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The depth of arterial supply of forehead: a meta-analysis

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ABSTRACT

Background: The rapid growth of aesthetic medicine has led to an increased demand for non-surgical cosmetic procedures in the frontal region of the face. However, alongside this rise in popularity, there is a growing awareness of the potential complications associated with these procedures especially connected with fillers. The intricate vascular anatomy of the forehead, specifically the supratrochlear (STA) and supraorbital (SOA) arteries, poses significant risks if not thoroughly understood. While the morphological course of these vessels is well-documented and analysed, detailed knowledge about their depth remains vital for enhancing procedural safety.

Materials and methods: Five research papers were analyzed in the meta-analysis. The analyses of STA and SOA were performed in two distinctive places bilaterally: at the level of the glabella and above the eyebrow.

Results: A total of 201 SOA arteries and 282 STA arteries were analysed at the following horizontal levels, respectively: at the level of the glabella and above the eyebrow. The final results were as follows: 5.68 mm, 95% CI (4.58–6.78) for SOA at the glabella, 5.53 mm, 95%

CI (4.79–6.28) for SOA above the eyebrow, 4.45 mm, 95% CI (3.43–5.47) for STA at the glabella, and 3.53 mm, 95% CI (3.21–3.85) for STA above the eyebrow.

Conclusions: The supratrochlear artery tends to become more superficial along its path, while the supraorbital artery remains at a consistent depth across various anatomical levels. For injections in the medial part of the forehead, it is advisable to place the needle up to 2.5 mm deep or laterally to the artery's path. In contrast, injections in the lateral part of the forehead can be administered at slightly deeper depths, up to 3.5 mm. To minimise the risk of complications, performing a high-resolution linear ultrasonography (USG) exam prior to injection is recommended, allowing for needle placement either laterally or medially to the vessels.

Keywords: supratrochlear artery, supraorbital artery, depth, cosmetic surgery, plastic surgery

INTRODUCTION

In recent years, aesthetic medicine has experienced unprecedented growth, with non-surgical cosmetic procedures becoming increasingly popular. Techniques such as injectable dermal fillers or botulinum toxins offer rapid improvements in facial aesthetics, addressing concerns such as wrinkles, volume loss, and facial contouring with minimal downtime [1, 2]. Dermal fillers restore lost volume in the forehead, addressing deep-set horizontal lines for a fuller, natural look [3]. Botulinum toxin (BTX) injections effectively smooth dynamic forehead wrinkles by temporarily relaxing the underlying muscles, creating a rejuvenated appearance. However, alongside this rise in popularity, there is a growing awareness of the potential complications associated with these procedures. The intricate vascular anatomy of the face plays a vital role in the safety of these procedures. For instance, the supratrochlear artery (STA), supraorbital artery (SOA), superior labial artery (SLA), facial artery (FA) are crucial structures that practitioners must consider when performing injections in the facial esthetic region [4, 5]. Given the high stakes involved in cosmetic procedures, it is essential for healthcare providers to possess a thorough understanding of facial vascular anatomy, be aware of individual anatomical variations, and apply effective risk mitigation strategies. Procedures such as neurotoxin injections and dermal filler injections conducted for both facial rejuvenation and contouring are considered as insignificantly invasive methodologies [6]. The aim of the study was to conduct a meta-analysis to quantitatively compare the depth of the main arteries that supply the forehead, based on USG studies.

MATERIALS AND METHODS

The meta-analysis was conducted in both models: random and common, to assess most valuable data analysis. The data established for analysis and the conclusions were based on the Random Effect Model considering the influential potential from different populations from around the globe. The 5 research papers were included in the whole Meta-Analysis. Details about each research are compared in a table (Tab. 1). The data collection process is shown in Flow diagram PRISMA (Fig. 1). The exact analysed locations were illustrated on (Fig. 2) and the USG pictures on the same levels were obtained (Fig. 3).

The analyses were performed in two distinctive places bilaterally. At the level of the glabella and above the eyebrow. The Results are presented in a combined forest plot (Fig. 4). Each of these regions is involved in countless Aesthetic, Plastic and Reconstructive Surgery procedures (Fig. 4).

Search strategy

Major online medical databases such as PubMed, Embase, Scopus, Web of Science, Google Scholar, and Cochrane Library were searched to gather information about the depth of facial artery, including depth, topography, morphology, variations, morphometry, course, cosmetic procedure, computed tomography and ultrasonography. The following search terms were used in that order:

Supraorbital artery

1. ((Supraorbital Artery [Title/Abstract]));
2. ((Supraorbital Artery [Title/Abstract]) AND (morphometry [Title/Abstract]));
3. ((Supraorbital Artery [Title/Abstract]) AND (morphology [Title/Abstract]));
4. ((Supraorbital Artery [Title/Abstract]) AND (topography [Title/Abstract]));
5. ((Supraorbital Artery [Title/Abstract]) AND (variation [Title/Abstract]));
6. ((Supraorbital Artery [Title/Abstract]) AND (depth [Title/Abstract]));
7. ((Supraorbital Artery [Title/Abstract]) AND (course [Title/Abstract]));
8. ((Supraorbital Artery [Title/Abstract]) AND (cosmetic procedure [Title/Abstract]));
9. ((Supraorbital Artery [Title/Abstract]) AND (plastic surgery [Title/Abstract]));
10. ((Supraorbital Artery [Title/Abstract]) AND (ultrasonography [Title/Abstract])).

Supratrochlear artery

1. ((Supratrochlear artery [Title/Abstract]));
2. ((Supratrochlear artery [Title/Abstract]) AND (morphometry [Title/Abstract]));
3. ((Supratrochlear artery [Title/Abstract]) AND (morphology [Title/Abstract]));
4. ((Supratrochlear artery [Title/Abstract]) AND (topography [Title/Abstract]));
5. ((Supratrochlear artery [Title/Abstract]) AND (variation [Title/Abstract]));
6. ((Supratrochlear artery [Title/Abstract]) AND (depth [Title/Abstract]));
7. ((Supratrochlear artery [Title/Abstract]) AND (course [Title/Abstract]));
8. ((Supratrochlear artery [Title/Abstract]) AND (cosmetic procedure [Title/Abstract]));
9. ((Supratrochlear artery [Title/Abstract]) AND (plastic surgery [Title/Abstract]));
10. ((Supratrochlear artery [Title/Abstract]) AND (ultrasonography [Title/Abstract])).

Eligibility assessment

After the search of the databases and an additional manual search through the references, a total of 1767 records were identified and reviewed by two independent reviewers. After removing duplicates and irrelevant records, a total of 630 articles were qualified for full-text evaluation. Papers such as case reports, case series, conference reports, reviews, letters to editors, and studies that provided incomplete or irrelevant data were excluded to minimise potential bias and maintain an accurate statistical methodology. The inclusion criteria involved original studies, based on USG imaging, with extractable numerical data on the general anatomy of the supratrochlear and supraorbital arteries. A total of n = 51 articles were excluded from the study because they did not have required data or because they did not have relevant and/or sufficient data regarding the anatomical depth parameters of the STA or SOA. In cases where the authors did not provide the exact data of average vessel depth, the measurements were included bilaterally to minimise the bias. Finally, a total of 5 studies were included in this meta-analysis [7–11]. The AQUA Tool, which was specifically designed for anatomical meta-analyses, was used to minimise the potential bias of included studies [12].

Data extraction

Two independent reviewers performed the extraction. qualitative data, such as year of publication, country, and continent, were gathered. quantitative data, such as sample size, and numerical data regarding the anatomical aspects of the facial artery were gathered. Any discrepancies between the studies identified by the two reviewers were resolved by contacting the authors of the original studies whenever possible or by consensus with a third reviewer.

Statistics and software

For random effect model: A random-effects model was fitted to the data. The amount of heterogeneity (τ^2) was estimated using the restricted maximum-likelihood estimator [13]. In addition to the estimate of τ^2, the Q-test for heterogeneity [14] and the I^2 statistic [15] are reported. If any amount of heterogeneity is detected (*i.e.*, $\hat{\tau}^2 > 0$, regardless of the results of the Q-test), a prediction interval for the true outcomes is also provided [16].

For Common (Fixed) Effect Model: A fixed-effects model was fitted to the data. The Q-test for heterogeneity [14] and the I^2 statistic [15] are reported.

For both models: Studentized residuals and Cook's distances are used to examine whether studies may be outliers and/or influential in the context of the model [17]. Studies with a studentized residual larger than the $100 \times (1 - 0.05/(2 \times k))$th percentile of a standard normal distribution are considered potential outliers (i.e., using a Bonferroni correction with a two-sided $\alpha = 0.05$ for k studies included in the meta-analysis). Studies with a Cook's distance larger than the median plus six times the interquartile range of the Cook's distances are considered to be influential.

The rank correlation test [18] and the regression test [19], using the standard error of the observed outcomes as a predictor, are used to check for funnel plot asymmetry.

The I-square statistics were interpreted as follows: values of 0–40% were considered 'may not be important', values of 30-60% were considered 'may indicate moderate heterogeneity', values of 50–90% were considered 'may indicate substantial heterogeneity' and values of 75–100% were considered 'may indicate substantial heterogeneity'.

Calculation software

Significance level for all statistical tests was set to 0.05 ($p < 0.05$, 95% CI). The calculations were performed using the following programs: R version 4.3.1 (2023-06-16) [20, 21] (R Core Team, 2020), RStudio v. (2023.06.1+524) for MacOs Sonoma 14.6.1 (Apple, Inc., Cupertino, CA, USA).

RESULTS

Based on the random effects model analysis we obtained the following depths results:

A total of n = 201 SOA arteries were included in the analysis at the horizontal level of the glabella with final depth result 5.68, 95% CI (4.58–6.78) [mm] (Fig. 4).

A total of n = 160 SOA arteries were included in the analysis above the eyebrow with final depth result of 5.53, 95% CI (4,79–6.28) [mm] (Fig. 4).

A total of n = 282 STA arteries were included in the analysis at the horizontal level of the glabella with final depth result 4.45, 95% CI (3.43–5.47) [mm] (Fig. 4).

A total of n = 327 STA arteries were included in the analysis at the horizontal level above the eyebrow with final depth result 3.53, 95% CI (3.21–3.85) [mm] (Fig. 4).

CONCLUSIONS

1. The supratrochlear artery becomes more superficial on its path.
2. The supraorbital artery is staying on same level on distinguished levels .
3. In more medial part of the forehead the injections should be placed up to 2.5 mm or placed laterally to the path of the artery.
4. In the more lateral part of the forehead the injection can be placed a little deeper up to 3.5 mm.
5. The most reasonable way to avoid complications is to perform the High-linear USG exam and place the needle laterally or medially to the vessels.

DISCUSSION

The frontal area is especially crucial while performing the botox procedures of the frontal zone. Due to various anastomoses, the glabella, forehead, and temple in the upper region of the face, as well as the nasolabial fold, tear trough, and nasal area, have been identified as high-risk zones by Isaac et al. [22]. STA lies within the glabellar frown line in 50% of cases [23]. The practical implication for that anatomical variability is filling the glabellar frown lines in a specific manner. Fillers should be injected using serial puncture technique with small aliquots deposited intradermally at a 90º angle to the glabellar crease. Recommendation for dermal injections is into the offending rhytides with a low-G′ filler using a serial puncture technique. One of possible solutions for avoiding complications is occluding the supraorbital and supratrochlear vessels with fingertip at the level of orbital rim to prevent retrograde flow of foreign material into the ophthalmic artery in the event of inadvertent intravascular injection [24]. Especially that the supraorbital nerve exit can be easily palpated along the supraorbital rim in a patient which runs with STA. In major cases the supraorbital notch can be also palpated because this anatomical variation is more common [25].

Based on the Ozturk et al [26]: Blindness was most often associated with injection of the glabella. Colon et al. provided meta-analysis about mild and not severe side effects related to cosmetic fillers [27]. Complications after fillers may range from minor issues, such as transient swelling and bruising, to severe complications, including vascular occlusion leading to tissue necrosis or vision loss [26, 28–32]. Vascular occlusion remains one of the most alarming complications resulting from dermal filler injections. Instances where filler material inadvertently enters a blood vessel can lead to ischemia, resulting in skin necrosis, permanent disfigurement, or even blindness [1, 32]. The most common side effects after the BTX include pain, edema, erythema, ecchymosis, and short-term hypesthesia. These do not differ from side-effects after other types of injections [33]. For now there is only one documented blindness case after BTX [34]. To avoid the complication Lee et al. suggests that a USG device might be a reasonable way to increase safety measures before any esthetic procedures [35]. The research published by Samizadeh S et al. [36] also recommends this solution. The USG probe might be also used in patients with vascular occlusion. Ultrasound color-flow (duplex mode) helps to determine the area with no flow or turbulent flow indicating vessel obstruction [37]. The USG might be also used to check the filler persistence as a valuable and non-invasive tool for identifying the site, quantity, real-time diagnosis of the type of implant or filler that has been placed or injected [38–41]. A detailed understanding of vascular anatomy, including the location and depth of these arteries, is critical for minimising the risk of intra-arterial injection and the associated complications [4, 29]. The increasing prevalence of non-medically trained individuals performing cosmetic procedures adds an additional layer of concern regarding patient safety. As the demand for aesthetic enhancements grows, it is imperative that trained healthcare professionals advocate for regulatory measures to ensure safe practice standards [26]. A unified protocol for reporting anatomical variations is essential to standardize descriptions, enhance clinical relevance, and ensure consistency in evidence-based anatomical research [42]. Continuous education regarding advancements in aesthetic medicine, including updated anatomical knowledge and emerging imaging technologies, is vital for practitioners to stay informed and provide the highest standard of care [2, 4].

Limitations

The primary limitation of our study is the broad origin of the included studies. Different human populations can have potentially different average depth of the arteries. Different human populations may exhibit varying average depths of arteries, and factors such as age, gender, and genetic predispositions could influence these differences. The primary issue related to the USG based research is how they could have been influenced by the amount of force applied while performing the measurement. The epidermis, the dermis and subcutaneous tissue undergo temporary elastic deformation when an appropriate force is applied to a specific point. Some studies have also examined how facial expressions can affect these measurements [8]. Future studies should separate the measurements obtained with probes pressed from those obtained without pressing. Clinically, this is still going to be relevant because the dermis can always be pressed by a finger before an injection, creating a controlled situation in which the needle can pierce tissue layers safely.

ARTICLE INFORMATION AND DECLARATIONS

Authors' contributions

Mateusz Trzeciak: search, extraction, literature, statistical analysis, writing, methodology. **Tomasz Gładysz:** methodology, extraction. **Wojciech Przybycień:** search, dissection. **Jędrzej Bartoszcze:** writing, dissection. **Julia Pisarek:** writing, search, dissection. **Michał Mordarski:** writing, dissection. **Joe Iwanaga:** methodology, statistical analysis, writing. **Mateusz Koziej:** methodology, statistical analysis, writing. **Jerzy Walocha:** methodology, statistical analysis, writing.

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Conflict of interest

The authors declare that they have nothing to disclose and there is no potential conflict of interest between all the co-authors.

Supplementary material

The supplementary materials are available on Journal's website. This include:

Supplementary Figure 1. Funnel plot, depth of supratrochlear artery at the level of glabella.

Supplementary Figure 2. Funnel plot, depth of supratrochlear artery above the eyebrow.

Supplementary Figure 3. Funnel plot, depth of supratorbital artery at the level of glabella.

Supplementary Figure 4. Funnel plot, depth of supraorbital artery above the eyebrow.

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Table 1. Research included in meta-analysis.

	Author	**Country**	**Year**	**N**	**Type of exam**
1.	Güvenç [7]	Türkiye	2022	71	USG
2.	Cotofana [8]	USA	2020	41	USG
3.	Phumyoo [9]	Thailand	2020	25	USG
4.	Shen [10]	China	2023	37	USG
5.	Khorasanizadeh [11]	Iran	2023	43	USG

USG — ultrasonography.

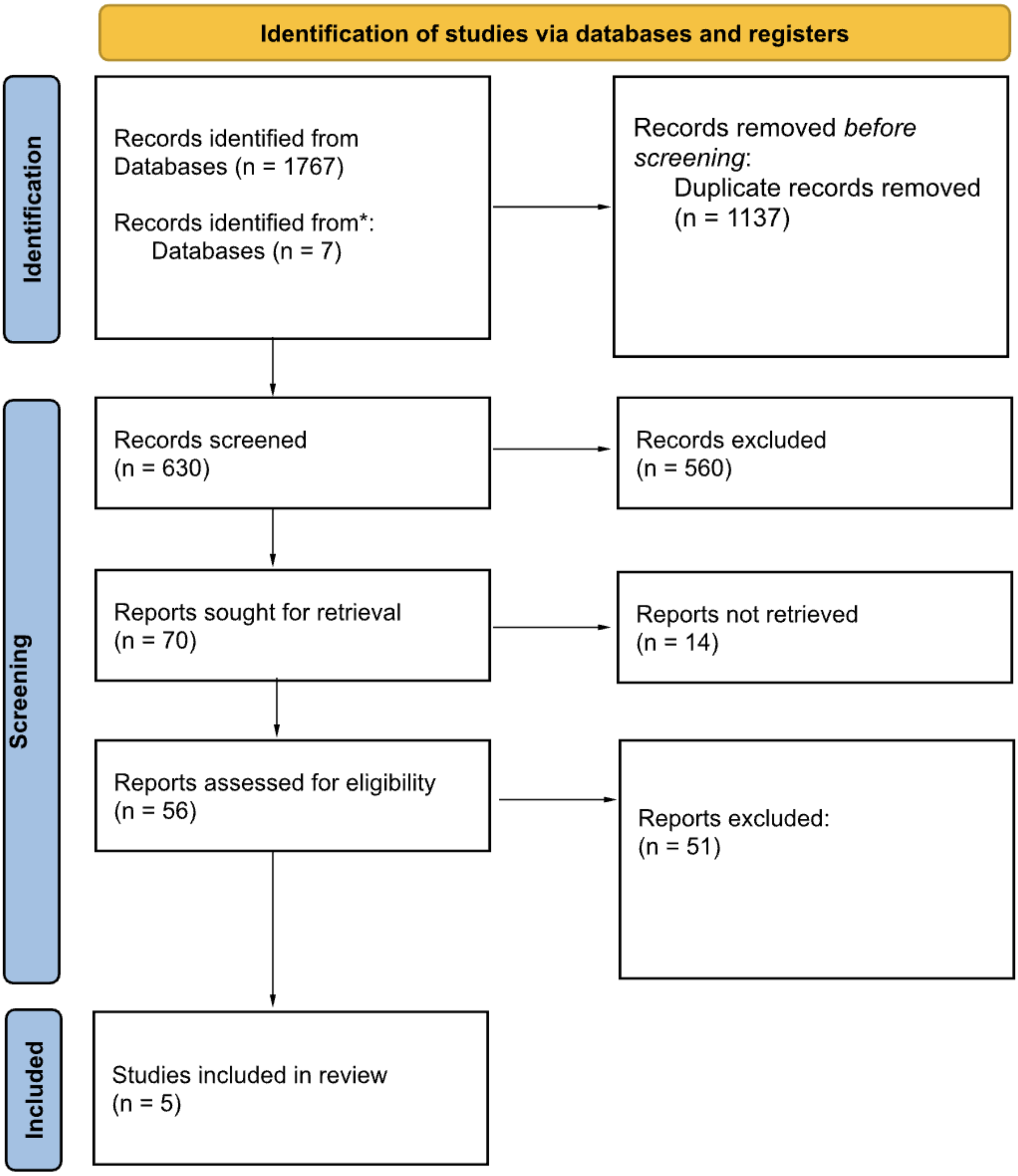


Figure 1. Flow diagram PRISMA.

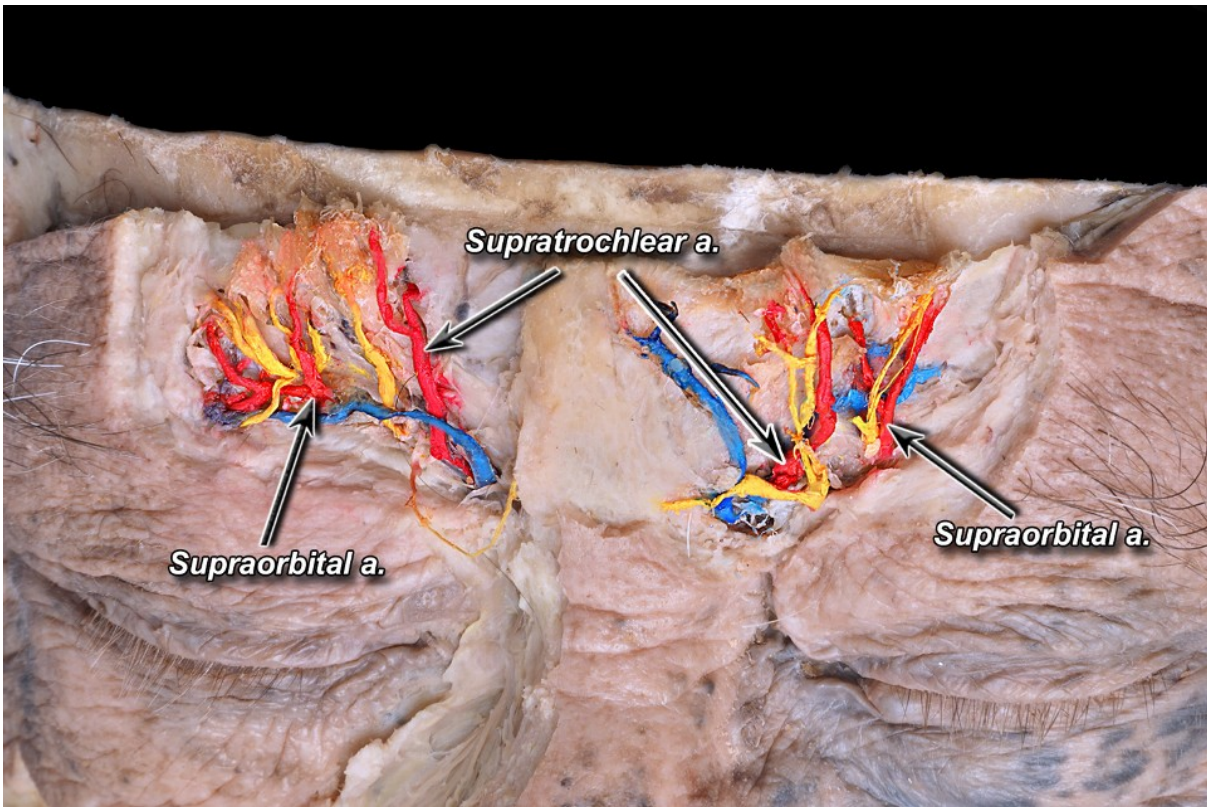


Figure 2. Cadaveric image with dissected supraorbital and supratrochlear artery.

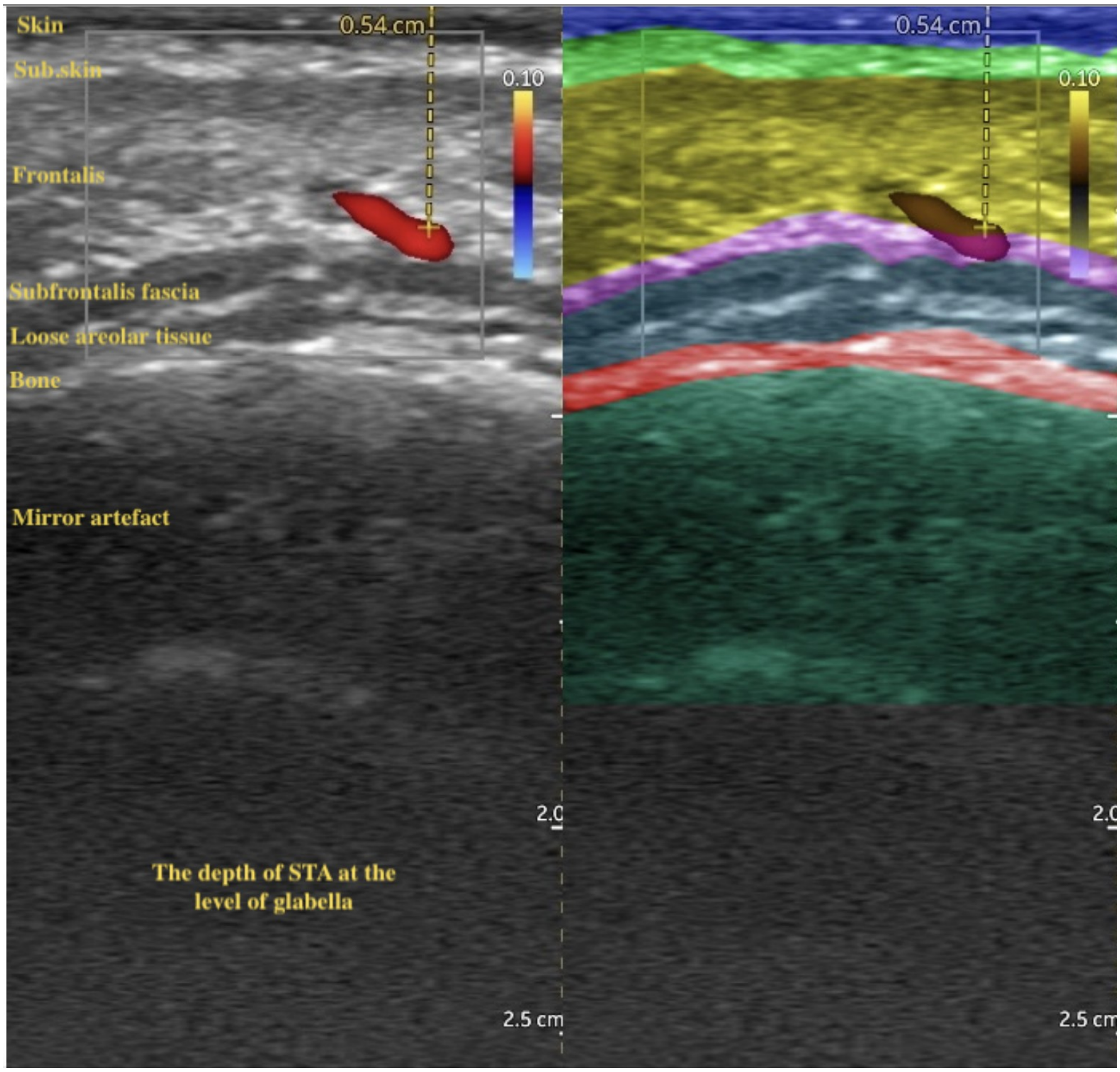


Figure 3. The ultrasonography (USG) picture was performed at Jagiellonian University Anatomy department using a wireless Vscan USG probe to show simplicity of procedure performed by a physician. The separate layers were distinguished with different translucent colors. STA — supratrochlear.

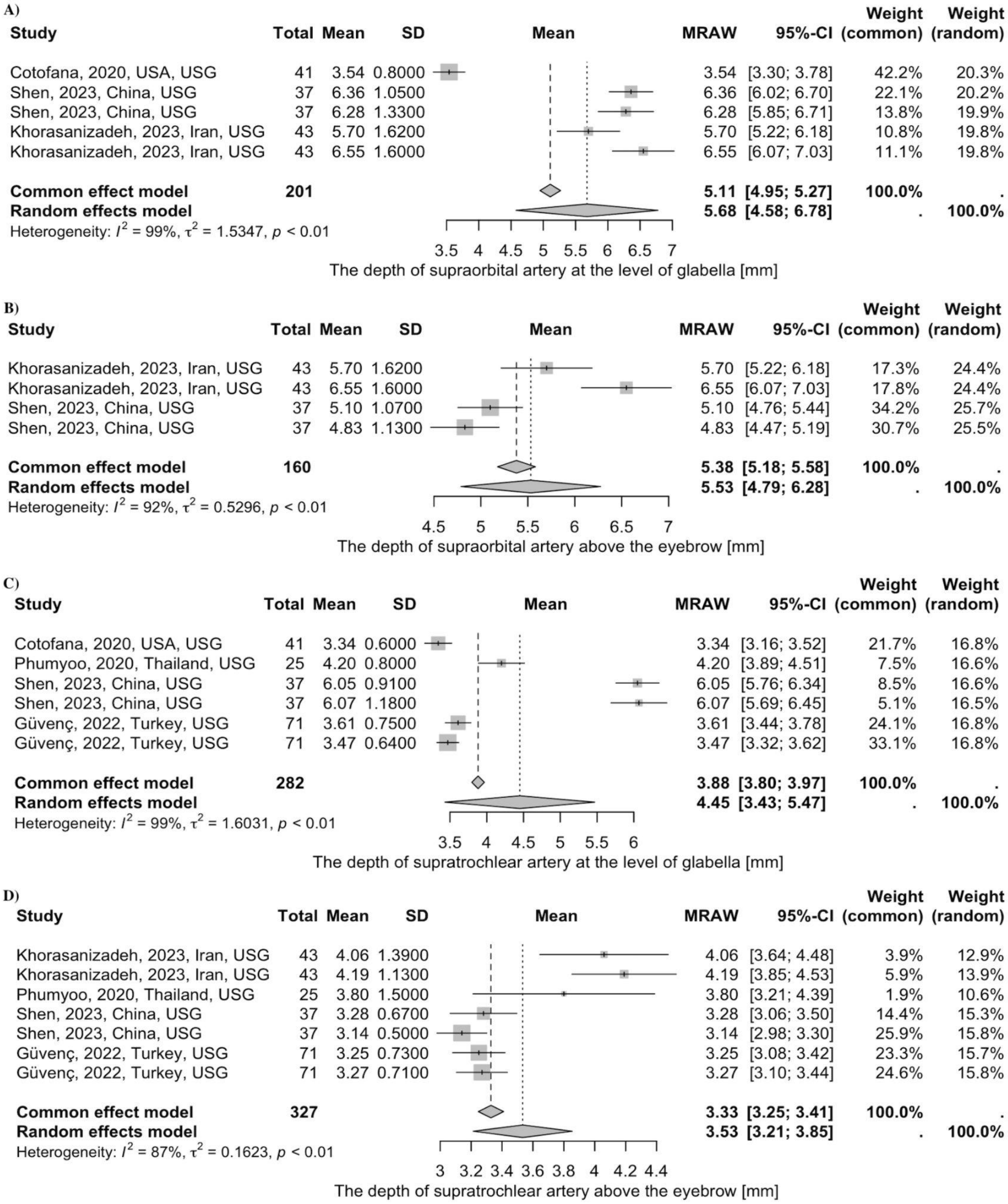
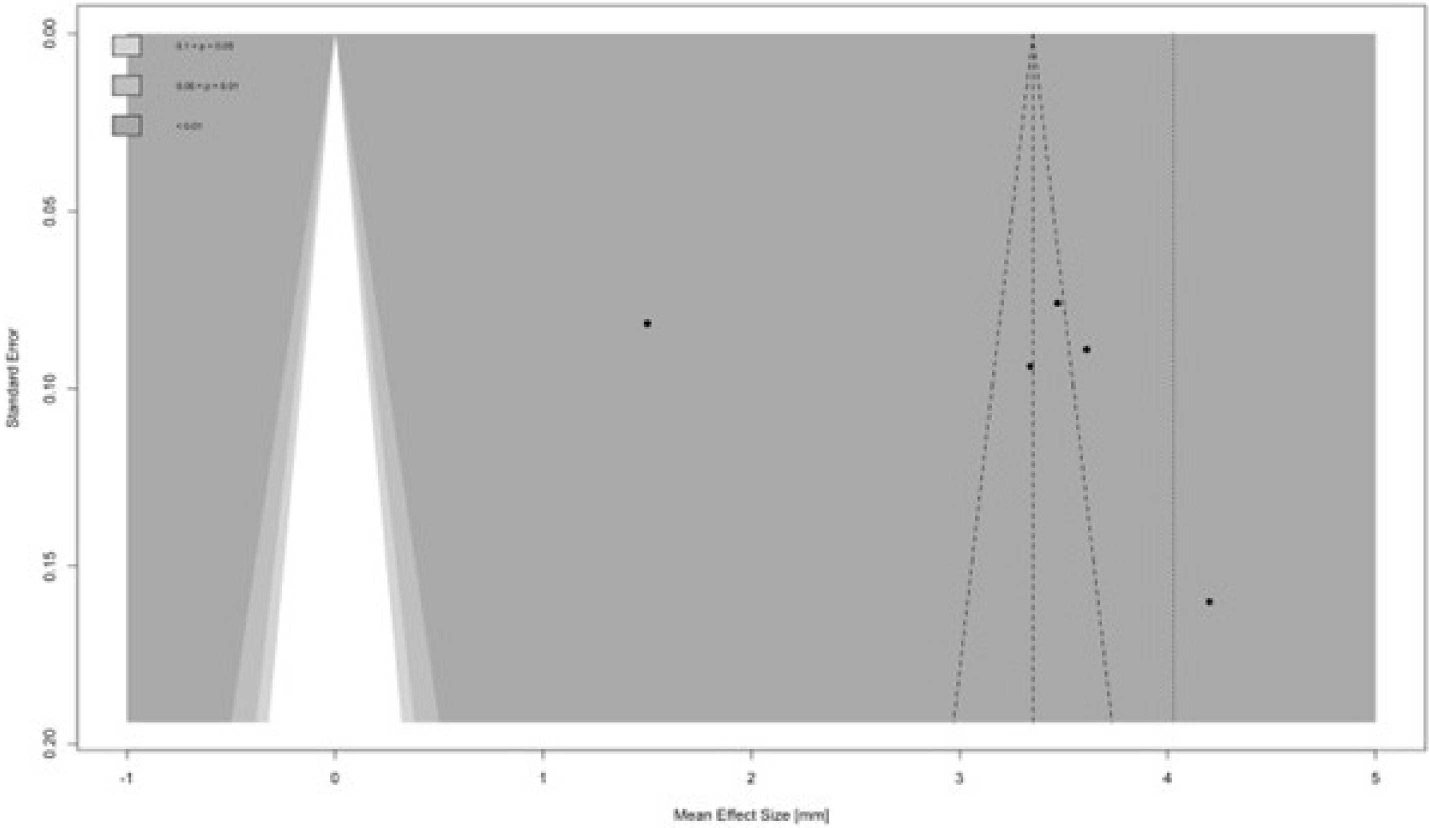


Figure 4. Combined Forest plot. **A.** The depth of supraorbital artery at the level of glabella; **B.** The depth of supraorbital artery above the eyebrow; **C.** The depth of supratrochlear artery at the level of glabella; **D.** The depth of supratrochlear artery above the eyebrow. CI — confidence interval; MRAW — mean residual absolute deviation; SD — standard deviation; USG — ultrasonography.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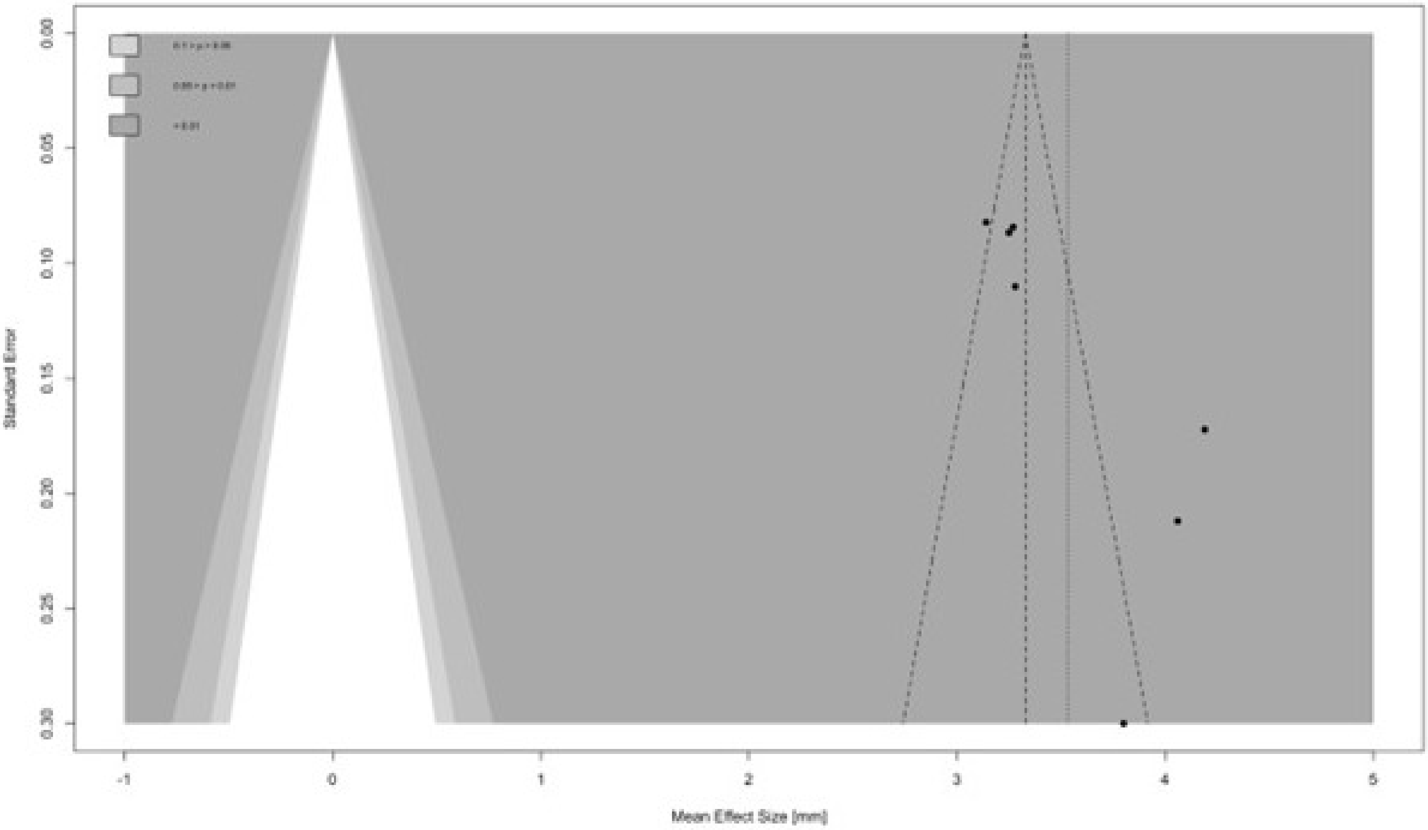
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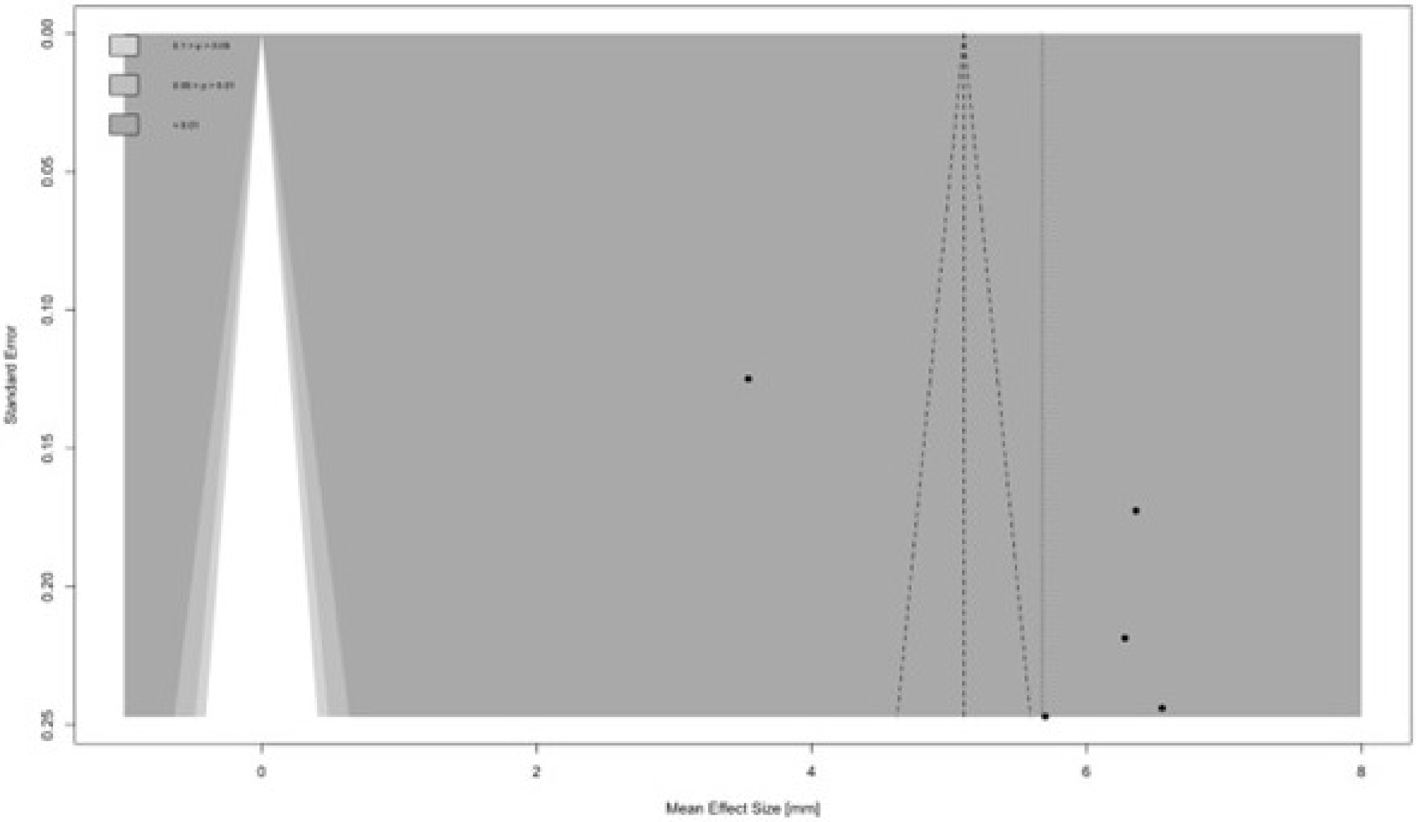

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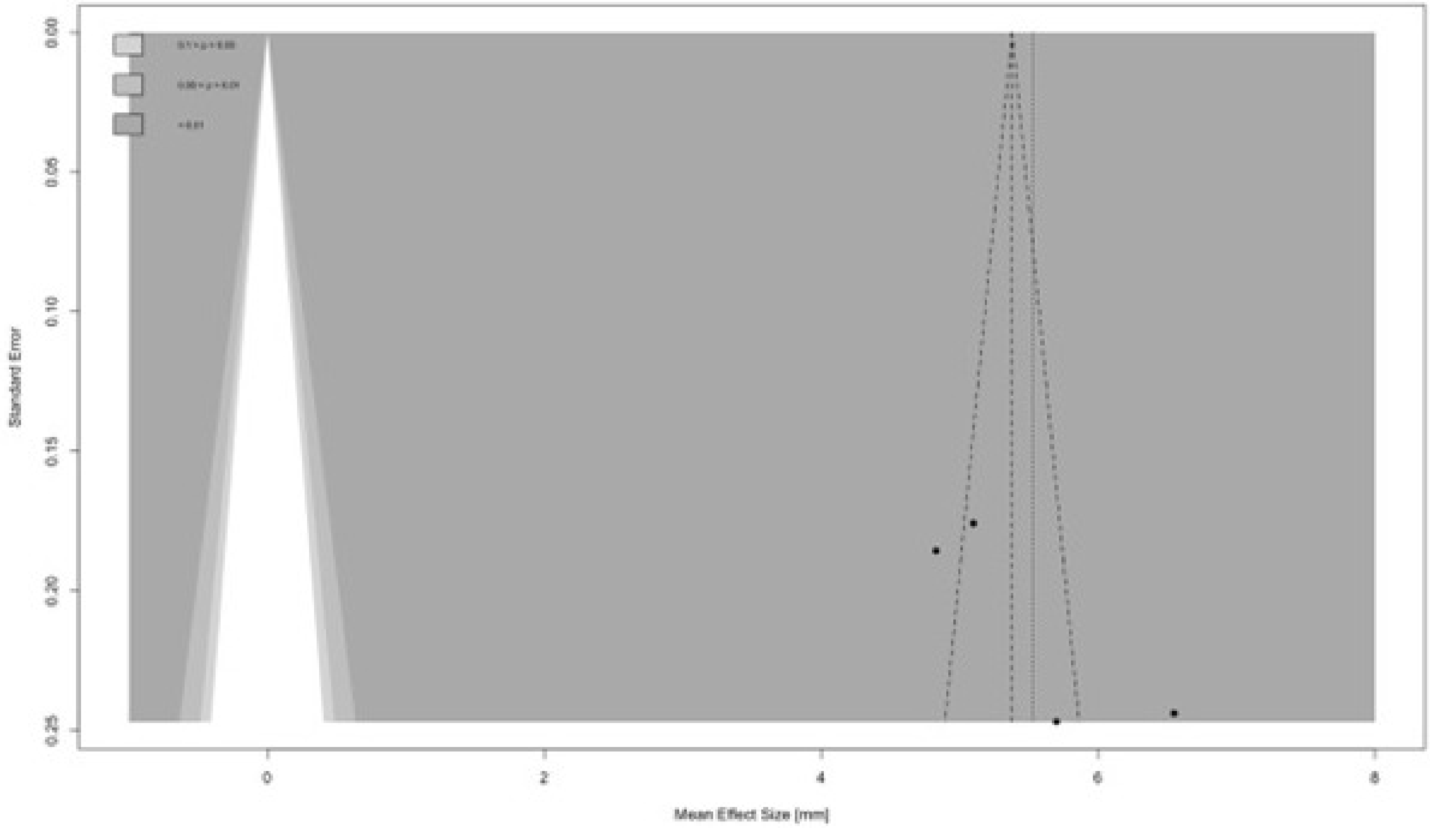
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