between the mean values of the bone conduction hearing devices, the Least Significant Difference (LSD) post hoc test was conducted following the one-way ANOVA. The LSD value was calculated using the t-value, significance level (α), degrees of freedom (df), and mean square within (MSW). The t-value was determined based on a significance level of 0.05 and 45 degrees of freedom. The mean square within (MSW) was 0.077571344, as obtained from the ANOVA. The statistical analysis of the collected data was performed using Microsoft Excel (Office 365, Microsoft, Redmond, USA).

3. Results

Figure 5 presents a box plot comparing the contact forces exerted by different bone conduction hearing devices (BCHDs), including the Bruckhoff la belle BC D50/70, Radioear B71 elastic headband, Cochlear Baha SoundArc M, Cochlear Baha elastic headband, and Radioear B71 headset. The plot displays the distribution of contact forces, measured in Newtons (N), for each device, highlighting the median, interquartile range (IQR), and outliers, thereby offering a comprehensive overview of the data. The analysis reveals notable differences in contact forces among the devices. The Bruckhoff la belle BC D50/70 exhibits a relatively narrow range of contact forces with a median of around 1.5 N and low variability. In contrast, the Radioear B71 elastic headband demonstrates a broader range of contact forces, including some higher outliers, with a median slightly above 1.5 N. The Cochlear Baha SoundArc M features the lowest median contact force, near 1.0 N, with a very narrow IQR, indicating consistent force application. Similarly, the Cochlear Baha elastic headband has low median contact forces and low variability. The Radioear B71 headset displays the highest median contact force, around 2.5 N, with a relatively wide IQR, suggesting greater variability in applied force. The Least Significant Difference (LSD) post hoc test indicates no significant differences between the Bruckhoff la belle BC D50/70 and the Radioear B71 elastic headband, and between the Cochlear Baha SoundArc M and the Cochlear Baha elastic headband.

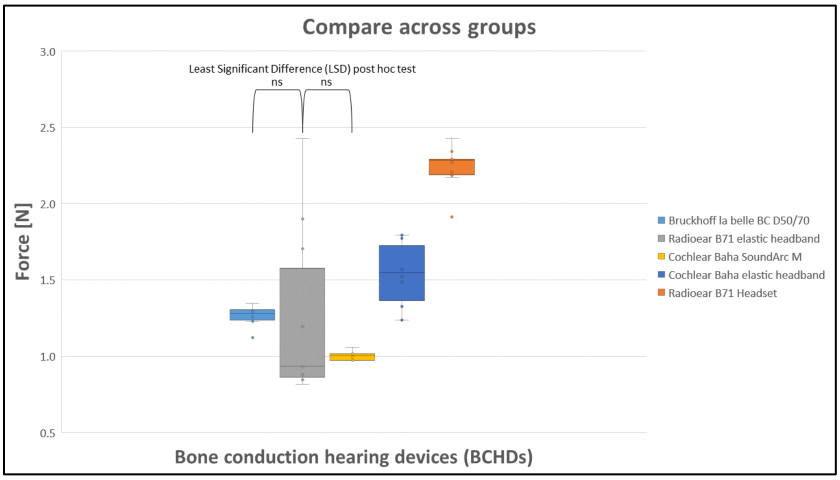

Figure 5. Boxplot comparison of contact forces exerted by different bone conduction hearing devices (BCHDs), including the Bruckhoff la belle BC D50/70, Radioear B71 elastic headband, Cochlear Baha SoundArc M, Cochlear Baha elastic headband, and Radioear B71 Headset. The Least Significant Difference (LSD) post hoc test shows no significant differences between some devices.

ANOVA analysis examined the differences in contact force among five different bone conduction hearing devices, measured in Newtons. The results are presented in Table 2.

Table 2. ANOVA results for contact force in Newtons.

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	Test Statistic (F)	P-Value	Critical F-Value
Between Groups e	9.06	4	2.27	29.2103	0.0001	2.5787
Within Groups	3.49	45	0.08			
Total	12.55	49				

The ANOVA results indicate significant differences in contact pressure among the studied groups ($F(4, 45) = 29.2103$, $p < 0.0001$). The calculated F value of 29.2103 significantly exceeds the critical F value of 2.5787, demonstrating that the differences between groups are statistically significant. This analysis was conducted to investigate the variance in measured weights (in grams) across five different bone conduction hearing devices, with the findings detailed in Table 3.

Table 3. ANOVA results of the measured weights in grams.

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	Test Statistic (F)	P-Value	Critical F-Value
Between Groups e	94180.21	4	23545.05	29.2103	0.0001	2.5787

Continued

Within Groups	36272.36	45	806.05			
Total	130452.5 7	49				

The ANOVA results indicate significant differences in the measured weights across the groups studied ($F (4, 45) = 29.2103$, $p < 0.0001$). The calculated F-value of 29.2103 significantly exceeds the critical F-value of 2.5787, confirming that the differences between the groups are statistically significant. ANOVA analysis was employed to investigate the differences in measured voltage values among five different bone conduction hearing devices, with voltage values measured in millivolts (mV) and presented in Table 4.

Table 4. ANOVA results for the voltage values in millivolts.

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	Test Statis-tic (F)	P-Value	Critical F-Value
Between Groups e	2844.92	4	711.23	28.7443	0.0001	2.5787
Within Groups	1113.45	45	24.74			
Total	3958.36	49				

The ANOVA results indicate significant differences in the measured stress values between the studied groups ($F (4, 45) = 28.7443$, $p < 0.0001$). The calculated F-value of 28.7443 significantly exceeds the critical F-value of 2.5787, confirming that the differences between the groups are statistically significant. After the one-way ANOVA, the Least Significant Difference (LSD) post-hoc test was conducted to compare the means of different bone conduction hearing devices, using a t-value of 2.014, a significance level (α) of 0.05, degrees of freedom (df) of 45, and a mean square within (MSW) of 0.077571344. This yielded an LSD value of 0.250869242. The results are presented below (see Table 5):

Table 5. Paired means comparisons.

Priority 1	Priority 2	Average 1	Average 2	Differ-ence	Significance
la belle BC D50/70	B71 Headset	1.2651	2.239	0.9739	significant
la belle BC D50/70	B71 elastic headband	1.2651	1.2496	0.0155	not sig.
la belle BC D50/70	Baha SoundArc M	1.2651	0.9994	0.2656	significant
la belle BC D50/70	Baha elastic headband	1.2651	1.532	0.2669	significant

Continued

B71 Headset	B71 elastic headband	2.239	1.2496	0.9894	significant
B71 Headset	Baha SoundArc M	2.239	0.9994	1.2396	significant
B71 Headset	Baha elastic headband	2.239	1.532	0.707	significant
B71 elastic headband	Baha SoundArc M	1.2496	0.9994	0.2501	not sig.
B71 elastic headband	Baha elastic headband	1.2496	1.532	0.2824	significant
Baha Sound-Arc M	Baha elastic headband	0.9994	1.532	0.5326	significant

The LSD post hoc tests revealed significant differences among most of the compared groups, supporting the ANOVA results. Specifically, the Radioear B71 headset exhibited significantly different contact forces from other systems. The universal bone conduction hearing spectacles La Belle BC D50/70 showed no significant differences compared to the Radioear B71 elastic headband, indicating comparable contact forces.

4. Discussion

The results indicate that the universal bone conduction spectacles La Belle BC D50/70 have a contact force comparable to established bone conduction hearing devices (BCHD). Specifically, La Belle BC D50/70 spectacles offer similar mechanical stability and fitting accuracy compared to the Radioear B71 elastic headband, confirming hypotheses H0 and H1 that the universal bone conduction spectacles can technically match established BCHDs. The average measured contact force of 1.3 N for La Belle BC D50/70 is within the range of established BCHDs, ensuring adequate sound transmission. These findings are significant as they demonstrate that the new spectacles meet audiological standards without causing the wearer discomfort or compromising sound transmission due to insufficient contact pressure.

The ANOVA and post-hoc tests showed significant differences among the BCHDs, especially between the Radioear B71 headset and other systems. The Radioear B71 headset exhibits significantly higher contact forces due to its design features and intended application areas. It is designed for short-term, targeted use in bone conduction testing of hearing thresholds, not for long-term bone conduction fitting in daily hearing. This highlights the importance of considering individual needs and fitting when choosing a bone conduction hearing aid. The universal bone conduction hearing spectacles la belle BC D50/70 demonstrated no significant differences compared to the Radioear B71 elastic headband, indicating similar contact pressure. This is a positive outcome, as the Radioear B71 elastic headband is recognized for its adaptability and comfort.

The positioning of the bone conduction earpiece is crucial for comfort. While this study did not directly evaluate sound transmission and comfort, literature suggests that optimal placement near the temporal line and mastoid process is vital for effective sound transmission. Lehnhardt and Laszig (2009) and Probst *et al.* (2008) highlight that receiver position varies with individual bone structure. The fit and stability of the bone conduction receiver are influenced by contact force. Adequate contact force ensures a secure fit. This study measured contact force to confirm the universal bone conduction spectacle la belle BC D50/70 would remain securely on the head. A maximum acceptable value of 5.4 N (about 400 g) is identified in literature, as higher forces may cause discomfort and long-term health issues. The measurements in this study show the la belle BC D50/70 remains below this threshold, indicating greater comfort. The la belle BC D50/70, modified trial spectacles, provide a practical solution for determining optimal front frame size and temple length with pre-fitted bone conduction hearing devices. This allows for the first time the adjustment of spectacle frames to the optimum contact pressure and correct positioning in front of the eyes before visual acuity determination. This approach considers the unique requirements of bone conduction hearing devices and avoids fitting issues when attaching the device to pre-made spectacles, which could compromise fit for both vision and hearing. The use of la belle BC D50/70 with two bone conduction temples for estimating required contact pressure could be beneficial in clinical practice. However, the impact on hearing device fitting and potential quality of life improvements compared to traditional fitting methods, where spectacle fitting precedes hearing device adjustment, has not been explored. In practice, the sequence of positioning, achieving proper contact pressure, and centering the spectacles is often overlooked, leading to issues such as insufficient contact pressure and improperly sized temples, which can hinder optimal receiver placement near the temporal line and mastoid process.

Differences between the artificial hearing simulator used in this study and the real human body can affect the results. To present the most realistic and reliable data, it is essential to consider these differences. The artificial head offers a standardized testing environment but lacks the variability found in human anatomy. Future studies should aim to minimize these discrepancies by using more advanced simulators or incorporating data from real human subjects. Future studies should explore how different contact pressures affect hearing performance and comfort. Future research should also examine the implementation of contact force control in the modified universal bone conduction hearing spectacles, aiming to standardize the contact force to a maximum of 5.4 N. This integration is key to standardizing the contact force, requiring extensive testing and adjustments for validation. Unlike traditional bone conduction hearing spectacles with fixed construction, the Bruckhoff la belle BC D50/70 features a modular design, allowing it to be attached to various spectacle frames. This increases its adaptability and precision in fitting different head shapes. Adapting the hearing system to different frames through contact pressure control could enhance its broad applicability.

Testing with various frames, including in situ bone conduction audiometry, is necessary to assess the precision of contact force and optimal sound transmission. Comparing sound transmission with traditional bone conduction devices will help ensure an optimal fit. Fine-tuning the prototype and conducting extensive user tests are essential to guarantee both comfort and effectiveness.

5. Conclusion

This study evaluated the technical fit and mechanical stability of the universal bone conduction hearing spectacles La Belle BC D50/70 in comparison to established bone conduction hearing devices (BCHDs). The results show that the La Belle BC D50/70 spectacles exhibit comparable contact forces to established BCHDs, ensuring sufficient sound transmission without exceeding the maximum recommended contact force of 5.4 N. Significant differences in contact forces were observed between different BCHDs, particularly the higher contact forces of the Radioear B71 headset. However, the La Belle BC D50/70 spectacles demonstrated similar contact pressures to the adaptable and comfortable Radioear B71 elastic headband. The modified refraction spectacles with the Bruckhoff La Belle BC D50/70 provide a practical solution for determining the optimal front frame size and temple length. Future studies should explore the effects of varying contact pressures on hearing performance and wearer comfort, as well as the integration of contact force control mechanisms in the spectacles. Addressing differences between artificial hearing simulators and real human anatomy is crucial for obtaining more realistic and reliable data. Overall, the universal bone conduction hearing spectacles La Belle BC D50/70 present a promising alternative to established BCHDs, meeting audiological practice requirements and offering a practical solution for optimal fitting and comfort.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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