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Review article

Perineal deformation during forceps, vacuum and OdonAssist™ assisted vaginal deliveries: A simulation study based on advanced image processing☆

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ABSTRACT

Objectives: The aim of this study was to analyse influence of the fetal head position and the type of instrument used (forceps, vacuum, OdonAssist™) on perineal deformation, during simulated vaginal deliveries monitored by stereophotogrammetry.

Methods: An exploratory study was conducted using mannequins simulating vaginal births. Fifty simulated deliveries were performed with different fetal head positions and instruments: Pajot's forceps, Kiwi-vacuum, and OdonAssist™. Stereophotogrammetry measured perineal deformations called equivalent strains E_{eq}.

Results: E_{eq} during spontaneous deliveries were minimal, average, and maximal at 0.8 %, 5.8 %, and 11.6 %, respectively. Assisted vaginal births (AVB) showed slightly higher strains compared to spontaneous deliveries. In the occipito-posterior position (OP), strains were significantly higher ($p < 0.05$). Equivalent strain Eeq trend towards higher mean (6.7 ± 0.6 %) and maximum (12.3 ± 0.8 %) with forceps compared to other methods in the occiput anterior position (OA), especially against spontaneous (mean: 5.3 ± 0.5 % and max: 9.9 ± 0.6; p = 0.06), vacuum AVB (mean: 4.6 ± 1.0 % and max: 9.4 ± 0.1 %, p = 0.06) and OdonAssist™ AVB (mean: 3.8 ± 0.9 % and max: 8.8 ± 1.0 %, p = 0.06). Forceps induced greater strains compared to vacuum and OdonAssits™. In OP position, OdonAssist™ tend to lower mean equivalent strain E_{eq} compared to spontaneous vaginal deliveries (4.9 ± 0.6 % vs 6.4 ± 0.5 %, p = 0.06).

Conclusion: Results confirmed increased mechanical perineal stress for OP fetal position and for forceps assisted deliveries compared to others devices. The OdonAssist™ may offer a less invasive alternative, reducing perineal strains. Stereophotogrammetry provides valuable data on the mechanical effects of childbirth.

Introduction

Vaginal childbirth is a complex physiological process that can lead to perineal tears, affecting approximately 9 out of 10 women [1,2]. Second-degree perineal tears are twice as likely to occur in primiparous births, with a incidence of 40 % [1–3]. The incidence of obstetrical anal sphincter injuries (OASIS) ranges between 1 % and 6 % in France, the United States, the United Kingdom and the Nordic countries [1,3–6]. Perineal trauma of any grade can lead to significant physical and psychological morbidity in both the immediate postpartum period and the long term [7]. As such, preventing and managing these tears are critical priorities for obstetricians. Several risk factors have already been identified, including the posterior fetal head position and instrumental deliveries [8–12]. According to the Cochrane 2021 review comparing forceps and vacuum, forceps were more likely to achieve vaginal birth, but were associated with a greater number of perineal tears, including OASIS [13].

Among the instruments for assisted vaginal deliveries, a new device has emerged: the OdonAssist™ device. The OdonAssist™ is a trademarked inflatable device (Maternal Newborn Health Innovations, PBC,

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Parsippany, NJ) designed for assisted vaginal births (AVB). It is intended to be safer, easier to use, and more acceptable to women and obstetricians compared to current instruments [14–16]. This innovative device uses a circumferential air cuff that generates lower pressure on the fetal head than forceps [17,18]. It combines three key mechanical principles—propulsion, flexion, and traction—to facilitate the progression of the fetal head. According to Mottet et al., the OdonAssist device has garnered increasing interest due to its potential to reduce perineal trauma: 47 % of intact perineum, 36 % of first-degree perineal tear, 13 % of second-degree, 2 % of third-degree (3A and 3B only) and no fourth-degree, in a prospective cohort of 104 assisted vaginal deliveries using the OdonAssist™ device [14].

From a biomechanical perspective, no study has assessed or compared perineal stress induced by instruments, which could inform the choice of instrument when necessary. Understanding perineal behaviour is essential to understand perineal tears, but in vivo experimentation raises ethical issues. Data concerning the mechanical properties of the perineum and fetal stresses during delivery are very limited [19–24]. To address this gap, stereophotogrammetry offers an innovative and non-invasive method for accurately measuring perineal deformations. This technique can be used in vivo or using mannequins simulating childbirth [25].

The hypothesis of this work was that perineal deformation increased when the fetal was in a posterior position and during instrumental deliveries, with forceps and vacuum in decreasing order. Indeed, perineal deformation increases when the tissue undergoes a significant strain. It could be correlated with higher incidence of clinically significant perineal tears, including second-degree tears and OASIS. One interesting advantage of the OdonAssist™ is the use of a soft air cuff inflated around the fetal head. With the circumferential support of the air-cuff, we think that perineal deformation could be better controlled and distributed, providing a good perineal support during head crowning limiting risk of perineal tears.

Therefore, the aim of this study was to analyse the influence of the fetal head position and the type of instrument used on perineal deformation, including the OdonAssist™ device, during simulated vaginal deliveries monitored by stereophotogrammetry. This study aims to identify instruments that induce the least perineal tension and improve the dispersion of forces to minimize perineal trauma during assisted delivery.

Methods

Simulation of operative vaginal births

An exploratory study was conducted in August 2023.The PROMPT birthing simulator fetal mannequin was used with a PROMPT Flex maternal mannequin birthing simulator (Limbs & Things Ltd, Bristol, UK) for the simulation of vaginal births, which has been certified for ten years and blinded to the measuremed data. All simulated vaginal birth (instrumental or not) were conducted by a single obstetrician. The PROMPT Flex® birthing simulator fetal mannequin has, an average size head for a term fetus with a bi-parietal diameter (BPD) of 96 mm, comparable to the 50th centile of 97 mm at 39–40 weeks' gestation [18,26]. Forty simulated vaginal deliveries were performed: 20 with a fetus in occipito-anterior (OA) position and 20 with a fetus in occipito-posterior (OP) position. Transverse positions were not studied. For both head position, 5 were non-assisted deliveries, 5 Kiwi-vacuum AVB, 5 Pajot's forceps AVB and 5 OdonAssist™ AVB.

For all deliveries, the maternal mannequin birthing simulator was fixed on a table. The maternal and fetal mannequins were lubricated. All vaginal birth were simulated on the same way. For vacuum AVB, a Kiwi vacuum was used. Its cup was placed on the flexion point of the fetal mannequin. For forceps AVB, a Pajot forceps was used. Regardless the instrument, traction direction followed the umbilical-coccygeal axis. The OdonAssist™ device consist of a plastic applicator and polyester sleeve (Fig. 1). The sleeve constrains a circumferential air chamber that is inflated around the fetal head, providing the grip for the operator to apply traction. When the head is crowding, the cuff is deflated and the delivery ends as usual. Regardless the head position, vertex was always, clinically, 2 cm below the ischial spines (station + 2 cm).

Stereophotogrammetry

Perineal deformation data were obtained with stereophotogrammetry (Fig. 2). The stereophotogrammetric system consists of two digital stereovision cameras (Alvium 1800 U-508 with Sony IMX250 CMOS sensor, Allied Vision Technologies GmbH, Germany) (Fig. 3).

Stereovision cameras were installed on the right of the right-handed operator, on a fixed articulated support, at a slight angle to provide an optimal view of the posterior fourchette, the area of interest. The cameras were parallel and 3 cm apart and at 50 cm from the region of interest.

After installation, the first step was calibration to obtain an accurate reconstruction of the geometry. A planar calibration object and then a non-planar calibration object were used. The planar calibration object was placed in various positions within the cameras' field of view. The number of rows and columns, as well as their spacing, had to be recorded. Several images were simultaneously captured by both cameras. In contrast, only a single image from each camera was needed for the non-planar calibration object. In this case, a cylindrical calibration object with known 3D positions in the real world was used. The 3D world coordinates could be created using a script that included the calibration object's diameter, the number of rows and columns, the size of the squares, and their spacing.

The next step was image acquisition. A speckle pattern with black paint was applied to the skin surface of the porcine perineum. To do this, a toothbrush was used to randomly project small droplets of paint, creating a pattern of black dots on the surface (Fig. 4). This irregular and random pattern was essential to facilitate deformation tracking during digital image correlation analysis. The speckle application was carried out before the simulation of spontaneous delivery or before the insertion of instruments except for OdonAssist AVB. In fact, in order to facilitate the procedure, the Odon device was placed on the foetus and then the whole unit was placed in the pelvis. Then the speckle was applied.

The light sources were LED bars equipped with high-power LEDs and polarizers, primarily used to eliminate glare. Thus, the obtained images were polarized color images. The images from both cameras were synchronized using internal or external triggers. The system uses Vimba-Python, an open-source Python application programming interface, to set camera parameters and synchronize acquisition using the Python "multithreading" function (simultaneous execution of two tasks, i.e., image acquisition from both cameras in parallel).

The 3D reconstruction of the stereophotogrammetric system was performed using the MultiDIC (Multi Digital Image Correlation) program. MultiDIC is an open-source MATLAB toolbox for performing 3D digital image correlation with multiple cameras. It integrates the open-source Ncorr software, which, using several camera calibration algorithms, can reconstruct 3D surfaces from stereophotogrammetric image pairs.

The role of the speckle pattern was to facilitate the tracking of spots

Fig. 1. The OdonAssist™ device with its aircuff (without the applicator).

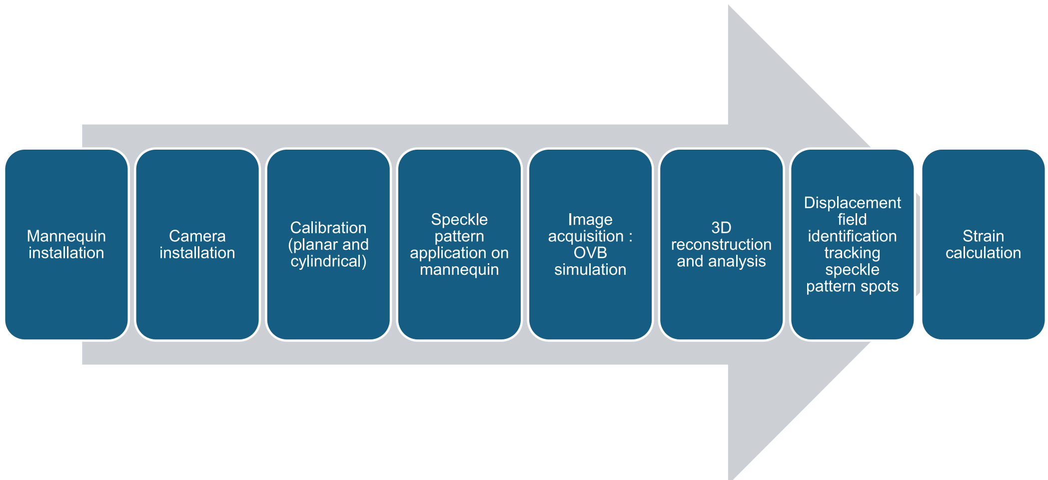


Fig. 2. Main steps of the procedure. OAB: operative vaginal delivery.

and to identify a displacement field from which the conventional strain field was calculated. Rigid body movements could also be identified to calculate deformations. Understanding the behavior would then allow for the identification of stress fields. The following measurements were taken at the end of traction and averaged afterwards [23]: equivalent strains (Eeq) at the perineum. Deformation data were obtained at expulsion of the head, at maximum stress. A region of interest (ROI) was determined regarding the posterior fourchette (the blue square in Fig. 4). The equivalent strain E_{eq} in the perineal plane is defined as: $E_{eq} = \frac{2}{3}\sqrt{(E_1^2 + E_2^2 - E_1E_2)}$, with E_1 as maximum principal strain, E_2 minimum principal strain and $E_3 = 0$ since it is in the same plane. The strain values were presented with their minimum, mean, and maximum among all the nodes of the ROI.

Statistical analysis

Results are presented using descriptive statistics for distention data in each scenario.

Initially, we analyzed the data on perineal deformations (E_{eq}) during spontaneous vaginal deliveries, comparing anterior and posterior fetal head positions. Subsequently, we extended this analysis to AVB. Data were analysed using a Wilcoxon test or Kruskal-Wallis test according to the number of groups that were compared. Then a Wilcoxon signed rank test for pairwise comparisons was performed if p-value vas ≤ 0.05 at the Kruskal-Wallis test. A p-value ≤ 0.05 was considered evidence of group difference. Analyses were conducted using R software (4.3.2 version).

Results

Equivalent strains E_{eq} during spontaneous vaginal deliveries were in minimum, in average and in maximum 0.8 % ± 0.9, 5.8 % ± 0.9 and 11.6 % ± 2.0, respectively. Equivalent strains E_{eq} during AVB were in minimum, in average and in maximum 0.5 % ± 0.5, 5.9 % ± 1.6 and 12.1 % ± 2.5, respectively.

Mean and maximum equivalent strains E_{eq} during spontaneous vaginal deliveries or AVB were statistically higher in the OP position compared to OA position (Table 1). In the OA position, the mean and maximum equivalent strains E_{eq} were significantly different across delivery methods, with p-values < 0.01 (Table 2). In the OP position, the mean and maximum equivalent strains E_{eq} also showed significant differences (p-values <0.01).

Overall, in Table 2 and 3, forceps tend to show higher equivalent strain E_{eq} across both OA and OP positions ($p = 0.06$), while OdonAssist™ generally showed lower strain values. Comparisons of equivalent strain E_{eq}, forceps showed a trend towards higher mean (6.7 ± 0.6 %) and maximum (12.3 ± 0.8 %) equivalent strain E_{eq} compared to other methods in the OA position: spontaneous deliveries (mean: 5.3 ± 0.5 % and max: 9.9 ± 0.6; $p = 0.06$), vacuum AVB (mean: 4.6 ± 1.0 % and max: 9.4 ± 0.1 %, $p = 0.06$) and OdonAssist™ AVB (mean: 3.8 ± 0.9 % and max: 8.8 ± 1.0 %, $p = 0.06$) (Table 3). A trend of lower maximum equivalent strain E_{eq} was found with OdonAssist ™ AVB compared to spontaneous vaginal deliveries in the OA position (8.8 ± 1.0 % vs 9.9 ± 0.6 %, $p = 0.06$). In the OP position, similar results were found. Comparisons of equivalent strain E_{eq}, forceps showed also a trend towards higher mean (7.8 ± 0.6 %) and maximum (16.8 ± 0.6 %) equivalent strain E_{eq} compared to other methods in OP position: spontaneous deliveries (mean: 6.4 ± 0.5 % and max: 13.2 ± 1.4; $p = 0.06$), vacuum AVB (mean: 5.3 ± 0.8 % and max: 12.7 ± 0.3 %, $p = 0.06$) and OdonAssist ™ AVB (mean: 4.9 ± 0.6 % and max: 12.3 ± 0.6 %, $p = 0.06$) (Table 4.). Vacuum AVB tend to induce a lower minimal equivalent strain E_{eq} compared to forceps in OP position (0.3 ± 0.2 % vs 0.9 ± 0.3 %, $p = 0.06$). In the OP position, OdonAssist ™ tend to lower mean equivalent strain E_{eq} compared to spontaneous vaginal deliveries (4.9 ± 0.6 % vs 6.4 ± 0.5 %, $p = 0.06$).

In summary, OP position always increased equivalent strain E_{eq} compared to the OA position: between 33 % and 40 % for the maximum equivalent strain E_{eq} and between 15 % and 20 % for the mean equivalent strain E_{eq} (Fig. 5). OdonAssist ™ and vacuum reduced equivalent strain E_{eq} compared to spontaneous vaginal deliveries regardless the fetal head position. Forceps increased equivalent strain E_{eq} compared to spontaneous vaginal deliveries regardless the head position.

Discussion

Analysis of perineal equivalent strain E_{eq} in different fetal head positions and delivery methods using obstetrical mannequins provides valuable insights into the perineal mechanical effects of childbirth. This study showed an increased mechanical stress in the OP fetal head position during spontaneous vaginal births and AVB, regardless of the instrument used. The results are in accordance with the literature. It is well-known that OP position are risk factor of perineal trauma during vaginal births [9,12].

During AVB in either the OA or OP position, forceps tended to increase the mannequin perineal equivalent strain E_{eq} compared to the vacuum and the OdonAssist ™. In vivo, forceps delivery has also been described as a perineal risk factor [8,11,27]. The most recent Cochrane review on AVB provided evidence that forceps may be more likely to achieve vaginal birth but may be associated with a greater risk of perineal trauma compared with vacuum [13]. From a biomechanical perspective, forceps exert a load on specific contact points on the

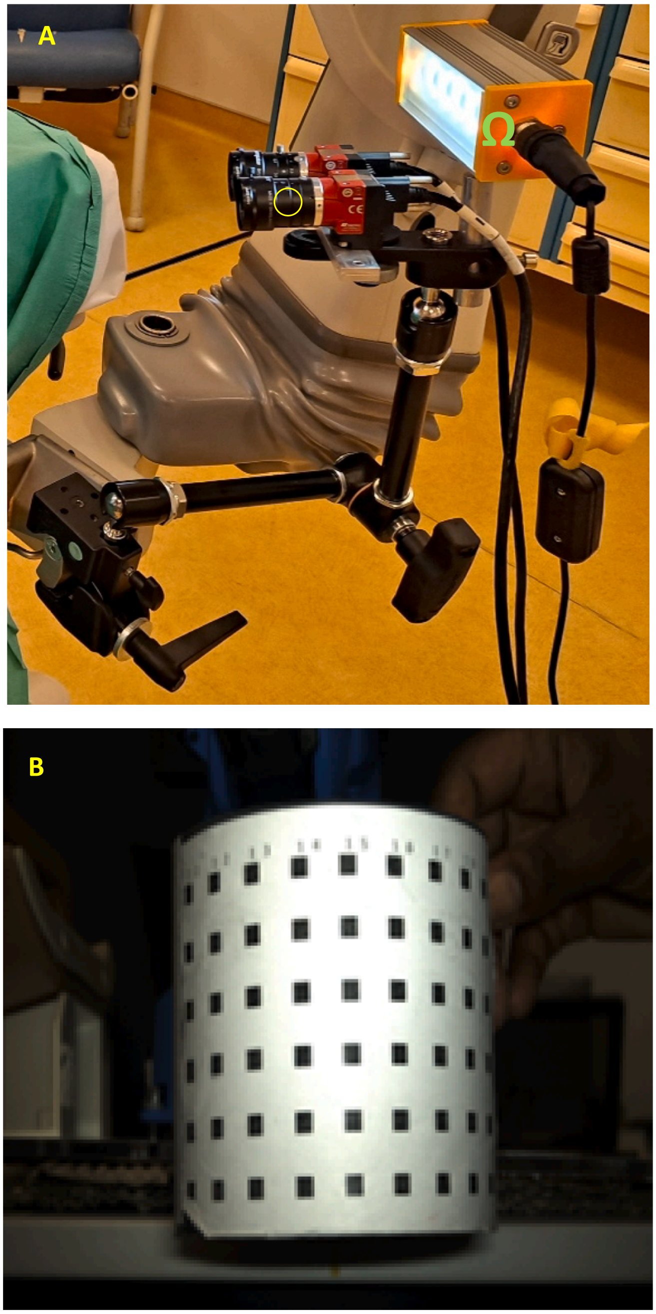
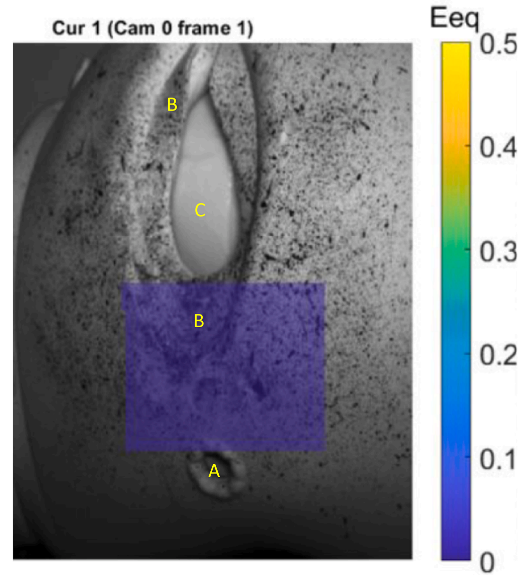


Fig. 3. Installation of stereophotogrammetry cameras (Alvium 1800 U-508 with Sony IMX250 CMOS sensor, Allied vision Technologies GmbH, Germany) on an articulated support and themselves mounted by LED bars (Ω) (A) and its cylindrical calibration object (B).

posterior perineum which is increased by traction and widening of the vaginal canal.

In the OA position, OdonAssist ™ device reduced the maximum equivalent strain on the mannequin perineum by 11 % and the mean equivalent strain by 28 %. These results were similar for deliveries in the OP position. These reductions in strain were greater with the OdonAssist ™ device than with the vacuum, but not statistically significant ($p > 0.05$), regardless of the head position. From a clinical perspective, these results support those from the Besançon Assist study [14]. In their study with a restrictive use of episiotomy (2.9 %), they manage to obtain a proper assessment regarding the clinical effect of the OdonAssist device on the perineum. In the study, the OASIS rate and intact perineum were 3.8 % and 44 % respectively. Perineal stress is likely to be reduced and



A. Anus, B. Posterior fourchette, C. Head, D. Right labia minora

Fig. 4. Region of interest in which the deformations (equivalent strain E_{eq}) have been studied (blue). Anus, B. Posterior fourchette, C. Head, D. Right labia minora.

Table 1
Comparison of equivalent strain E_{eq} between OA and OP position during spontaneous vaginal births or AVB.

	OA position	OP position	p-value
Spontaneous vaginal births			
E_{eq} min (%)	0.6 ± 0.5	1.1 ± 1.2	0.4
E_{eq} mean (%)	5.3 ± 0.5	6.4 ± 0.5	**0.02**
E_{eq} max (%)	9.9 ± 0.6	13.2 ± 1.4	**<0.01**
Vacuum AVB			
E_{eq} min (%)	0.4 ± 0.2	0.3 ± 0.2	0.8
E_{eq} mean (%)	4.6 ± 1.0	5.3 ± 0.8	0.4
E_{eq} max (%)	9.4 ± 0.1	12.7 ± 0.3	**<0.01**
Forceps AVB			
E_{eq} min (%)	0.5 ± 0.3	0.9 ± 0.3	0.1
E_{eq} mean (%)	6.7 ± 0.6	7.8 ± 0.6	**0.03**
E_{eq} max (%)	12.3 ± 0.8	16.8 ± 0.6	**<0.01**
OdonAssist AVB			
E_{eq} min (%)	0.3 ± 0.1	0.4 ± 0.2	0.5
E_{eq} mean (%)	3.8 ± 0.9	4.9 ± 0.6	**0.06**
E_{eq} max (%)	8.8 ± 1.0	12.3 ± 0.6	**<0.01**

AVB: Assisted vaginal deliveries; E_{eq}: equivalent strain; OA: occipito-anterior; OP: occipito-posterior.

better distributed during head crowning with the OdonAssist™ aircuff. We believe that the aircuff can mimic perineal manual support and help to control the head progression to better distribute the pressure on the perineum, preventing the initiation of tears. This concept is similar to that published by Lavesson et al. for a perineal protection device designed to protect the perineum during labor [28].

The results of this study complement those of O'Brien study [18]. They studied perineal distension from three fixed points on the maternal mannequin during simulated operative vaginal births performed with the OdonAssist™ device. They found that vacuum AVB and OdonAssist ™ AVB in the OA position induced similar maximum perineal distension, whereas forceps AVB was associated with higher maximum perineal distension.

Stereophotogrammetry is an innovative, non-invasive and non-destructive advanced image processing used to obtain biomechanical properties. This technique has diverse applications across various fields, including medical imaging, aerospace engineering, and industrial design

Table 2
Comparative analysis of equivalent strain E_{eq} in spontaneous and AVB versus AVB alone (Kruskal-Wallis test)".

	Spontaneous	Vacuum	Forceps	OdonAssist	p-value*	p-value**
OA position						
E_{eq} min (%)	0.6 ± 0.5	0.4 ± 0.2	0.5 ± 0.3	0.3 ± 0.1	0.5	0.4
E_{eq} mean (%)	5.3 ± 0.5	4.6 ± 1.0	6.7 ± 0.6	3.8 ± 0.9	**<0.01**	**<0.01**
E_{eq} max (%)	9.9 ± 0.6	9.4 ± 0.1	12.3 ± 0.8	8.8 ± 1.0	**<0.01**	**<0.01**
OP position						
E_{eq} min (%)	1.1 ± 1.2	0.3 ± 0.2	0.9 ± 0.3	0.4 ± 0.2	0.3	**0.02**
E_{eq} mean (%)	6.4 ± 0.5	5.3 ± 0.8	7.8 ± 0.6	4.9 ± 0.6	**<0.01**	**<0.01**
E_{eq} max (%)	13.2 ± 1.4	12.7 ± 0.3	16.8 ± 0.6	12.3 ± 0.6	**<0.01**	**<0.01**

AVB: Assisted vaginal deliveries; E_{eq}: equivalent strain; OA: occipito-anterior; OP: occipito-posterior
P-value * compares spontaneous deliveries and each sub-group of AVB (including vacuum, forceps, and OdonAssist)
P-value ** compares the sub-groups of AVB (vacuum, forceps, OdonAssist) between themselves.

Table 3
Wilcoxon signed-rank test p-values for pairwise comparisons of equivalent strain E_{eq} in spontaneous and assisted vaginal deliveries in OA position when the Kruskal-Wallis test indicated significant differences (Table 2).

p-value	Spontaneous	Vacuum	Forceps	OdonAssist
E_{eq} mean				
Vacuum	0.3	/	**0.06**	0.3
Forceps	**0.06**	**0.06**	/	**0.06**
OdonAssist	0.1	0.3	**0.06**	/
E_{eq} max				
Vacuum	0.1	/	**0.06**	0.3
Forceps	**0.06**	**0.06**	/	**0.06**
OdonAssist	**0.06**	0.3	**0.06**	/

E_{eq}: equivalent strain; OA: occipito-anterior; OP: occipito-posterior

Table 4
Wilcoxon signed-rank test p-values for pairwise comparisons of equivalent strain Eeq in spontaneous and assisted vaginal deliveries in OP position when the Kruskal-Wallis test indicated significant differences (Table 2).

p-value	Spontaneous	Vacuum	Forceps	OdonAssist
E_{eq} min (%)				
Vacuum	0.6	/	**0.06**	1
Forceps	1	**0.06**	/	0.1
OdonAssist	0.4	1	0.1	/
E_{eq} mean (%)				
Vacuum	**0.06**	/	**0.06**	0.3
Forceps	**0.06**	**0.06**	/	**0.06**
OdonAssist	**0.06**	0.3	**0.06**	/
E_{eq} max (%)				
Vacuum	0.6	/	**0.06**	0.3
Forceps	**0.06**	**0.06**	/	**0.06**
OdonAssist	0.2	0.3	**0.06**	/

Eeq: equivalent strain; OA: occipito-anterior; OP: occipito-posterior.

[29]. In the medical field, stereophotogrammetry has been used to measure wound healing, facial volumes, and to compare facial scanning systems [30–33]. Zemčík et al. used this technique to analyze deformation of the perineum during spontaneous vaginal delivery in order to identify clinical steps that might be beneficial when performing manual perineal protection [23]. They proposed a modified "hands-poised" technique for manual perineal protection in which the anterior hand only slows down the expulsion of the fetal head, and the posterior hand and its fingers are placed alongside the fourchette and vaginal opening precisely at the precise moment of expulsion. This concept is also similar to the aircuff concept of the Odon Assist ™ device and the Lavesson perineal protection device [28].

This study is the first one to provide quantified stereophotogrammetry data on perineal strain during simulated spontaneous and assisted vaginal deliveries. This information offers a more objective and detailed understanding of the biomechanical stresses on the perineum during childbirth. This is crucial as it moves beyond descriptive observations towards measurable data that can be used to refine clinical practices. For clinical practice, the results suggested that although assisted methods are necessary in some indicated clinical situations, they may result in increased mechanical strain, especially with forceps. However, the OdonAssist ™ may offer a less invasive alternative, potentially reducing strain on the posterior fourchette. In this study, perineal strains were obtained using a reproducible and valid technique [25]. All simulations were performed by a single operator, which promoted internal consistency of measurement and eliminated interoperator variability. However, there may be inherent limitations to this strategy, in particular the possibility of repeated systematic error. Another potential criticism of this study is the uncertainty whether our results can be generalised to actual use of the AVB device in clinical practice. However, the operator was well experienced with vacuum, OdonAssist ™ and forceps devices. For practical reasons, we only examined a small area of the perineum. It would be interesting to extend this research to other areas of the perineum. In addition, we used the PROMPT Flex maternal mannequin birthing simulator (Limbs & Things Ltd, Bristol, UK) to simulate vaginal birth in this study. It would be interesting to compare these results with other mannequin models. The other possible biases are related to the stereophotogrammetry itself. For example, the random application of speckle over the entire surface of the perineal part of the mannequin introduced significant variability. The number of speckle points was not consistent across the cohort, and the location of the deformation points varied from one field to field. This variability could affect the minimum, mean and maximum strain measurements. To improve reproducibility and reduce variability between samples, it would be beneficial to establish a precise pattern for the location and number of speckle points.

It is important to recognise that these results are preliminary because they are derived from a simulated environment using a mannequin modelled from CT scan data. Although the simulations were performed by an experienced obstetrician and the methods are rigorously described, caution should be exercised in extrapolating these findings directly into clinical recommendations requires caution. Further clinical trials are needed to validate these findings in vivo. Furthermore, the study focuses only on the biomechanical aspects of perineal strain. Other important factors influencing perineal tears, such as maternal tissue characteristics and the labour management, are not considered in this model. Therefore, the results should not be interpreted in isolation but as part of a broader understanding of perineal trauma.

Conclusion

Perineal strain measured by stereophotogrammetry during simulated assisted vaginal deliveries was increased for fetal OP position or during forceps AVB. However, OdonAssist™ may offer a less invasive alternative, potentially reducing perineal strain. Further research is needed to better understand obstetric and perineal biomechanics.

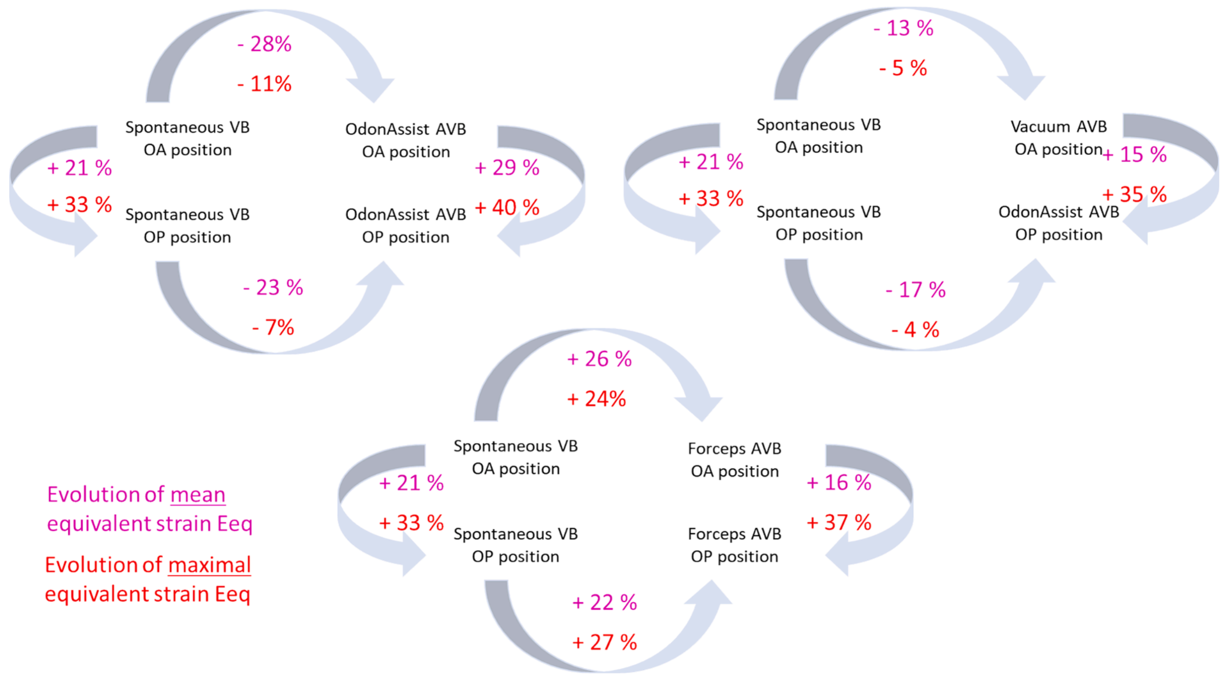


Fig. 5. Changes in the mean and maximum equivalent strain (E_{eq}) across spontaneous vaginal birth, different AVB methods and head position. AVB: Assisted vaginal deliveries; E_{eq}: equivalent strain; OA: occipito-anterior; OP: occipito-posterior.

CRediT authorship contribution statement

M. Lallemant: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **R. Ecoffet:** Methodology, Investigation, Data curation. **T. Kadiake:** Formal analysis, Data curation, Conceptualization. **J. Chambert:** Writing – review & editing, Methodology. **E. Jacquet:** Investigation, Conceptualization. **A. Lejeune:** Formal analysis, Data curation. **N. Mottet:** Writing – review & editing, Writing – original draft, Validation, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Okeahialam NA, Sultan AH, Thakar R. The prevention of perineal trauma during vaginal birth. Am J Obstet Gynecol 2023. https://doi.org/10.1016/j.ajog.2022.06.021. S0002-9378(22)00464-1.
[2] Smith LA, Price N, Simonite V, Burns EE. Incidence of and risk factors for perineal trauma: a prospective observational study. BMC Pregn Childbirth 2013;13:59. https://doi.org/10.1186/1471-2393-13-59.
[3] Le Ray C, Lelong N, Cinelli H, Blondel B, Collaborators - Members of the ENP2021 Study Group. Results of the 2021 French National Perinatal Survey and trends in perinatal health in metropolitan France since 1995. J Gynecol Obstet Hum Reprod 2022;(51):102509. https://doi.org/10.1016/j.jogoh.2022.102509.
[4] Landy HJ, Laughon SK, Bailit JL, Kominiarek MA, Gonzalez-Quintero VH, Ramirez M, et al. Characteristics associated with severe perineal and cervical lacerations during vaginal delivery. Obstet Gynecol 2011;117:627–35. https://doi.org/10.1097/AOG.0b013e31820afaf2.
[5] Laine K, Gissler M, Pirhonen J. Changing incidence of anal sphincter tears in four Nordic countries through the last decades. Eur J Obstet Gynecol Reprod Biol 2009;146:71–5. https://doi.org/10.1016/j.ejogrb.2009.04.033.
[6] Thubert T, Cardaillac C, Fritel X, Winer N, Dochez V. Definition, epidemiology and risk factors of obstetric anal sphincter injuries: CNGOF Perineal Prevention and Protection in Obstetrics Guidelines. Gynecol Obstet Fertil Senol 2018;46:913–21. https://doi.org/10.1016/j.gofs.2018.10.028.
[7] McDonald EA, Gartland D, Small R, Brown SJ. Frequency, severity and persistence of postnatal dyspareunia to 18 months post partum: A cohort study. Midwifery 2016;34:15–20. https://doi.org/10.1016/j.midw.2016.01.012.
[8] Lowder JL, Burrows LJ, Krohn MA, Weber AM. Risk factors for primary and subsequent anal sphincter lacerations: a comparison of cohorts by parity and prior mode of delivery. Am J Obstet Gynecol 2007;196(344):e1–5. https://doi.org/10.1016/j.ajog.2006.10.893.
[9] Pergialiotis V, Vlachos D, Protopapas A, Pappa K, Vlachos G. Risk factors for severe perineal lacerations during childbirth. Int J Gynaecol Obstet Off Organ Int Fed Gynaecol Obstet 2014;125:6–14. https://doi.org/10.1016/j.ijgo.2013.09.034.
[10] André K, Stuart A, Källén K. Obstetric anal sphincter injuries-Maternal, fetal and sociodemographic risk factors: A retrospective register-based study. Acta Obstet Gynecol Scand 2022;101:1262–8. https://doi.org/10.1111/aogs.14425.
[11] Gonzalez Rios AR, Zighelboim I, Anasti J, Merola J, Stoltzfus J, Lucente V. A search for novel risk factors for obstetric anal sphincter injury. Female Pelvic Med Reconstr Surg 2022;28:104–8. https://doi.org/10.1097/SPV.0000000000001077.
[12] Hu Y, Lu H, Huang Q, Ren L, Wang N, Huang J, et al. Risk factors for severe perineal lacerations during childbirth: A systematic review and meta-analysis of cohort studies. J Clin Nurs 2022. https://doi.org/10.1111/jocn.16438.
[13] Verma GL, Spalding JJ, Wilkinson MD, Hofmeyr GJ, Vannevel V, O'Mahony F. Instruments for assisted vaginal birth. Cochrane Database Syst Rev 2021;9. https://doi.org/10.1002/14651858.CD005455.pub3. CD005455.
[14] Mottet N, Hotton E, Eckman-Lacroix A, Bourtembourg A, Metz JP, Cot S, et al. Safety and efficacy of the OdonAssist inflatable device for assisted vaginal birth: the BESANCON ASSIST study. Am J Obstet Gynecol 2024;230:S947–58. https://doi.org/10.1016/j.ajog.2023.05.016.
[15] Hotton EJ, Lenguerrand E, Alvarez M, O'Brien S, Draycott TJ, Crofts JF, et al. Outcomes of the novel Odon Device in indicated operative vaginal birth. Am J Obstet Gynecol 2021;224:607.e1–607.e17. https://doi.org/10.1016/j.ajog.2020.12.017.
[16] Gonçalves-Henriques M, Brandão P. The BD Odon Device™: an update of its current state. J Obstet Gynaecol J Inst Obstet Gynaecol 2021;41:1057–61. https://doi.org/10.1080/01443615.2020.1837756.
[17] O'Brien SM, Winter C, Burden CA, Boulvain M, Draycott TJ, Crofts JF. Pressure and traction on a model fetal head and neck associated with the use of forceps, Kiwi™ ventouse and the BD Odon Device™ in operative vaginal birth: a simulation study. BJOG Int J Obstet Gynaecol 2017;124(Suppl 4):19–25. https://doi.org/10.1111/1471-0528.14760.
[18] O'Brien S, Winter C, Burden C, Boulvain M, Draycott T, Crofts J. Fetal head position and perineal distension associated with the use of the BD Odon Device™ in operative vaginal birth: a simulation study. BJOG Int J Obstet Gynaecol 2017;124:10–8. https://doi.org/10.1111/1471-0528.14759.
[19] Lallemant M, Kadiakhe T, Chambert J, Lejeune A, Ramanah R, Mottet N, et al. In vitro biomechanical properties of porcine perineal tissues to better understand human perineal tears during delivery. Acta Obstet Gynecol Scand 2024. https://doi.org/10.1111/aogs.14791.
[20] Pu F, Xu L, Li D, Li S, Sun L, Wang L, et al. Effect of different labor forces on fetal skull molding. Med Eng Phys 2011;33:620–5. https://doi.org/10.1016/j.medengphy.2010.12.018.
[21] Moura R, Oliveira DA, Parente MPL, Kimmich N, Natal Jorge RM. A biomechanical perspective on perineal injuries during childbirth. Comput Methods Programs Biomed 2024;243:107874. https://doi.org/10.1016/j.cmpb.2023.107874.

[22] Jansova M, Kalis V, Rusavy Z, Zemcik R, Lobovsky L, Laine K. Modeling manual perineal protection during vaginal delivery. Int Urogynecology J 2014;25:65–71. https://doi.org/10.1007/s00192-013-2164-1.

[23] Zemčík R, Karbanova J, Kalis V, Lobovský L, Jansová M, Rusavy Z. Stereophotogrammetry of the perineum during vaginal delivery. Int J Gynaecol Obstet Off Organ Int Fed Gynaecol Obstet 2012;119:76–80. https://doi.org/10.1016/j.ijgo.2012.05.018.

[24] Silva MET, Oliveira DA, Roza TH, Brandão S, Parente MPL, Mascarenhas T, et al. Study on the influence of the fetus head molding on the biomechanical behavior of the pelvic floor muscles, during vaginal delivery. J Biomech 2015;48:1600–5. https://doi.org/10.1016/j.jbiomech.2015.02.032.

[25] Khadiaké Tiguida, Lallemant Marine, Lejeune Arnaud, Mac Sophie, Sainthillier Jean Marie, Chambert Jerôme, et al. In-vivo displacement field measurement from subcutaneous texture: Methodology and validation. J Biomed Opt 2024. under-review.

[26] Dupuis O, Decullier E, Clerc J, Moreau R, Pham M-T, Bin-Dorel S, et al. Does forceps training on a birth simulator allow obstetricians to improve forceps blade placement? Eur J Obstet Gynecol Reprod Biol 2011;159:305–9. https://doi.org/10.1016/j.ejogrb.2011.09.002.

[27] Baghestan E, Irgens L, Børdahl P, Rasmussen S. Risk of recurrence and subsequent delivery after obstetric anal sphincter injuries. BJOG Int J Obstet Gynaecol 2012; 119:62–9. https://doi.org/10.1111/j.1471-0528.2011.03150.x.

[28] Lavesson T, Griph ID, Skärvad A, Karlsson A-S, Nilsson HB, Steinvall M, et al. A perineal protection device designed to protect the perineum during labor: a multicenter randomized controlled trial. Eur J Obstet Gynecol Reprod Biol 2014; 181:10–4. https://doi.org/10.1016/j.ejogrb.2014.07.006.

[29] Bhargav VN, Francescato N, Mettelsiefen H, Usmani AY, Scarsoglio S, Raghav V. Spatio-temporal relationship between three-dimensional deformations of a collapsible tube and the downstream flowfield. J Fluids Struct 2024;127:104122. https://doi.org/10.1016/j.jfluidstructs.2024.104122.

[30] Honig SE, Toyoda Y, Ewing JN, Lemdani MS, Gala Z, Amro C, et al. Multimodal pilot evaluation of a hyaluronic acid infraorbital filler using precise, multipositional, 3-dimensional imaging quantification, patient-reported outcomes, and anatomic cadaveric assessments. Aesthetic Surg J Open Forum 2024;6: ojae086. https://doi.org/10.1093/asjof/ojae086.

[31] Peixoto D, Tostes H, Aguilar W, Samieirad S, Grillo R. An open source framework for free precise digital facial analysis. World J Plast Surg 2024;13:111–4. https://doi.org/10.61186/wjps.13.3.111.

[32] Nguyen TT, Cohen SM, Shaw KS, Dedeoglu F, Vleugels RA, Ganske IM. Comparison of 3D facial photographs and clinical documentation in patients with craniofacial morphea. Skin Health Dis 2024;4:e438.

[33] Bharadia SK, Gabriel V. Comparison of clinical estimation and stereophotogrammic instrumented imaging of burn scar height and volume. Eur Burn J 2024;5:38–48. https://doi.org/10.3390/ebj5010004.