



# Assessment of different sonographic cervical measures to predict labor induction outcomes: a systematic review and meta-analysis

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**Background:** Induction of labor (IOL) is a common obstetric approach to start or encourage uterine contractions to achieve a vaginal birth. It is recommended when continuing the pregnancy may be more dangerous for the mother or baby. Different ultrasonographic measures, such as cervical length, have been investigated as possible predictors of the outcomes of IOL. This meta-analysis aimed to assess the accuracy of ultrasound measurements in anticipating successful IOL.

**Methods:** The study conducted a thorough search on three databases (PubMed, Scopus, and Web of Science) until 04 March 2023, to find clinical studies published in English that reported different sonographic cervical measures and their ability to predict IOL outcomes. The chosen studies were stratified based on the type of indicator reported, and a meta-analysis was conducted to determine the best indicator for both successful and failed induction. The risk of bias and concerns about the applicability of the included studies was evaluated using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) method.

**Results:** This study analyzed 57 studies with 9,338 patients. Cervical length is moderately effective in predicting successful IOL, with pooled sensitivity (SN) and specificity (SP) of 0.67 and 0.70, respectively. However, cervical length had a pooled SN and SP of 0.70 and 0.61 for predicting failed IOL. The posterior cervical angle was found to have a higher pooled SN and SP of 0.79 and 0.73 for predicting successful IOL. Fetal head-perineum distance demonstrated moderate accuracy with a pooled SN, SP, positive likelihood ratio, negative likelihood ratio, diagnostic odds ratio, and area under the curve of 0.58, 0.66, 1.95, 0.36, 5.33, and 0.9992, respectively, for predicting successful IOL.

**Conclusions:** Fetal head-perineum distance was the most effective predictor for successful IOL compared to cervical length, which only had a moderate predictive ability. Shortening of cervical length was not a useful indicator for successful IOL. On the other hand, the posterior cervical angle was the most reliable factor for predicting failed induction. The study's findings can aid in developing more effective management strategies for IOL.

**Keywords:** Induction of labor (IOL); obstetrics; intervention; radiology; sonography

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## Introduction

Induction of labor (IOL) is a therapeutic modality to start or encourage uterine contractions to achieve a vaginal birth (1). It is often advised when it is deemed safer to deliver the baby than to continue the pregnancy, such as in situations of pre-eclampsia, gestational diabetes, or protracted pregnancy (1,2). IOL may also be considered if the woman has a medical condition that the pregnancy might aggravate, such as heart disease or renal illness, or worries about the baby's health (2,3). Prostaglandin and oxytocin are two pharmacological agents that may be used to induce labor, as well as mechanical techniques such as stripping the membranes or inserting a Foley catheter, as well as a combination of both (4-9). Many variables, including the gestational age of the fetus, the cervical state, and the purpose for induction, influence the choice of induction technique (10,11). IOL may have many advantages, but it is not without possible dangers. The likelihood of cesarean delivery, uterine rupture, and fetal distress may increase with labor induction (9,12-14). Consequently, before deciding to continue with induction, it is crucial to weigh the risks and advantages of the operation thoroughly.

In recent years, ultrasonography assessment of the length of the cervix is a vital technique in obstetric practice for predicting the risk of preterm delivery and identifying women that do not respond to conventional therapies, like progesterone supplementation or cervical cerclage to avoid premature birth (15-18). Ultrasonic assessment of cervical length is a non-invasive and precise approach for assessing the cervix and has been found to reliably predict preterm birth in women with high-risk during mid-pregnancy (19-21).

In addition to predicting preterm delivery, ultrasonography assessment of the length of the cervix has also been investigated to potentially predict effective IOL (22-24). This is because a shorter cervix may suggest that the cervix is already in the process of ripening and preparing for labor, which increases the probability of a successful induction (25,26). Nonetheless, the information supporting the prognostic usefulness of cervical length for a successful induction is concerning (27-29), and further exploration is required to explain its relevance in this context. Besides, many ultrasonographic variables, including fetal head-perineum distance, cervical wedging, degree of cervical length shortening, and posterior cervical angle, have been investigated as predictors for successful vaginal delivery after IOL (15,30-32).

A previous meta-analysis of 31 articles found that sonographic measurements of cervical wedging and

length at or near term show a modest ability to predict the success of IOL (33). However, multiple investigations have been published since the last meta-analysis. This meta-analysis aims to update the current evidence and evaluate the accuracy of ultrasound measurements of cervical wedging and length, fetal head-perineum distance, degree of cervical length shortening, and posterior cervical angle in anticipating successful IOL. By synthesizing the available evidence, we hope to provide clinicians with a better understanding of the measures that can impact effective induction and aid in developing more effective and personalized management strategies for women undergoing IOL. We present this article in accordance with the PRISMA reporting checklist (34) (available at <https://qims.amegroups.com/article/view/10.21037/qims-23-507/rc>).

## Methods

We conducted the current meta-analysis in accordance with the PRISMA declaration standards and the review was not registered and no the protocol was not prepared. The Cochrane Handbook of Systematic Reviews and Meta-Analyses of Interventions was strictly followed at every stage (<https://training.cochrane.org/>). The following inclusion criteria were applied on finding the relevant articles: (I) studies on pregnant women who required IOL, (II) reporting the use of pharmacological or mechanical methods for IOL, (III) investigating either of the following outcomes: cervical length and wedging, fetal head-perineum distance, degree of cervical length shortening, and posterior cervical angle as a predictor of effective or failed IOL, and (IV) were original (i.e., recruiting human individuals only). On the other hand, our exclusion criteria were (I) articles with unreliable data for extraction and analysis, (II) non-original studies with no human data, (III) presented only as thesis or abstracts, (IV) with full texts unavailable, and (V) not published in English.

## Search strategy

We ran a thorough search on three databases (PubMed, Scopus, and Web of Science) until 04 March 2023 (Table S1), by the following query: ("Labor, Obstetric" OR "Labor Pain" OR "Trial of Labor" OR "Obstetric Labor, Premature" OR "Labor, Induced" OR "Labor Stage, Third" OR "Labor Stage, Second" OR "Labor Stage, First" OR "Labor Presentation" OR "Labor Onset" OR "Obstetric Labor Complications" OR "Child Labor") AND ("induction

of labour” OR “induced labour”) AND (“cervical length” OR “cervical wedging” OR “funneling cervical elastography” OR “cervical shear wave elastography” OR “uterocervical angle” OR “cervical volume” OR “Bishop score” OR “Manipal cervical scoring system”). No restrictions regarding the year or country of publication were applied. Moreover, manual searches were done to find any other possibly suitable research in the listed studies’ references.

### Screening

Endnote (Clarivate Analytics, PA, USA) was used to eliminate duplicate records, and the obtained references were screened in two phases: the first phase involved evaluating the titles and abstracts of all identified articles to establish their applicability to this meta-analysis, and the second step involved evaluating the full-text versions of the identified abstracts to assess their final suitability to meta-analysis. The selection process was conducted on the Rayyan website (35). All steps were conducted by at least three authors on an individual basis.

### Data extraction and quality assessment

A standard data extraction sheet was used for data extraction. The extracted information included (I) study characteristics, (II) study population characteristics, (III) quality assessment domains, and (IV) outcome measures. The risk of bias and concerns about the applicability of the included studies was evaluated using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) method (36). Independently using the tool, two reviewers used it, and a conversation settled disagreements with a third reviewer. The patient selection, index test, reference standard, and flow and time domains make up the QUADAS-2 tool. Each topic is evaluated for bias risk and questions about applicability. Bias risk is rated as being low, high, or unclear. For the patient selection and index test domains, applicability concerns are rated as low, high, or unclear; for the reference standard, flow, and time domains, they are rated as low or high.

### Data synthesis and analysis

#### Synthesis methods

Since this meta-analysis was conducted for the study of the diagnostic test accuracy, which reported outcomes in the form of particular test(s), including sensitivity (SN),

specificity (SP), positive likelihood ratio (PLR), negative likelihood ratio (NLR), and receiver operating characteristic (ROC) curves. These measures helped evaluate the performance of the diagnostic test(s) in correctly identifying true positive and true negative cases. For all outcomes, the diagnostic odds ratio (DOR) and the corresponding 95% confidence intervals (CIs) were pooled in the DerSimonian Liard meta-analysis model using Meta-disc (version 1.4 for Windows).

#### Choice of the meta-analysis model

The combined effect size for all outcomes was calculated using the DerSimonian Liard meta-analysis model. This approach, which uses a random effects framework, considers that the included studies represent a random sample of the population and assigns smaller studies less weight than bigger studies. This model is appropriate for contradictory or debatable estimates since it can manage a bigger standard error (SE) in the pooled estimate. As a result, the effects computed in our meta-analysis were cautious estimates that had considered any discrepancies.

#### Assessment of heterogeneity

In order to assess statistical heterogeneity among the studies, we used the Cochrane Q test, which involves the Chi-squared test. We then calculated the I-squared value based on the Cochrane Q test results using the equation:

$$I^2 = \left( \frac{Q - df}{Q} \right) \times 100\% \quad [1]$$

Significant heterogeneity was considered with a Chi-squared P value of <0.1 or an I-square value of 50% or more.

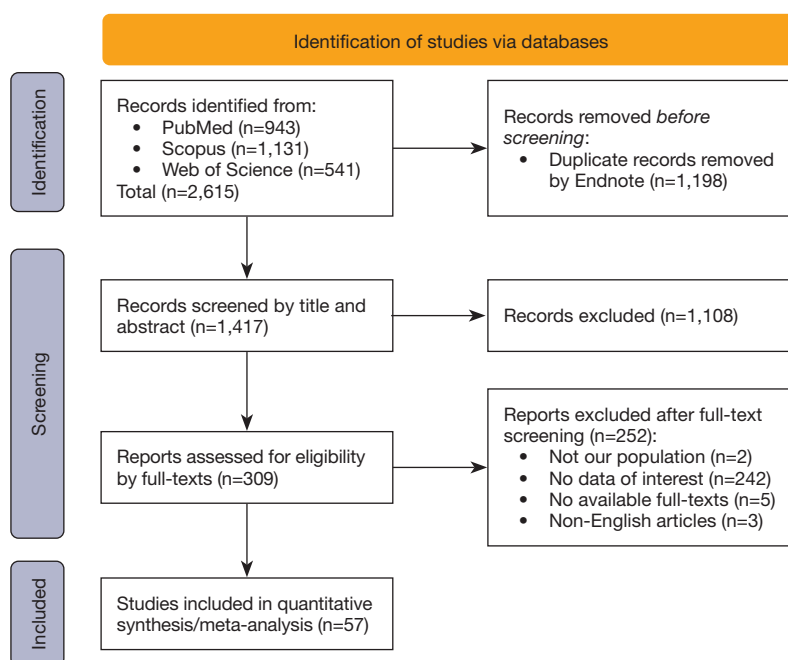
#### Certainty assessment

We performed a sensitivity analysis (leave-one-out approach) to conduct a certainty assessment to examine the evidence’s validity. We conducted sensitivity analyses for each outcome in the meta-analysis, eliminating one study from each scenario to confirm that the pooled effect size was independent of a certain research.

## Results

### Search results

There were 2,615 results finally identified, including 309



**Figure 1** PRISMA flow diagram of studies' screening and selection.

articles that were qualified for full-text screening after being subjected to title and abstract screening. The meta-analysis included 57 of these articles. No further papers were included after manually searching the references of the listed studies. *Figure 1* depicts the PRISMA flow chart of this step.

### Baseline characteristics

The meta-analysis included 57 trials with a total of 9,338 individuals who underwent IOL. *Table 1* exhibits the features of the included articles. Overall, according to the QUADAS-2 tool, we found that the included investigations had a moderate to low probability of bias (*Figures S1,S2*).

### Outcomes

#### Cervical length for prediction of successful IOL

Pooled analysis for 36 studies with a sample size of 5,506 patients, the pooled SN, SP, PLR, NLR, DOR, and area under the curve (AUC) (SE), with 95% CI for cervical length in predicting successful IOL were 0.67 (95% CI: 0.66–0.69), 0.70 (95% CI: 0.68–0.72), 2.31 (95% CI: 1.87–2.86), 0.40 (95% CI: 0.33–0.49), 6.54 (95% CI: 4.47–9.50),

and 0.78 (SE: 0.0250), respectively (*Table 2, Figure 2*).

The analysis of the combined results for the diagnostic odds ratio revealed that the Cochrane Q test yielded a value of 222.66 with 35 degrees of freedom, resulting in a P value <0.0001. These findings indicated compelling evidence of significant heterogeneity among the studies included in the analysis. This heterogeneity is expected due to a higher number of included studies and potential sources of heterogeneity, such as differences in study design or patient population characteristics. Therefore, a random effect model was used to customize these results, and the leave-one-out method failed to resolve this heterogeneity.

#### Cervical length for prediction of failed IOL

Pooled analysis for 19 studies with a sample size of 3,560 patients, the pooled SN, SP, PLR, NLR, DOR, and AUC (SE) with 95% CI for cervical length in predicting failed IOL were 0.70 (95% CI: 0.67–0.73), 0.61 (95% CI: 0.59–0.62), 1.82 (95% CI: 1.61–2.06), 0.49 (95% CI: 0.39–0.61), 4.01 (95% CI: 2.89–5.54), 0.6861 (SE: 0.0261), respectively (*Table 2, Figure 3*).

The analysis of the combined results for the diagnostic odds ratio revealed that the Cochrane Q test yielded a value of 52.15 with 18 degrees of freedom, resulting in a P value <0.0001. These findings indicated compelling evidence of

Table 1 A summary of the baseline characteristics

References	Design	Country/region	Sample size	Maternal age (years), mean (SD)/median [range]	BMI (kg/m <sup>2</sup> ), mean (SD)/median [range]	Gestational age at induction of labor (days), mean (SD)/median [range]	Nulliparity
Abdullah 2022 (22)	A comparative clinical trial	Malaysia	294	30.30 (5.0)	26.54 (5.9)	274 (8.4)	132 (44.90%)
Al-Adwy 2018 (37)	POS	Egypt	70	26.24 (4.1)	26.94 (3.4)	NR	29 (41.40%)
Alanwar 2021 (38)	POS	Egypt	320	27.20 (3.4)	27.60 (1.4)	275.800 (5.6)	78 (33.90%)
Ali 2019 (30)	Prospective case-control	United Arab Emirates	219	26.95 (3.5)	25.78 (3.5)	217.740 (7.6)	164 (74.90%)
Alvarez-Colomo 2016 (39)	POS	Spain	151	32.60	NR	NR	103 (68.20%)
Aracic 2017 (40)	POS	Croatia	101	28.70 (5.4)	NR	278.250 (11.62)	50 (49.50%)
Athulathmudali 2021 (41)	POS	Sri Lanka	100	28.40 (4.6)	NR	279.920 (8.9)	71 (71.00%)
Bastani 2011 (42)	POS	Iran	200	29.90 (5.6)	NR	277.200 (9.8)	133 (66.67%)
Brik 2017 (43)	POS	Spain	245	32.20 (4.7)	30 (5.5)	287 [7]	165 (67.30%)
Çaliskan 2006 (44)	POS	Turkey	74	27.50 (5.7)	28 (3.5)	274.400 (8.4)	38 (51.40%)
Cheung 2010 (45)	POS	China	460	29.40 [5]	NR	NR	282 (61.30%)
Cromi 2007 (46)	POS	Italy	155	31.50 (5.1)	27.4 (5.5)	277.900 [238-294]	118 (76.10%)
Cubal 2013 (47)	POS	Portugal	197	28.61 [5]	26.49 (2.2)	285.500 (2.7)	122 (61.90%)
Daskalakis 2006 (48)	POS	Greece	137	24.30 [19-37]	28.90 [18-41.30]	280 [259-294]	137 (100%)
Gül 2020 (49)	ROS	Turkey	260	31.90 (5.49)	29.22 (3.73)	284.200 (3.6)	260 (100%)
Döğül 2011 (50)	ROS, originating from a randomized controlled trial	Norway	216	30.10 (4.7)	30.10 (4.0)	NR	NR
Eggeboe 2008 (51)	ROS	Norway	275	30 [18-45]	24 [17-45]	280 [259-301]	129 (47%)
Elghorori 2006 (52)	POS	UK	104	26.70 [14-37]	NR	287 [259-294]	54 (52%)
El-Maghraby 2021 (53)	POS	Egypt	140	23.34 (4.1)	29.12 (2.57)	279 (9.9)	NR
Funghi 2018 (54)	POS	Italy	41	30.80 (4.9)	NR	NR	NR
Gabriel 2002 (55)	POS	France	179	NR	NR	NR	86 (48%)
Gillor 2017 (56)	POS	Spain	150	27.50 [24-30.70]	25 [21.50-30.10]	289.100 [275.100-291.900]	150 (100%)
Gómez-Laencina 2007 (57)	POS	Spain	177	31.22 [18-46]	28.60 [20.55-47.18]	277.480 [252-294]	124 (70.10%)
Gómez-Laencina 2012 (58)	POS	Spain	177	31.22 [18-46]	28.60 [20.55-47.18]	277.480 [252-294]	124 (70.10%)
Gonen 1998 (59)	POS	Israel	86	28.40 [19-42]	NR	281.400 [238-294]	41 (48%)
Hwang 2013 (60)	POS	Korea	145	31 [22-42]	26 [19-44]	288 [259-298]	145 (100%)
Kang 2010 (61)	POS	Korea	92	31.44 (3.7)	27.90 (4.3)	266 [13]	78 (84.80%)
Kant 2016 (62)	POS	India	200	24.80	26.30 (3.1)	273 (9.8)	200 (100%)

Table 1 (continued)

Table 1 (continued)

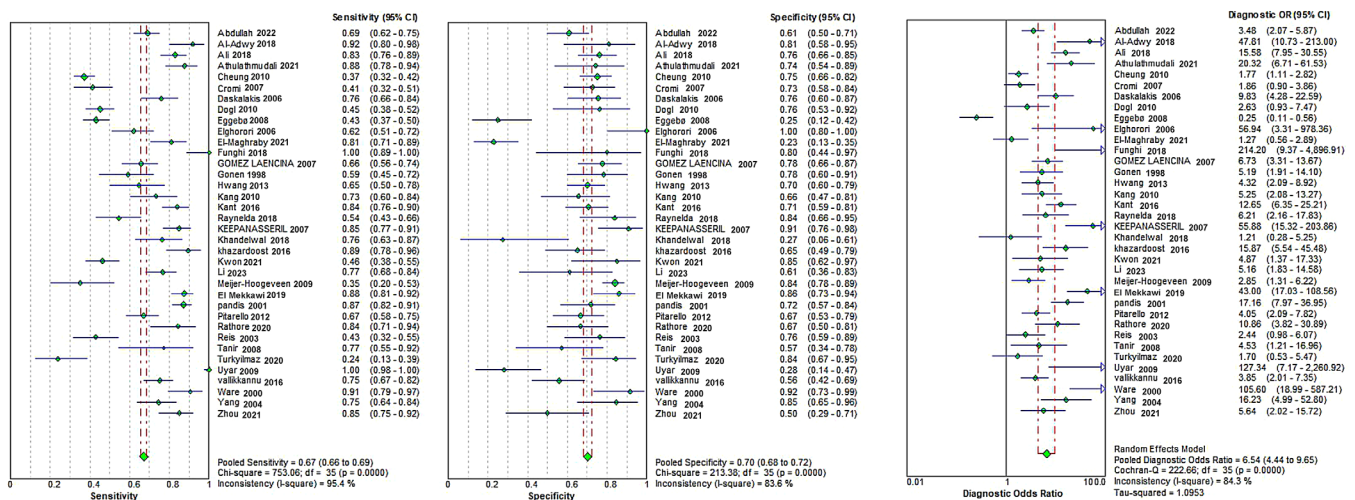
References	Design	Country/region	Sample size	Maternal age (years), mean (SD)/mean [SD]/mean/median [range]	BMI (kg/m <sup>2</sup> ), mean (SD)/median [range]	Gestational age at induction of labor (days), mean (SD)/mean [SD]/median [range]	Nulliparity
Raynelda 2018 (63)	Cross-sectional observational analytical study	Indonesia	110	NR	NR	NR	98 (89.10%)
Keepanasseril 2007 (64)	POS	India	145	26.25 (4.39)	30.23 (2.4)	37.75 (2.0)	145 (100%)
Khandelwal 2018 (65)	POS	India	66	NR	NR	NR	62 (93.90%)
Khazardoost 2016 (66)	Cross-sectional study	Iran	100	25.10 (4.4)	24.12 (3.4)	NR	NR
Kwon 2021 (29)	POS	Korea	165	32.50 (2.6)	21.90 (3.3)	39 (0.78)	NR
Li 2023 (25)	ROS	Taiwan	138	30.19 (5.5)	29.83 (0.6)	77.80 (0.07)	79 (57.24%)
Meijer-Hoogveen 2009 (67)	POS	The Netherlands	225	31 (5.77)	25.24 (2.79)	NR	150 (67%)
El Mekkawi 2019 (68)	POS	Egypt	210	24.13 (2.34)	NR	38 (1.2)	210 (100%)
Pandis 2001 (24)	POS	UK	240	29.70 (8.1)	30.85 (9.7)	40.25 (1.5)	128 (53.30%)
Park 2007 (69)	POS	Korea	161	30.25 (2.9)	NR	21.30 (0.05)	161 (100%)
Park 2012 (70)	POS	Korea	146	31.25 (2.3)	NR	34.20 (0.1)	111 (76%)
Paterson-Brown 1991 (71)	POS	UK	50	NR	NR	NR	NR
Pitarello 2013 (72)	POS	Brazil	190	24.55 (4.9)	28.45 (0.6)	40.05 (0.6)	NR
Rane 2003 (73)	POS	UK	382	NR	NR	41.25 (0.3)	192 (50.20%)
Rathore 2021 (74)	Cross-sectional study	India	84	23.22 (3.2)	25.97 (3.5)	NR	NR
Reis 2003 (75)	POS	Italy	111	32 (1.7)	NR	40.38 (0.01)	NR
Roman 2004 (76)	POS	France	106	31.20 (5.3)	NR	39.70 (0.1)	NR
Rozenberg 2005 (77)	POS	France	266	29.55 (1.75)	NR	39.60 (0.9)	189 (71%)
Tan 2007 (78)	POS	Malaysia	249	30.45 (0.2)	NR	39.85 (0.1)	109 (43.70%)
Tan 2006 (79)	POS	Malaysia	152	30.55 (0.3)	NR	NR	65 (42.80%)
Tanir 2008 (80)	POS	Turkey	43	26.10 (0.7)	24.65 (0.6)	38.40 (0.2)	43 (100%)
Türkyilmaz 2020 (81)	POS	Turkey	78	25.70 (5.5)	23.80 (3.7)	25.20 (6.4)	78 (100%)
Uyar 2009 (82)	POS	Turkey	189	24 (4.1)	25.60 (2.9)	40 (1.4)	55 (29%)
Uzun 2013 (83)	Randomized trial	Turkey	90	24.68 (0.3)	27.88 (0.2)	288.065 (0.4)	90 (100%)
Vallikkannu 2017 (84)	POS	Malaysia	193	28.60 (1.6)	29.68 (2.1)	39.45 (0.7)	193 (100%)
Ware 2000 (85)	POS	Atlanta	77	NR	NR	40 (1.7)	32 (42%)
Yang 2004 (86)	POS	Korea	105	27.30 (3.2)	NR	40 (1.7)	78 (74%)
Yang 2021 (87)	ROS	Korea	205	32 (5.3)	24.80 (4.96)	NR	125 (61%)
Zhou 2021 (88)	POS	China	97	29 (1.6)	20.97 (1.03)	38.88 (0.2)	NR

SD, standard deviation; BMI, body mass index; POS, prospective observational study; NR, not reported; ROS, retrospective observational study.

**Table 2** Summary of the accuracy results of all indicators for the prediction of IOL

Indicator	Pooled studies (N)	Patients (N)	Pooled SN (95% CI)	Pooled SP (95% CI)	Pooled PLR (95% CI)	Pooled NLR (95% CI)	Pooled DOR (95% CI)	AUC (SE)
CL for successful IOL	36	5,506	0.67 (0.66–0.69)	0.70 (0.68–0.72)	2.31 (1.87–2.86)	0.40 (0.33–0.49)	6.54 (4.47–9.50)	0.78 (0.0250)
CL for failed IOL	19	3,560	0.70 (0.67–0.73)	0.61 (0.59–0.62)	1.82 (1.61–2.06)	0.49 (0.39–0.61)	4.01 (2.89–5.54)	0.6861 (0.0261)
CW for failed IOL	8	2,851	0.35 (0.31–0.38)	0.8 (0.74–0.85)	1.71 (1.22–2.40)	0.78 (0.67–0.91)	2.29 (1.43–3.68)	0.6555 (0.0742)
CLS for successful IOL	2	257	0.77 (0.70–0.83)	0.61 (0.50–0.72)	2.01 (1.48–2.74)	0.36 (0.25–0.52)	5.72 (2.84–11.52)	0.5 (0.0)
PCA for successful IOL	7	1,345	0.79 (0.76–0.82)	0.73 (0.67–0.77)	2.48 (1.89–3.25)	0.30 (0.21–0.43)	9.77 (5.15–18.54)	0.8484 (0.0425)
PCA for failed IOL	3	550	0.67 (0.59–0.74)	0.61 (0.56–0.66)	2.36 (0.70–7.97)	0.45 (0.10–1.97)	5.37 (0.40–72.47)	0.8564 (0.0265)
FHPD for successful IOL	3	594	0.58 (0.53–0.63)	0.66 (0.58–0.73)	1.95 (0.12–31.66)	0.36 (0.02–6.70)	5.33 (0.04–763.32)	0.9992 (0.0094)

IOL, induction of labor; SN, sensitivity; CI, confidence interval; SP, specificity; PLR, positive likelihood ratio; NLR, negative likelihood ratio; DOR, diagnostic odds ratio; AUC, area under the curve; CL, cervical length; CW, cervical wedging; CLS, cervical length shortening; PCA, posterior cervical angle; FHPD, fetal head-perineal distance.



**Figure 2** Forest plot of sensitivity, specificity, and diagnostic OR for CL in predicting successful induction of labor. CI, confidence interval; OR, odds ratio; CL, cervical length.

significant heterogeneity among the studies included in the analysis.

**Posterior cervical angle for prediction of successful IOL**

Pooled analysis for seven studies with a sample size of 1,345 patients, the pooled SN, SP, PLR, NLR, DOR, and AUC

(SE), with 95% CI for posterior cervical angle in predicting successful IOL were 0.79 (95% CI: 0.76–0.82), 0.73 (95% CI: 0.67–0.77), 2.48 (95% CI: 1.89–3.25), 0.30 (95% CI: 0.21–0.43), 9.77 (95% CI: 5.15–18.54), 0.8484 (SE: 0.0425), respectively (Table 2, Figure 4A).

The analysis of the combined results for the diagnostic

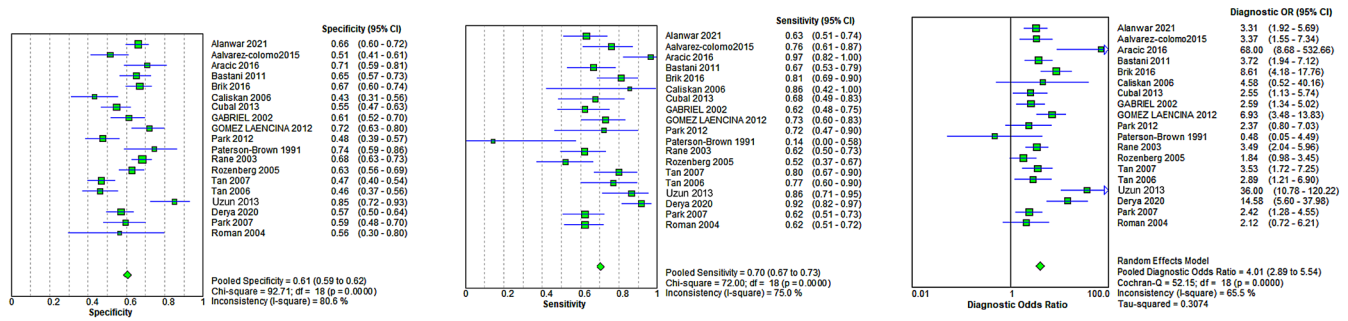


Figure 3 Forest plot of sensitivity, specificity, and diagnostic OR for CL in predicting failed induction of labor. CI, confidence interval; OR, odds ratio; CL, cervical length.

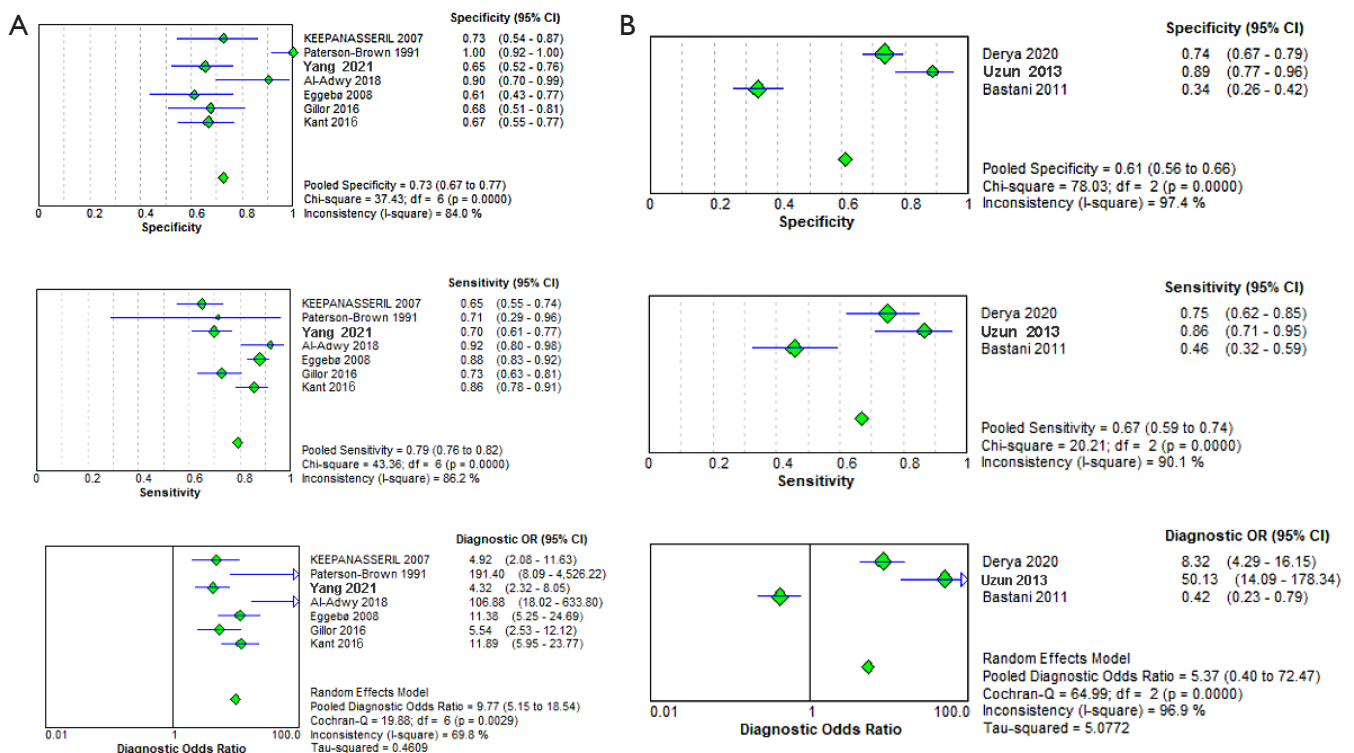
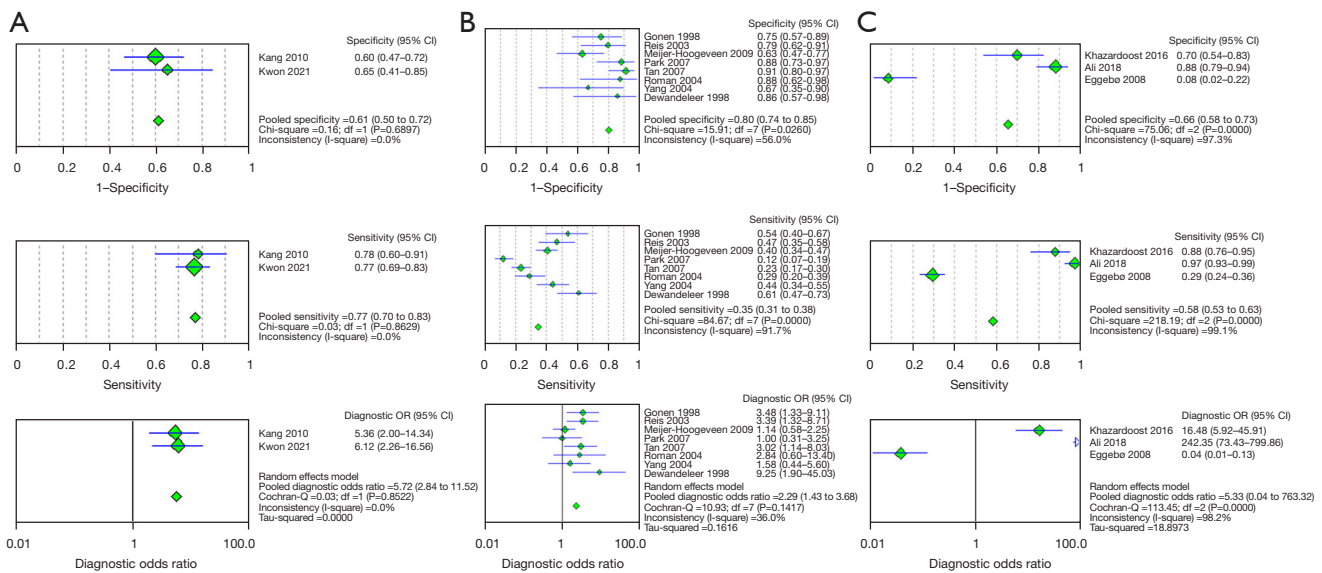


Figure 4 Forest plot of sensitivity, specificity, and diagnostic OR for posterior cervical angle in predicting (A) successful and (B) failed induction of labor. CI, confidence interval; OR, odds ratio.

odds ratio revealed that the Cochran Q test yielded a value of 19.88 with 6 degrees of freedom, resulting in a P value <0.0001. These findings indicated compelling evidence of significant heterogeneity among the studies included in the analysis.

**Posterior cervical angle for prediction of failed IOL**  
 Pooled analysis for three studies with a sample size of 550 patients, the pooled SN, SP, PLR, NLR, DOR, and AUC (SE), with 95% CI for posterior cervical angle in predicting failed IOL were 0.67 (95% CI: 0.59–0.74), 0.61 (95%





**Figure 5** Forest plot of sensitivity, specificity, and diagnostic OR of (A) CL shortening, (B) cervical wedging, and (C) feto-perineal head distance in predicting successful induction of labor. CI, confidence interval; OR, odds ratio; CL, cervical length.

CI: 0.56–0.66), 2.36 (95% CI: 0.70–7.97), 0.45 (95% CI: 0.10–1.97), 5.37 (95% CI: 0.40–72.47), 0.8564 (SE: 0.0265), respectively (Table 2, Figure 4B).

The analysis of the combined results for the diagnostic odds ratio revealed that the Cochran Q test yielded a value of 64.99 with 2 degrees of freedom, resulting in a P value <0.0001. These findings indicated compelling evidence of significant heterogeneity among the studies included in the analysis.

**Cervical length shortening for prediction of successful IOL**

Pooled analysis for two studies with a sample size of 257 patients, the pooled SN, SP, PLR, NLR, DOR, and AUC (SE) with 95% CI for cervical length shortening in predicting successful IOL were 0.77 (95% CI: 0.70–0.83), 0.61 (95% CI: 0.50–0.72), 2.01 (95% CI: 1.48–2.74), 0.36 (95% CI: 0.25–0.52), 5.72 (95% CI: 2.84–11.52), 0.5 (SE: 0.0), respectively (Table 2, Figure 5A).

The analysis of the combined results for the diagnostic odds ratio revealed that the Cochran Q test yielded a value of 0.03 with 1 degree of freedom, resulting in a P value of 0.8522. These findings indicated compelling no heterogeneity among included studies.

**Cervical wedging for prediction of failed IOL**

Pooled analysis for eight studies with a sample size of 2,851

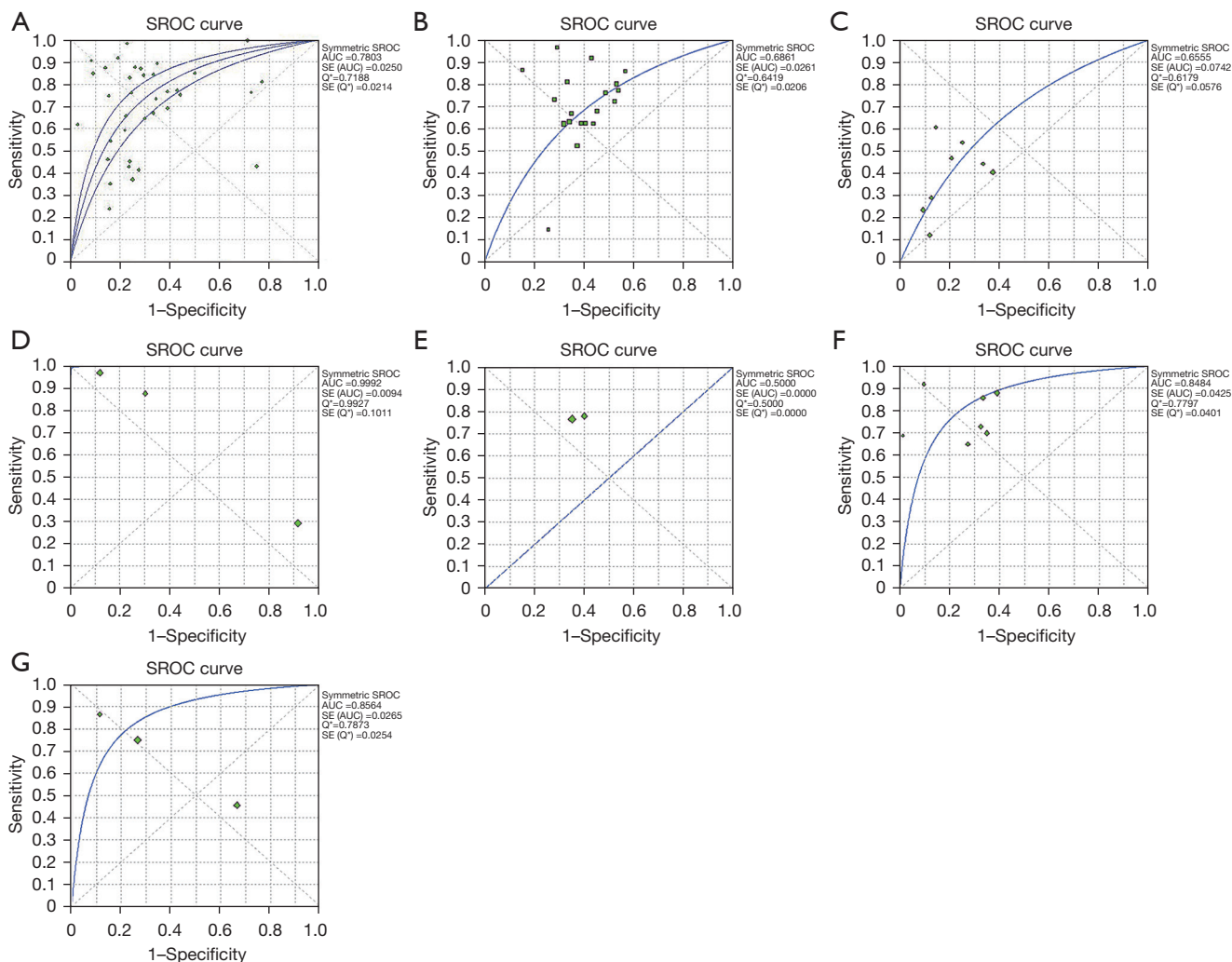
patients (59,67,69,75,76,78,86,89), the pooled SN, SP, PLR, NLR, DOR, and AUC (SE), with 95% CI for cervical wedging in predicting failed IOL were 0.35 (95% CI: 0.31–0.38), 0.8 (95% CI: 0.74–0.85), 1.71 (95% CI: 1.22–2.40), 0.78 (95% CI: 0.67–0.91), 2.29 (95% CI: 1.43–3.68), 0.6555 (SE: 0.0742), respectively (Table 2, Figure 5B).

The analysis of the combined results for the diagnostic odds ratio revealed that the Cochran Q test yielded a value of 10.93 with 7 degrees of freedom, resulting in a P value of 0.1417. These findings indicated no significant heterogeneity among the studies included in the analysis.

**Fetal head-perineum distance for prediction of successful IOL**

Pooled analysis for three studies with a sample size of 594 patients, the pooled SN, SP, PLR, NLR, DOR, and AUC (SE), with 95% CI for fetal head-perineum distance in predicting successful IOL were 0.58 (95% CI: 0.53–0.63), 0.66 (95% CI: 0.58–0.73), 1.95 (95% CI: 0.12–31.66), 0.36 (95% CI: 0.02–6.70), 5.33 (95% CI: 0.04–763.32), 0.9992 (SE: 0.0094), respectively (Table 2, Figure 5C).

The analysis of the combined results for the diagnostic odds ratio revealed that the Cochran Q test yielded a value of 113.45 with 2 degrees of freedom, resulting in a P value <0.0001. These findings indicated compelling evidence of significant heterogeneity among the studies included in the analysis.



**Figure 6** SROC curve of CL for predicting (A) successful and (B) failed IOL, (C) cervical wedging, (D) fetal-perineal distance, (E) cervical shortening and (F) posterior cervical angle of successful IOL, and (G) posterior cervical angle of failed IOL. SROC, summary receiver operating characteristic; AUC, area under the curve; SE, standard error; CL, cervical length; IOL, induction of labor.

Moreover, we presented the AUC (SE) for all of the reported variables in *Figure 6A-6G*. The outcomes reported by each study included in the meta-analysis are presented in [Table S2](#). The cutoff values for each outcome reported by the individual studies are presented in [Table S3](#).

### Discussion

IOL is a general obstetric procedure that utilizes artificial techniques to initiate the onset of labor (1). The bishop score has been the go-to method for assessing the cervix's condition and predicting successful IOL for a long time. However, it has some limitations, such as inconsistencies

among observers. Thus, recent attempts have explored other options for anticipating a successful IOL. Ultrasound scanning has become a more feasible option, with reduced variability, lower cost, and less invasiveness, and has shown promise as an alternative to the bishop score (78). Despite multiple studies testing the effectiveness of ultrasound measurements of the cervix in predicting successful induction, their outcomes have been inconsistent.

This systematic review and meta-analysis included 57 studies with 9,338 patients to evaluate the effectiveness of various ultrasonographic measures in predicting successful IOL. The results showed that fetal head-perineum distance had the highest diagnostic odds ratio for predicting

successful IOL, followed by the posterior cervical angle, cervical length, and cervical length shortening. The fetal-pelvic distance also had the highest AUC for predicting successful IOL, followed by the posterior cervical angle and length. However, cervical length shortening showed no discriminative ability to predict successful IOL, as its AUC was only 0.5. Based on the reported SN and SP, the best predictor for successful IOL was the posterior cervical angle, followed by cervical length shortening and cervical length. The study suggested that fetal-perineal distance may be the most useful predictor for successful IOL compared to cervical length, which has a moderate predicting ability for successful IOL. Cervical length alone has a moderate ability to predict successful IOL; therefore, its combination with other indicators is important. Therefore, the combination of fetal head-perineum distance and cervical length can be useful predictors for successful IOL. This study illustrated three indicators for predicting failed induction: cervical length, cervical wedging, and posterior cervical angle. The posterior cervical angle showed the best indicator based on the AUC, DOR, SN, and SP. This was followed by the cervical length, which had a double odd ratio compared to cervical wedging and higher AUC.

In studies related to IOL, certain indicators are more commonly reported than others. One such commonly used method is the measurement of cervical length, as it is easy to perform and interpret and it provides a clear image of the cervix in almost all cases. However, it is important to note that many studies do not mention the possibility of uninterpretable results or withdrawals when using this method. Our meta-analysis included many studies that reported on cervical length, and our findings are consistent with the results of a previously published meta-analysis by Hatfield *et al.* (90). However, our overall results suggested that larger sample sizes increase the statistical power to predict the moderate ability of cervical length for predicting IOL outcomes.

Our meta-analysis provides greater statistical power to identify the best predictor of IOL outcome. Additionally, our study is unique in that it investigates the predictive ability of cervical length shortening and fetal head-perineum distance for IOL outcomes, which had not been previously explored in meta-analyses. Hatfield *et al.* (90) and Verhoeven *et al.* (33) included evidence up to 2007 and 2013, respectively, but our study included all published evidence up to the present, as well as 29 additional studies which had never been included in previous meta-analyses. Our findings indicated that cervical length alone is a moderate

predictor of IOL outcome but its predictive ability is still relatively weak, requiring further combination with other indicators, consistent with Verhoeven *et al.*'s results (33) and different from the findings of Hatfield *et al.* (90). This difference may be attributed to the higher sample size in Verhoeven *et al.* (33) and our study. A previous systematic review reported that the bishop score had moderate SN and low SP for predicting C-sections, with values of 0.78 and 0.44, respectively, which are similar to the predictive ability of cervical length for failed IOL in our study, with values of 0.70 and 0.61, respectively (91).

### Strengths and limitations

The main strength of this systematic review is the large number of the included studies and the huge sample size of included patients. Moreover, most of the reported outcomes did not have a significant heterogeneity, which is a remarkable indicator of the validity of these outcomes. One significant limitation of this paper is its heterogeneity, which could be attributed to various factors. Firstly, the included studies reported data differently, such as parity, with some studies including only nulliparous participants while others including both nulliparous and multiparous participants. Additionally, there was variation in the definition of successful and failed induction endpoints, with some studies using cesarean delivery for fetal distress and others using the active phase of labor endpoint, which has been a topic of debate. Therefore, the heterogeneity of some outcomes may interfere with the interpretation of results. Accordingly, we encourage future researchers to conduct further studies and put inconsideration points to make this heterogeneity high. Secondly, there was heterogeneity in the methods of IOL and indications for cesarean delivery, which could have affected the accuracy of the results. A limitation of the meta-analysis was that it only considered single variable without exploring whether multiple sonographic measures had any additional value to the bishop score. To address this limitation, a multivariable approach combining various factors such as the method of induction, gestational age, and parity would be necessary to improve the accuracy of prediction models. Thus, further research using this approach is recommended.

### Conclusions

This study showed that fetal head-perineum distance might be the most useful predictor for successful IOL compared

to the cervical length, which has a moderate predicting ability for successful IOL, and cervical length shortening has no discriminative ability to predict successful IOL. The posterior cervical angle showed the best indicator for predicting failed induction, based on AUC, DOR, SN, and SP, followed by cervical length. However, there are certain limitations to the study. The heterogeneity in the reported data among included studies, variation in methods of IOL, and the indication for cesarean delivery may limit the findings' generalizability. Moreover, the study used a single-variable approach; thus, a multivariable approach is necessary to determine the added value of measuring multiple sonographic measures to the bishop score. In addition, further studies with larger sample sizes and multivariable approaches are necessary to confirm these findings and determine the added value of measuring multiple sonographic measures to the bishop score.

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### Footnote

*Reporting Checklist:* The authors have completed the PRISMA reporting checklist. Available at <https://qims.amegroups.com/article/view/10.21037/qims-23-507/rc>

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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### References

1. Tsakiridis I, Mamopoulos A, Athanasiadis A, Dagklis T. Induction of Labor: An Overview of Guidelines. *Obstet Gynecol Surv* 2020;75:61-72.
2. Coates D, Homer C, Wilson A, Deady L, Mason E, Foureur M, Henry A. Induction of labour indications and timing: A systematic analysis of clinical guidelines. *Women Birth* 2020;33:219-30.
3. Saccone G, Della Corte L, Maruotti GM, Quist-Nelson J, Raffone A, De Vivo V, Esposito G, Zullo F, Berghella V. Induction of labor at full-term in pregnant women with uncomplicated singleton pregnancy: A systematic review and meta-analysis of randomized trials. *Acta Obstet Gynecol Scand* 2019;98:958-66.
4. Goetzl L. Methods of cervical ripening and labor induction: pharmacologic. *Clin Obstet Gynecol* 2014;57:377-90.
5. Tenore JL. Methods for cervical ripening and induction of labor. *Am Fam Physician* 2003;67:2123-8.
6. Gupta J, Baev O, Duro Gomez J, Garabedian C, Hellmeyer L, Mahony R, Maier J, Parizek A, Radzinsky V, Stener Jorgensen J, Britt Wennerholm U, Carlo Di Renzo G. Mechanical methods for induction of labor. *Eur J Obstet Gynecol Reprod Biol* 2022;269:138-42.
7. Nunes I, Dupont C, Timonen S, Ayres de Campos D, Cole V, Schwarz C, et al. European Guidelines on Perinatal Care – Oxytocin for induction and augmentation of labor Formula: see text. *J Matern Fetal Neonatal Med* 2022;35:7166-72.
8. Baranowska B, Kajdy A, Kiersnowska I, Sys D, Tataj-Puzyna U, Daly D, Rabijewski M, Bączek G, Węgrzynowska M. Oxytocin administration for induction and augmentation of labour in polish maternity units – an observational study. *BMC Pregnancy Childbirth* 2021;21:764.
9. Middleton P, Shepherd E, Crowther CA. Induction of labour for improving birth outcomes for women at or beyond term. *Cochrane Database Syst Rev* 2018;5:CD004945.

10. Bączek G, Rzońca E, Rzońca P, Rychlewicz S, Budner M, Bień A. Retrospective Analysis of the Factors Affecting the Induction of Childbirth in 4350 Women from a Single Center in Warsaw, Poland. *Int J Environ Res Public Health* 2022;19:9540.
11. Marconi AM. Recent advances in the induction of labor. *F1000Res* 2019;8:Ef1000 Faculty Rev-1829.
12. Kim HI, Choo SP, Han SW, Kim EH. Benefits and risks of induction of labor at 39 or more weeks in uncomplicated nulliparous women: a retrospective, observational study. *Obstet Gynecol Sci* 2019;62:19-26.
13. Place K, Kruit H, Tekay A, Heinonen S, Rahkonen L. Success of trial of labor in women with a history of previous cesarean section for failed labor induction or labor dystocia: a retrospective cohort study. *BMC Pregnancy Childbirth* 2019;19:176.
14. Debele TZ, Cherkos EA, Badi MB, Anteneh KT, Demssie FW, Abdo AA, Mihret MS. Factors and outcomes associated with the induction of labor in referral hospitals of Amhara regional state, Ethiopia: a multicenter study. *BMC Pregnancy Childbirth* 2021;21:225.
15. Boozarjomehri F, Timor-Tritsch I, Chao CR, Fox HE. Transvaginal ultrasonographic evaluation of the cervix before labor: presence of cervical wedging is associated with shorter duration of induced labor. *Am J Obstet Gynecol* 1994;171:1081-7.
16. Lazanakis M, Marsh M, Brockbank E, Economides D. Assessment of the cervix in the third trimester of pregnancy using transvaginal ultrasound scanning. *Eur J Obstet Gynecol Reprod Biol* 2002;105:31-5.
17. Larma JD, Iams JD. Is sonographic assessment of the cervix necessary and helpful? *Clin Obstet Gynecol* 2012;55:324-35.
18. Hassan SS, Romero R, Vidyadhari D, Fusey S, Baxter JK, Khandelwal M, et al. Vaginal progesterone reduces the rate of preterm birth in women with a sonographic short cervix: a multicenter, randomized, double-blind, placebo-controlled trial. *Ultrasound Obstet Gynecol* 2011;38:18-31.
19. Romero R, Espinoza J, Erez O, Hassan S. The role of cervical cerclage in obstetric practice: can the patient who could benefit from this procedure be identified? *Am J Obstet Gynecol* 2006;194:1-9.
20. Vayssière C, Morinière C, Camus E, Le Strat Y, Poty L, Fermanian J, Ville Y. Measuring cervical length with ultrasound: evaluation of the procedures and duration of a learning method. *Ultrasound Obstet Gynecol* 2002;20:575-9.
21. Coutinho CM, Sotiriadis A, Odibo A, Khalil A, D'Antonio F, Feltovich H, Salomon LJ, Sheehan P, Napolitano R, Berghella V, da Silva Costa F. ISUOG Practice Guidelines: role of ultrasound in the prediction of spontaneous preterm birth. *Ultrasound Obstet Gynecol* 2022;60:435-56.
22. Abdullah ZHA, Chew KT, Velayudham VRV, Yahaya Z, Jamil AAM, Abu MA, Ghani NAA, Ismail NAM. Pre-induction cervical assessment using transvaginal ultrasound versus Bishops cervical scoring as predictors of successful induction of labour in term pregnancies: A hospital-based comparative clinical trial. *PLoS One* 2022;17:e0262387.
23. Kamel R, Garcia FSM, Poon LC, Youssef A. The usefulness of ultrasound before induction of labor. *Am J Obstet Gynecol MFM* 2021;3:100423.
24. Pandis GK, Papageorghiou AT, Ramanathan VG, Thompson MO, Nicolaides KH. Preinduction sonographic measurement of cervical length in the prediction of successful induction of labor. *Ultrasound Obstet Gynecol* 2001;18:623-8.
25. Li PC, Tsui WL, Ding DC. The Association between Cervical Length and Successful Labor Induction: A Retrospective Cohort Study. *Int J Environ Res Public Health* 2023;20:1138.
26. Mackenzie IZ. Induction of labour at the start of the new millennium. *Reproduction* 2006;131:989-98.
27. Mohamed El Bishry G, Serag Allam I, Rasheedy R, Mahmoud A. Accuracy of the Manipal Cervical Scoring System for predicting successful induction of labour. *J Obstet Gynaecol* 2019;39:1057-64.
28. Garcia-Simon R, Oros D, Gracia-Cólera D, Moreno E, Paules C, Cañizares S, Gascón E, Fabre E. Cervix assessment for the management of labor induction: reliability of cervical length and Bishop score determined by residents. *J Obstet Gynaecol Res* 2015;41:377-82.
29. Kwon JY, Wie JH, Choi SK, Park S, Kim SM, Park IY. The degree of cervical length shortening as a predictor of successful or failed labor induction. *Taiwan J Obstet Gynecol* 2021;60:503-8.
30. Ali J, Hebbar S. Ultrasound Assessment of Foetal Head-Perineum Distance Prior to Induction of Labour as a Predictor of Successful Vaginal Delivery. *J Obstet Gynaecol India* 2019;69:129-35.
31. Sabry SMH, Ahmed EAO, Ahmed ME, El-Din MM. Cervical Length and Posterior-Cervical Angle in Prediction of Successful Induction of Labor. *J Gynecol Women's Health* 2022;23:556112.
32. Kim EJ, Heo JM, Kim HY, Ahn KH, Cho GJ, Hong

- SC, Oh MJ, Lee NW, Kim HJ. The Value of Posterior Cervical Angle as a Predictor of Vaginal Delivery: A Preliminary Study. *Diagnostics (Basel)* 2021;11:1977. Erratum in: *Diagnostics (Basel)* 2022;12:1647.
33. Verhoeven CJ, Opmeer BC, Oei SG, Latour V, van der Post JA, Mol BW. Transvaginal sonographic assessment of cervical length and wedging for predicting outcome of labor induction at term: a systematic review and meta-analysis. *Ultrasound Obstet Gynecol* 2013;42:500-8.
34. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
35. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev* 2016;5:210.
36. Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, Leeflang MM, Sterne JA, Bossuyt PM; . QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med* 2011;155:529-36.
37. Al-Adwy AM, Sobh SM, Belal DS, Omran EF, Hassan A, Saad AH, Afifi MM, Nada AM. Diagnostic accuracy of posterior cervical angle and cervical length in the prediction of successful induction of labor. *Int J Gynaecol Obstet* 2018;141:102-7.
38. Alanwar A, Hussein SH, Allam HA, Hussein AM, Abdelazim IA, Abbas AM, Elsayed M. Transvaginal sonographic measurement of cervical length versus Bishop score in labor induction at term for prediction of caesarean delivery. *J Matern Fetal Neonatal Med* 2021;34:2146-53.
39. Alvarez-Colomo C, Gobernado-Tejedor JA. The validity of ultrasonography in predicting the outcomes of labour induction. *Arch Gynecol Obstet* 2016;293:311-6.
40. Aracic N, Stipic I, Jakus Alujevic I, Poljak P, Stipic M. The value of ultrasound measurement of cervical length and parity in prediction of cesarean section risk in term premature rupture of membranes and unfavorable cervix. *J Perinat Med* 2017;45:99-104.
41. Athulathmudali SR, Patabendige M, Chandrasinghe SK, De Silva PHP. Transvaginal two-dimensional ultrasound measurement of cervical volume to predict the outcome of the induction of labour: a prospective observational study. *BMC Pregnancy Childbirth* 2021;21:433.
42. Bastani P, Hamdi K, Abasalizadeh F, Pourmousa P, Ghatrehsamani F. Transvaginal ultrasonography compared with Bishop score for predicting cesarean section after induction of labor. *Int J Womens Health* 2011;3:277-80.
43. Brik M, Mateos S, Fernandez-Buhigas I, Garbayo P, Costa G, Santacruz B. Sonographical predictive markers of failure of induction of labour in term pregnancy. *J Obstet Gynaecol* 2017;37:179-84.
44. Çaliskan E, Doger E, Çakiroglu Y, Özkan S, Özeren S, Çorakçi A. Does cervical length measurement help to predict the success rate of labor induction using misoprostol at term in women with strictly unfavorable cervix? *J Turk Ger Gynecol Assoc* 2006;7:184-8.
45. Cheung CW, Leung TY, Sahota DS, Chan OK, Chan LW, Fung TY, Lau TK. Outcome of induction of labour using maternal characteristics, ultrasound assessment and biochemical state of the cervix. *J Matern Fetal Neonatal Med* 2010;23:1406-12.
46. Cromi A, Ghezzi F, Tomera S, Scandroglio S, Colombo G, Bolis P. Cervical ripening with a Foley catheter: the role of pre- and postripening ultrasound examination of the cervix. *Am J Obstet Gynecol* 2007;196:41.e1-7.
47. Cubal A, Carvalho J, Ferreira MJ, Rodrigues G, Carmo OD. Value of Bishop score and ultrasound cervical length measurement in the prediction of cesarean delivery. *J Obstet Gynaecol Res* 2013;39:1391-6.
48. Daskalakis G, Thomakos N, Hatzioannou L, Mesogitis S, Papantoniou N, Antsaklis A. Sonographic cervical length measurement before labor induction in term nulliparous women. *Fetal Diagn Ther* 2006;21:34-8.
49. Gül DK. Can uterocervical angle and cervical length determine the success of induction of labor in late-term and post-term nulliparous pregnant women? *Cukurova Medical Journal*. 2020;45:1634-43.
50. Dögl M, Skogvoll E, Heimstad R. Cervical insulin-like growth factor binding protein-1 (IGFBP-1) to predict spontaneous onset of labor and induction to delivery interval in post-term pregnancy. *Acta Obstet Gynecol Scand* 2011;90:57-62.
51. Eggebø TM, Heien C, Økland I, Gjessing LK, Romundstad P, Salvesen KA. Ultrasound assessment of fetal head-perineum distance before induction of labor. *Ultrasound Obstet Gynecol* 2008;32:199-204.
52. Elghorori MR, Hassan I, Dartey W, Abdel-Aziz E, Bradley M. Comparison between subjective and objective assessments of the cervix before induction of labour. *J Obstet Gynaecol* 2006;26:521-6.
53. El-Maghraby IM. Cervical Length as a Predictor of Success of Induction of Labor. *The Egyptian Journal of Hospital Medicine* 2021;85:3921-6.
54. Funghi L, Torricelli M, Novembri R, Vannuccini S, Cevenini G, Di Tommaso M, Severi FM, Petraglia F.

- Placental and maternal serum activin A in spontaneous and induced labor in late-term pregnancy. *J Endocrinol Invest* 2018;41:171-7.
55. Gabriel R, Darnaud T, Chalot F, Gonzalez N, Leymarie F, Quereux C. Transvaginal sonography of the uterine cervix prior to labor induction. *Ultrasound Obstet Gynecol* 2002;19:254-7.
  56. Gillor M, Vaisbuch E, Zaks S, Barak O, Hagay Z, Levy R. Transperineal sonographic assessment of angle of progression as a predictor of successful vaginal delivery following induction of labor. *Ultrasound Obstet Gynecol* 2017;49:240-5.
  57. Gómez-Laencina AM, Sánchez FG, Gimenez JH, Martínez MS, Valverde Martínez JA, Vizcaíno VM. Comparison of ultrasonographic cervical length and the Bishop score in predicting successful labor induction. *Acta Obstet Gynecol Scand* 2007;86:799-804.
  58. Gómez-Laencina AM, García CP, Asensio LV, Ponce JA, Martínez MS, Martínez-Vizcaíno V. Sonographic cervical length as a predictor of type of delivery after induced labor. *Arch Gynecol Obstet* 2012;285:1523-8.
  59. Gonen R, Degani S, Ron A. Prediction of successful induction of labor: comparison of transvaginal ultrasonography and the Bishop score. *Eur J Ultrasound* 1998;7:183-7.
  60. Hwang HS, Sohn IS, Kwon HS. Imaging analysis of cervical elastography for prediction of successful induction of labor at term. *J Ultrasound Med* 2013;32:937-46.
  61. Kang WS, Park KH, Kim SN, Shin DM, Hong JS, Jung HJ. Degree of cervical shortening after initial induction of labor as a predictor of subsequent successful induction. *Ultrasound Obstet Gynecol* 2010;36:749-54.
  62. Kant RH, Bashir A, Gupta S. Study of Transvaginal Sonographic Assessment of Cervix in Predicting the Success of Labour Induction in Nulliparous Women. *JK Science* 2016;18:6-11.
  63. Raynela F, Lukas E, Qadar S, Chalid MT. Comparison of Bishop score and cervical length measurement through transvaginal ultrasound as prediction against labor induction. *Asian Pacific Journal of Reproduction* 2018;7:280-4.
  64. Keepanasseril A, Suri V, Bagga R, Aggarwal N. Pre-induction sonographic assessment of the cervix in the prediction of successful induction of labour in nulliparous women. *Aust N Z J Obstet Gynaecol* 2007;47:389-93.
  65. Khandelwal R, Patel P, Pitre D, Sheth T, Maitra N. Comparison of Cervical Length Measured by Transvaginal Ultrasonography and Bishop Score in Predicting Response to Labor Induction. *J Obstet Gynaecol India* 2018;68:51-7.
  66. Khazardoost S, Ghotbizadeh Vahdani F, Latifi S, Borna S, Tahani M, Rezaei MA, Shafaat M. Pre-induction translabial ultrasound measurements in predicting mode of delivery compared to bishop score: a cross-sectional study. *BMC Pregnancy Childbirth* 2016;16:330.
  67. Meijer-Hoogveen M, Roos C, Arabin B, Stoutenbeek P, Visser GH. Transvaginal ultrasound measurement of cervical length in the supine and upright positions versus Bishop score in predicting successful induction of labor at term. *Ultrasound Obstet Gynecol* 2009;33:213-20.
  68. El Mekkawi S, Hanafi S, Khalaf-Allah AE, Abdelazim IA, Mohammed EK. Comparison of transvaginal cervical length and modified Bishop's score as predictors for labor induction in nulliparous women. *Asian Pacific Journal of Reproduction* 2019;8:34-8.
  69. Park KH. Transvaginal ultrasonographic cervical measurement in predicting failed labor induction and cesarean delivery for failure to progress in nulliparous women. *J Korean Med Sci* 2007;22:722-7.
  70. Park KH, Lee SY, Jeong EH, Ryu A, Oh KJ, Kim SN. Bishop score and cervical length at 33-35 weeks of gestation and the risk of intrapartum cesarean delivery of twins. *J Perinat Med* 2012;40:383-8.
  71. Paterson-Brown S, Fisk NM, Edmonds DK, Rodeck CH. Preinduction cervical assessment by Bishop's score and transvaginal ultrasound. *Eur J Obstet Gynecol Reprod Biol* 1991;40:17-23.
  72. Pitarello Pda R, Tadashi Yoshizaki C, Ruano R, Zugaib M. Prediction of successful labor induction using transvaginal sonographic cervical measurements. *J Clin Ultrasound* 2013;41:76-83.
  73. Rane SM, Guirgis RR, Higgins B, Nicolaidis KH. Pre-induction sonographic measurement of cervical length in prolonged pregnancy: the effect of parity in the prediction of the need for Cesarean section. *Ultrasound Obstet Gynecol* 2003;22:45-8.
  74. Rathore A, Sharma R, Kar R, Tandon A, Suneja A, Guleria K. Role of Cervical Phosphorylated Insulin-Like Growth Factor-Binding Protein 1 (pIGFBP1) for Prediction of Successful Induction Among Primigravida with Prolonged Pregnancy. *J Obstet Gynaecol India* 2021;71:38-44.
  75. Reis FM, Gervasi MT, Florio P, Bracalente G, Fadalti M, Severi FM, Petraglia F. Prediction of successful induction of labor at term: role of clinical history, digital examination, ultrasound assessment of the cervix, and fetal fibronectin assay. *Am J Obstet Gynecol* 2003;189:1361-7.
  76. Roman H, Verspyck E, Vercoustre L, Degre S, Col

- JY, Firmin JM, Caron P, Marpeau L. Does ultrasound examination when the cervix is unfavorable improve the prediction of failed labor induction? *Ultrasound Obstet Gynecol* 2004;23:357-62.
77. Rozenberg P, Chevret S, Chastang C, Ville Y. Comparison of digital and ultrasonographic examination of the cervix in predicting time interval from induction to delivery in women with a low Bishop score. *BJOG* 2005;112:192-6.
78. Tan PC, Vallikkannu N, Suguna S, Quek KF, Hassan J. Transvaginal sonographic measurement of cervical length vs. Bishop score in labor induction at term: tolerability and prediction of Cesarean delivery. *Ultrasound Obstet Gynecol* 2007;29:568-73.
79. Tan PC, Suguna S, Vallikkannu N, Hassan J. Ultrasound and clinical predictors for Caesarean delivery after labour induction at term. *Aust N Z J Obstet Gynaecol* 2006;46:505-9.
80. Tanir HM, Sener T, Yildiz Z. Digital and transvaginal ultrasound cervical assessment for prediction of successful labor induction. *Int J Gynaecol Obstet* 2008;100:52-5.
81. Türkyılmaz G, Karaaslan O, Türkyılmaz S, Ertürk E. Does Cervical Length Predict the Successful Labor Induction in Term Nulliparous Women Who Had Unfavorable Cervix? *Eastern Journal Of Medicine* 2020;25:540-5.
82. Uyar Y, Erbay G, Demir BC, Baytur Y. Comparison of the Bishop score, body mass index and transvaginal cervical length in predicting the success of labor induction. *Arch Gynecol Obstet* 2009;280:357-62.
83. Uzun I, Sık A, Sevket O, Aygün M, Karahasanoglu A, Yazıcıoglu HF. Bishop score versus ultrasound of the cervix before induction of labor for prolonged pregnancy: which one is better for prediction of cesarean delivery. *J Matern Fetal Neonatal Med* 2013;26:1450-4.
84. Vallikkannu N, Lam WK, Omar SZ, Tan PC. Insulin-like growth factor binding protein 1, Bishop score, and sonographic cervical length: tolerability and prediction of vaginal birth and vaginal birth within 24 hours following labour induction in nulliparous women. *BJOG* 2017;124:1274-83.
85. Ware V, Raynor BD. Transvaginal ultrasonographic cervical measurement as a predictor of successful labor induction. *Am J Obstet Gynecol* 2000;182:1030-2.
86. Yang SH, Roh CR, Kim JH. Transvaginal ultrasonography for cervical assessment before induction of labor. *J Ultrasound Med* 2004;23:375-82, quiz 384-5.
87. Yang SW, Kim SY, Hwang HS, Kim HS, Sohn IS, Kwon HS. The Uterocervical Angle Combined with Bishop Score as a Predictor for Successful Induction of Labor in Term Vaginal Delivery. *J Clin Med* 2021;10:2033.
88. Zhou Y, Jin N, Chen Q, Lv M, Jiang Y, Chen Y, Xi F, Yang M, Zhao B, Huang H, Luo Q. Predictive value of cervical length by ultrasound and cervical strain elastography in labor induction at term. *J Int Med Res* 2021;49:300060520985338.
89. Dewandeleer S, Hansske A, Parmentier D. Evaluation of the uterine cervix by intravaginal ultrasonography prior to prostaglandin gel maturation. *Revue française de gynécologie et d'obstétrique* 1998;93:106-10.
90. Hatfield AS, Sanchez-Ramos L, Kaunitz AM. Sonographic cervical assessment to predict the success of labor induction: a systematic review with metaanalysis. *Am J Obstet Gynecol* 2007;197:186-92.
91. Kolkman DG, Verhoeven CJ, Brinkhorst SJ, van der Post JA, Pajkrt E, Opmeer BC, Mol BW. The Bishop score as a predictor of labor induction success: a systematic review. *Am J Perinatol* 2013;30:625-30.

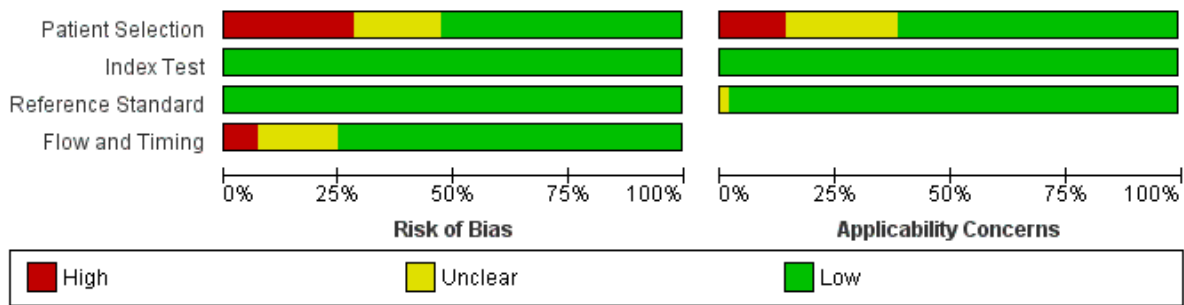
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**Supplementary**

**Table S1** Search strategy and results of the included databases

Database	Strategy	Filters	Date	Results
PubMed	("Labor, Obstetric" OR "Labor Pain" OR "Trial of Labor" OR "Obstetric Labor, Premature" OR "Labor, Induced" OR "Labor Stage, Third" OR "Labor Stage, Second" OR "Labor Stage, First" OR "Labor Presentation" OR "Labor Onset" OR "Obstetric Labor Complications" OR "Child Labor") AND ("induction of labour" OR "induced labour") AND ("cervical length" OR "cervical wedging" OR "funneling cervical elastography" OR "cervical shear wave elastography" OR "uterocervical angle" OR "cervical volume" OR "Bishop score" OR "Manipal cervical scoring system")	None	To March 04, 2023	943
Scopus	("Labor, Obstetric" OR "Labor Pain" OR "Trial of Labor" OR "Obstetric Labor, Premature" OR "Labor, Induced" OR "Labor Stage, Third" OR "Labor Stage, Second" OR "Labor Stage, First" OR "Labor Presentation" OR "Labor Onset" OR "Obstetric Labor Complications" OR "Child Labor") AND ("induction of labour" OR "induced labour") AND ("cervical length" OR "cervical wedging" OR "funneling cervical elastography" OR "cervical shear wave elastography" OR "uterocervical angle" OR "cervical volume" OR "Bishop score" OR "Manipal cervical scoring system")	Title, Abstract, Keywords		1,131
Web of Science	("Labor, Obstetric" OR "Labor Pain" OR "Trial of Labor" OR "Obstetric Labor, Premature" OR "Labor, Induced" OR "Labor Stage, Third" OR "Labor Stage, Second" OR "Labor Stage, First" OR "Labor Presentation" OR "Labor Onset" OR "Obstetric Labor Complications" OR "Child Labor") AND ("induction of labour" OR "induced labour") AND ("cervical length" OR "cervical wedging" OR "funneling cervical elastography" OR "cervical shear wave elastography" OR "uterocervical angle" OR "cervical volume" OR "Bishop score" OR "Manipal cervical scoring system")	Title		541



**Figure S1** Summary of the percentage of the quality of the included studies for each domain.

	Risk of Bias				Applicability Concerns		
	Patient Selection	Index Test	Reference Standard	Flow and Timing	Patient Selection	Index Test	Reference Standard
Aalvarez-colomo2015	+	+	+	+	+	+	+
Abdullah 2022	+	+	+	+	+	+	+
Al-Adwy 2018	+	+	+	?	+	+	+
Alanwar 2021	+	+	+	+	+	+	+
Ali 2018	+	+	+	+	+	+	+
Aracic 2016	+	+	+	+	+	+	+
Athulathmudali 2021	+	+	+	+	+	+	+
Bastani 2011	+	+	+	+	?	+	?
Brik 2016	+	+	+	+	+	+	+
Caliskan 2006	?	+	+	+	+	+	+
Cheung 2010	+	+	+	+	+	+	+
Cromi 2007	+	+	+	+	+	+	+
Cubal 2013	+	+	+	+	+	+	+
Daskalakis 2006	+	+	+	+	+	+	+
Öül 2020	+	+	+	+	?	+	+
Dogl 2010	+	+	+	+	+	+	+
Eggeba 2008	+	+	+	+	+	+	+
Elghorori 2006b	+	+	+	+	+	+	+
El-Maghraby 2021	?	+	+	?	?	+	+
Funghi 2018	+	+	+	?	+	+	+
GABRIEL 2002	+	+	+	+	+	+	+
Gillor2016	?	+	+	+	?	+	+
GOMEZ LAENCINA 2007	?	+	+	+	+	+	+
GOMEZ LAENCINA 2012	+	+	+	+	+	+	+
Gonen 1998	+	+	+	+	+	+	+
Hwang 2013	+	+	+	+	+	+	+
Kang 2010	+	+	+	+	+	+	+
Kant 2016	+	+	+	?	?	+	+
KEEPANASSERIL 2007	+	+	+	?	+	+	+
Khandelwal 2018	+	+	+	?	+	+	+
khazardoost 2016	+	+	+	+	+	+	+
Kwon 2021	+	+	+	+	+	+	+
Li 2003	+	+	+	?	?	+	+
Meijer-Hoogeveen 2009	+	+	+	+	+	+	+
El Mekkawi 2019	?	+	+	+	?	+	+
pandis 2001	+	+	+	+	+	+	+
Park 2007	+	+	+	+	?	+	+
Park 2012	?	+	+	+	?	+	+
Paterson-Brown 1991	+	+	+	+	+	+	+
Pitarello 2012	+	+	+	+	+	+	+
Rane 2003	?	+	+	+	?	+	+
Rathore 2020	+	+	+	+	+	+	+
Raynela 2018	?	+	+	?	?	+	+
Reis 2003	+	+	+	+	+	+	+
Roman 2004	?	+	+	+	?	+	+
Rozenberg 2005	+	+	+	+	+	+	+
Tan 2006	+	+	+	+	+	+	+
Tan 2007	+	+	+	+	+	+	+
Tanir 2008	+	+	+	?	+	+	+
Turkylmaz 2020	+	+	+	+	+	+	+
Uyar 2009	+	+	+	+	+	+	+
Uzun 2013	?	+	+	+	?	+	+
vallikkannu 2016	+	+	+	+	+	+	+
Ware 2000	?	+	+	+	+	+	+
Yang 2004	+	+	+	+	+	+	+
Yang 2021	+	+	+	+	+	+	+
Zhou 2021	+	+	+	?	?	+	+

High
 Unclear
 Low

Figure S2 Summary of the quality assessment of the included studies for each study individually.

**Table S2** Outcome summary table for each study

Study ID	Cervical length for IOL	Cervical length for failed IOL	Posterior cervical angle for successful IOL	Posterior cervical angle for failed IOL	Cervical length shortening for successful IOL	Cervical length shortening for failed IOL
Alanwar		Yes				
Abdullah	Yes					
Al-Adwy	Yes		Yes			
Alvarez-Colomo		Yes				
Aracic		Yes				
Athulathmudali	Yes					
Bastani		Yes		Yes		
Brik		Yes				
Cheung	Yes					
Çaliskan		Yes				
Cromi	Yes					
Cubal		Yes				
Daskalakis	Yes					
Gül		Yes		Yes		Yes
Dewandeleer						
Dögl	Yes					
Eggebo	Yes		Yes			
Al-Maghraby	Yes					
Funghi	Yes					
Gabriel		Yes				
Gómez Laencina	Yes	Yes				
Gillor			Yes			
Gonen	Yes					Yes
Hwang	Yes					
Kang	Yes				Yes	
Kant	Yes		Yes			
Kawn					Yes	
Raynelda	Yes					
Keepanasseril	Yes		Yes			
Khazardoost	Yes					
Kwon	Yes					
Li	Yes					
Meijer-Hoogeveen	Yes					Yes
El Mekkawi	Yes					
Pandis	Yes					
Paterson-Brown		Yes	Yes			
Pitarello	Yes					
Ran		Yes				
Rozenberg		Yes				
Roman		Yes				Yes
Rathore	Yes					
Park		Yes				Yes
Reis	Yes					Yes
Tan 2006		Yes				
Tan 2007		Yes				
Tanir	Yes					
Türkyilmaz	Yes					
Uyar	Yes					
Uzun		Yes		Yes		
Vallikkannu	Yes					
Ware	Yes					
Yang	Yes		Yes			Yes
Zhou	Yes					

IOL, induction of labor.

**Table S3** The cutoff values for each outcome reported by the individual studies

Study ID	Prediction	Cut-off value or mean value for cervical length	Cut-off value or mean value for posterior cervical angle	Cut-off value or mean value for posterior cervical angle for fetal head-perineum distance
Abdullah 2022	Successful induction of labour within 24 hours	≤27 mm	NR	NR
Al-Adwy 2018	Successful induction of labour within 24 hours	<34 mm	>99.5°	NR
Alanwar 2021	Prediction of cesarean delivery within 24 hours	>23 mm	NR	NR
Ali 2019	Successful induction of labour within 24 hours	<3 cm	NR	<5.5 cm
Alvarez-Colomo 2016	Prediction of cesarean delivery within 60 hours	>25 mm	NR	>0.45 mm
Aracic 2017	Prediction of cesarean delivery within 12 hours	34 mm	NR	NR
Athulathmudali 2021	Successful induction of labour within 24 hours	<37 mm	NR	NR
Bastani 2011	Prediction of cesarean delivery	>19	≥117°	NR
Brik 2017	Prediction of cesarean delivery within 12 hours	>28 mm	NR	NR
Çalışkan 2006	Prediction of cesarean delivery within 24 hours	30 mm	NR	NR
Cheung 2010	Successful induction of labour within 24 hours	≤2.045 cm	NR	NR
Cromi 2007	Successful induction of labour within 24 hours	≤33 mm	NR	NR
Cubal 2013	Prediction of cesarean delivery within 24 hours	30 mm	NR	NR
Daskalakis 2006	Successful induction of labour within 24 hours	≤27 mm	NR	NR
Gül 2020	Prediction of prolonged latent phase more than 24 hours (failure of induction)	29.5	98.5°	NR
Dögl 2011	Successful induction of labour within 72 hours	26 mm NR	NR	NR
	Successful induction of labour within 24 hours		NR	
Eggebo 2008	Successful induction of labour within 24 hours	≤25 mm	>90°	<40 mm
Elghorori 2006	Successful induction of labour within 24 hours	≤34 mm	NR	NR
El-Maghraby 2021	Successful induction of labour within 24 hours	≤27 mm	NR	NR
		≤29 mm	NR	NR
Funghi 2018	Successful induction of labour	≤24 mm	NR	NR
Gabriel 2002	Prediction of cesarean delivery	26 mm	NR	NR
Gillor 2017	Successful induction of labour	NR	>92°	NR
Gómez Laencina 2007	Successful induction of labour within 12 hours	24 mm	NR	NR
Gómez-Laencina 2012	Prediction of cesarean delivery within 12 hours	25.2 mm	NR	NR
Gonen 1998	Successful induction of labour	≤27 mm	NR	NR
Hwang 2013	Successful induction of labour within 9 hours	<20 mm	NR	NR
	Successful induction of labour within 24 hours	<20 mm	NR	NR
Kang 2010	Successful induction of labour	24 mm	NR	NR
Kant 2016	Successful induction of labour	30 mm	100°	NR
Raynelda 2018	Successful induction of labour	29.8 mm	NR	NR
Keepanasseril 2007	Successful induction of labour	30 mm	100°	NR
Khandelwal 2018	Induction of labor active phase within 6 hours	25 mm	NR	NR
	Induction of labor active phase within 6 hours	30 mm	NR	NR
Khazardoost 2016	Successful induction of labour	12.5 mm	NR	12 mm
Kwon 2021	Successful induction of labour	29 mm	NR	NR
Laencina 2007	Successful induction of labour	24 mm	NR	NR
Li 2023	Successful induction of labour	34 mm	NR	NR
Meijer-Hoogveen 2009	Successful induction of labour	NR	NR	NR
El Mekkawi 2019	Successful induction of labour	28 mm	NR	NR
Pandis 2001	Successful induction of labour within 24 hours	28 mm	NR	NR
Park 2007	Failed induction of Labor	28 mm	NR	NR
Park 2012	Risk of cesarean section	20 mm	NR	NR
Paterson-Brown 1991	Predicting cesarean section	NR	70°	NR

**Table S3** (continued)

**Table S3** (continued)

Study ID	Prediction	Cut-off value or mean value for cervical length	Cut-off value or mean value for posterior cervical angle	Cut-off value or mean value for posterior cervical angle for fetal head-perineum distance
Pitarelo 2013	Vaginal delivery overall	26.5 mm	NR	NR
	Vaginal delivery up to 24 hours	26.5 mm	NR	NR
Rane 2003	Predicting cesarean section	NR	NR	NR
Rathore 2021	Successful induction of labour	35 mm	NR	NR
Reis 2003	Successful induction of labour within 24 hours	20 mm	NR	NR
Roman 2004	Predicting failure of induction	28 mm	NR	NR
Rozenberg 2005	Predicting cesarean section	NR	NR	NR
Tan 2007	Predicting cesarean section	20 mm	NR	NR
Tan 2006	Predicting cesarean section	20 mm	NR	NR
Tanir 2008	Successful induction of labour	25 mm	NR	NR
Türkyilmaz 2020	Successful induction of labour	30 mm	NR	NR
Uyar 2009	Successful induction of labour	19 mm	NR	NR
Uzun 2013	Predicting cesarean section	27 mm	98°	NR
Vallikkannu 2017	Vaginal delivery after IOL	29 mm	NR	NR
	Vaginal delivery within 24 hours of IOL	29 mm	NR	NR
Ware 2000	Predictor of vaginal delivery	30 mm	NR	NR
Yang 2004	Successful induction of labour	30 mm	NR	NR
Yang 2021		NR	NR	NR
Zhou 2021	Successful induction of labour	27.7 mm	NR	NR

NR, not reported; IOL, induction of labor.