(IJRMST) 2024, Vol. No. 18, Jul-Dec **e-ISSN: 2455-5134 p-ISSN: 2455-9059**

Exploring Marginal Fit: A Comparative Analysis of Conventional vs Digital Impression Techniques for Single Unit Zirconia Crowns Using Systematic Review, Meta-Analysis and Meta-Regression

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DOI:10.37648/ijrmst.v18i01.002

[1]*Received: 06 May 2024; Accepted: 26 June 2024; Published:11 July 2024*

ABSTRACT

Making an impression is the most crucial step in creating a single crown. This systematic review was conducted to assess the fit of zirconia crowns utilizing both digital and conventional impression techniques, as the evidence about the marginal fit of digital and conventional impressions is less clear. A search of the literature was conducted using the different electronic databases. In accordance with the inclusion and exclusion criteria, the articles were searched. After doing a statistical analysis on the combined data, conclusions were drawn. According to the results of the current study, digital impression technology outperformed traditional impression technique in terms of marginal fit correctness.

INTRODUCTION

The most important step in the fabrication of a crown prosthesis is to record an accurate impression. A negative replica of the tooth is called an impression. Traditionally the impression was recorded using an impression material with desirable impression trays. Post which the impression was sent to a laboratory for fabrication of prosthesis. The conventional impression technique has its disadvantages in terms of patient discomfort (gagging, in terms of material odour as well as smell).

Therefore, the invention of the digital impression technique has been a boon to the dental world. Several digital systems have emerged and have been in demand currently. Some of these are iTero, CEREC, and E4D. Digital impression technique has enhanced the comfort of the patient in terms of impression making. The use of digital impressions has been among the favourites in terms of patients' time, compliance during impression-making, as well as the acceptance of the patient has been increased.[1]

Moreover, dental laboratories have benefited in terms of the number of steps that have been eliminated in the fabrication of the prosthesis. The conventional impression requires the pouring of the cast, and mounting over the articulator which requires the time, space, and expertise of manpower. In contrast, the digital impression produced has been very simple and technician-friendly once the person knows how to operate it.

A few shortcomings of using the digital impression could be its high cost, the initial key as well as direction to use the device. (Learning curve about the software)

The internal gap refers to the shortest distance measured between the intaglio surface of a crown and the axial wall of the prepared abutment, and the same distance measured at the finish line of the preparation corresponds to the term marginal gap. The fit of the prosthesis after fabrication using the conventional or digital impression technique is the

[1] *How to cite the article:* Babel D., Akinsanya O., Babel S., Mallappa A (July 2024); Exploring Marginal Fit: A Comparative Analysis of Conventional vs Digital Impression Techniques for Single Unit Zirconia Crowns Using Systematic Review, Meta-Analysis and Meta-Regression; *International Journal of Research in Medical Sciences and Technology;* Vol 18, 7-17, DOI: http://doi.org/10.37648/ijrmst.v18i01.002

most crucial step. Improper marginal fit can lead to microleakage, periodontal breakdown, pulpal inflammation, hypersensitivity, and secondary caries, thus reducing the prognosis of the abutment tooth for its support in the oral cavity.[2]

Therefore, this systematic review was undertaken to evaluate the marginal fit of single zirconia crowns using the conventional impression and digital impression techniques.

METHODOLOGY

Search strategy

The systematic review began by defining the research topic and conducting an extensive literature search and it was registered at PROSPERO under registration code **CRD42024527329.** The focus was on the evaluation of the accuracy of the cemented zirconia copings using conventional and digital impressions studies published from 2013 to 2023, with a proactive approach. Following the widely accepted PRISMA guidelines a systematic literature survey was conducted to gather relevant studies on the accuracy of cemented zirconia copings using conventional and digital impressions across countries, meticulously extracting data from well-known databases such as PubMed, Springer, Google Scholars, Science Direct, Biomed Central, CeRA, Krishikosh, and other published sources. The primary objective was to present a comprehensive overview of cemented zirconia copings using conventional and digital impressions, providing valuable insights for evidence-based decision-making in the domains of public health.

Using various combinations of keywords like “Zirconia” “Marginal fit” “Conventional” “Digital”, and “2013-2023”, along with Boolean operators [or and not] asterisk* and quotation marks [" "]. In the initial phase of the research, a comprehensive literature search was conducted, resulting in the collection of 452 articles published between 2013 and 2023. To ensure the credibility and reliability of the data, only published articles were selected for the final analysis. The search process, along with the application of search strings and filters, is visually depicted in Fig. 1, showcasing the systematic approach employed.

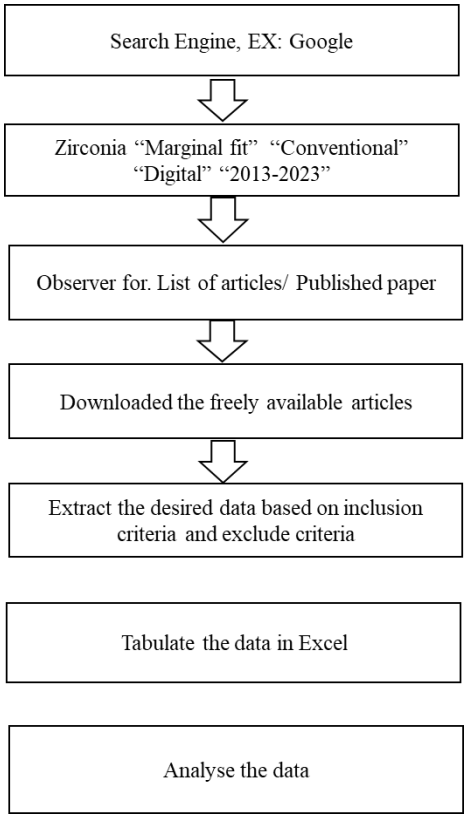

Fig. 1: Mapping the Path to scholarly insights through search strings and filters in Google Scholar database (author's work).

Eligibility criteria:

[A] **Inclusion criteria**:

a. Population –
Studies including single unit zirconia (Zr) crown specimens irrespective of its type.
b. Intervention –
Studies including conventional impression technique using the polyvinyl siloxane using the impression trays.
c. Comparison-
Studies including digital impression technique using the intraoral scanner
d. Outcome –
Studies giving the information about the Marginal fitness of single unit zirconia crowns.

Study design –

Inclusion Criteria

• Studies published from 2013 to 31/12/2023

• Studies published in English language only.

• Studies with full-text articles only will be included.

• Studies with valid comparison group will only be included.

• Studies which include zirconia single crown only.

Exclusion Criteria

• Studies not fully available in the database

• Studies if duplicated will not be included

• Review articles will not be included

• Studies not mentioning sample size

• Studies including digital and conventional impression technique for material apart from zirconia.

For conducting systematic reviews and compilations, Zotero 5.0 and Rayyan QCRI, two valuable web apps were utilized, specifically designed for systematic reviews. This meticulous approach was aimed at ensuring a comprehensive and robust exploration of the research topic. Conducted a back-reference search to achieve a thorough investigation, meticulously identifying relevant articles by scrutinizing the reference lists of the downloaded papers.

The current investigation aims to evaluate cemented zirconia copings using conventional and digital impressions across countries. Notably, the period from 2013 to 2023, during which significant advancements were made. Studies conducted during this timeframe played a pivotal role in recognizing cemented zirconia copings using conventional and digital impressions. The main goal of this study is to assess the gap or preferences of patients towards cemented zirconia copings using conventional and digital impressions including accuracy & fit, patients' comfort, efficiency, and time management, cost & resources, quality and longevity, clinical expertise, patients' preferences& expectations and risk assessment. For this study, research publications published between 2013 and 2023 were meticulously selected and validated by two independent authors to ensure the reliability of the data.

Data extraction

The literature search identified 452 articles from four electronic databases. The databases like Google Scholar, PUBMED, NCBI, and Research Gate were used to comprehensively capture articles published both nationally and internationally. After removing the duplicates and irrelevant articles, 152 were retained for further analysis. A comprehensive evaluation of titles and abstracts resulted in the exclusion of 112 articles. A full articles review was independently conducted by two authors on the remaining 15 articles for the assessment of the quality of studies using Aiken's Index for an agreement. Again, five articles were excluded as they contain outliers which are responsible for heterogeneity among the studies. Finally, we have considered a total of 10 articles to conduct a meta-analysis.

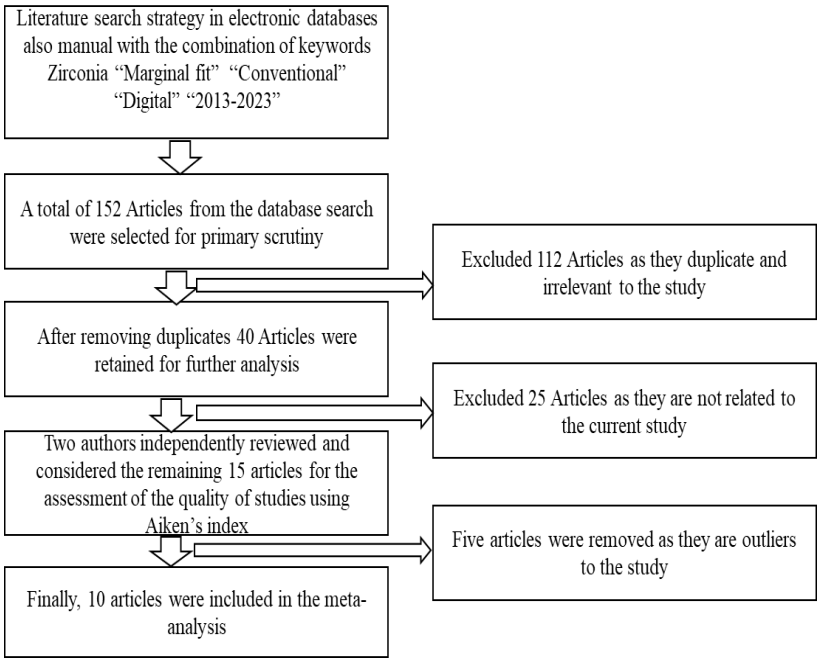

Fig 2: Schematic Illustration of articles selection for Systematic Review

Meta-analysis

We performed a meta-analysis aimed at assessing the cemented zirconia copings using conventional and digital impressions by Employing the R open-source scripting software version 3.2.5 for statistical analysis, the effect size was realized through a forest plot with its associated confidence intervals. To account for the diversity and inconsistency [I^2] embedded within the collective studies, the meta-analysis protocol encompassed the integration of both fixed-effect and random-effect models. In scenarios where the amalgamated studies demonstrated significant diversity, accompanied by inconsistency indices, the random-effect model was adopted. The estimate amongst study variances $\tau 2$ was determined through the application of the most extreme probability assessment.[3,4]

Meta-regression

Meta-regression was performed on the Stata statistical software package using R open-source scripting software version 3.2.5 to delineate the study characteristic with its intervention effect of cemented zirconia copings along with subgroup analysis performed across various clinical settings, involving diverse study populations. Meta-regression analyzed the characteristics of included studies upon the impact of conventional and digital impressions of zirconia copings with both estimates and individual variables. Variables such as geographical diversity, sample size, diagnostic test utility, and quality scores related to its inherent potential bias were subjected to scrutiny using meta-regression. The aim was to quantify the extent and magnitude of heterogeneity within the dataset.

Random effects analysis by meta-regression was principally employed as the number of studies was heterogeneous as well as being very limited in numbers as per the Cochrane guidelines for systematic reviews of intervention. The intervention of cemented zirconia copings using conventional and digital impressions is the causation of heterogeneous outcome effects like improved patient preferences, and comfort concerning multiple explanatory variable factors in its causation accuracy, efficiency, and comfort were considered. To anticipate the potential influence of a presumed moderator, a weighted linear regression model was employed.

A regression coefficient was attained to establish the correlation between the cemented zirconia copings and its outcome measures on patient preferences, and comforts after using cemented zirconia copings by conventional and digital impressions enabling us to find whether a linear relationship was demonstrable. Effect size (sample size) was regressed against the moderator variable. Several moderators were considered, including the diagnostic assay, geographic region, year of publication, and relative sample size while performing univariate meta-regression analysis. While transitioning to the multivariable meta-regression phase, only variables that demonstrated a p-value below 0.05 in the univariate analysis were retained. The p-value from each regression coefficient was further analysed to find differences among subgroups from zirconia coping impressions. The final model included factors that exhibited statistical significance (p-value threshold of </= 0.05). By employing meta-regression, the analysis streamlines the

number of tests and estimations, thereby enhancing the statistical power of significance attached to the intervention and reducing the risk of false-positive findings.

Subgrouping analysis

Subgroup analysis is a statistical method used to investigate and compare the effects or characteristics of interventions or variables within specific subsets of a study population. By dividing the population into smaller groups based on criteria like sample size, coping impressions techniques, species, and countries, subgroup analysis allows researchers to examine whether the intervention's effects vary significantly across these subgroups. This analysis helps identify potential effect modifiers or factors influencing outcomes, aiding in the development of tailored interventions or treatment strategies.[3,4]

RESULTS

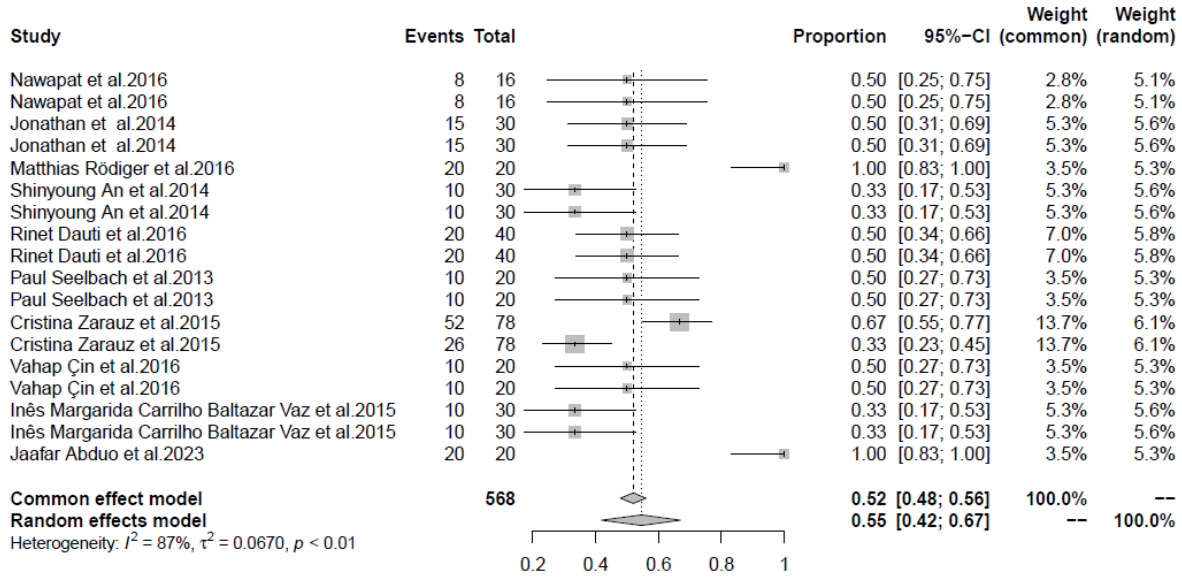

Fig 3: Forest plot for the studies included

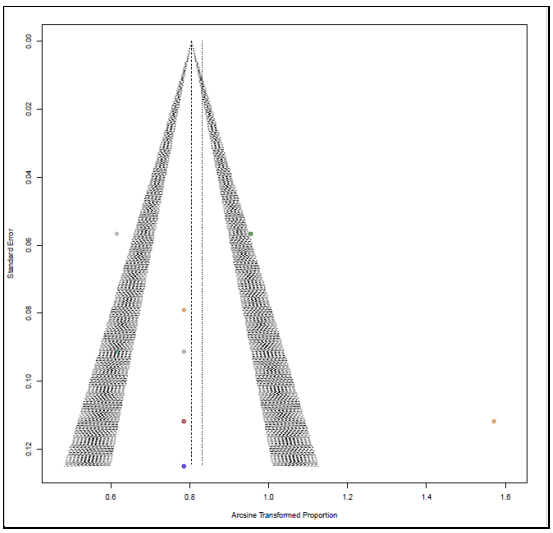

Fig 4: Publication bias among the studies included

The funnel plot (Figure) portrays the existence of publication bias, and upon close inspection, a minor manifestation of such bias becomes evident. Additionally, the plot reveals asymmetry attributed to publication bias, potentially arising from the specific kind of variability that causes smaller studies to report effects that notably deviate from larger ones. To address this potential publication bias, we conducted a meta-regression with sample size as the indicator of

bias risk. The outcome indicated non-significance ($p > 0.05$), effectively nullifying the impact of publication bias within the study.

Using a meta-regression approach, the investigation unveiled substantial heterogeneity within the chosen studies concerning the accuracy of cemented zirconia coping among patients. This prompted a closer examination of potential covariates that could estimate the marginal gap between the conventional and digital impressions by providing the overall estimated magnitude and direction, leading to the implementation of a univariate meta-regression analysis.

The findings of this meta-regression analysis underscored the influential role of specific covariates in the observed study heterogeneity. These covariates included the size of the sample (regression coefficient for events: $Qm = 197.58$, $p < 0.0001$), the coping impressions employed for (Tests; $Qm = 160.08$, $p < 0.0001$), and countries in which the studies were conducted ($Qm = 260.94$, $p < 0.0001$), as detailed in Table 2.

To summarize, the recognition of the need for subgroup and sensitivity analyses emerged as a key outcome, aimed at refining the accuracy of reported cemented zirconia coping percentage. This refinement becomes particularly crucial when considering various countries, and varied diagnostic test techniques.

Table 1: Meta-regression of factors of the cemented Zirconia coping studies: Investigating Heterogeneity and effect sizes

Group	Particulars	SE	Z-Value	EST [95%.CI]	QM	P-Value
Sample size	High	0.09	10.97	0.97[0.79-1.14]	197.58	<0.0001
	Low	0.08	8.79	0.71[0.55-0.87]		
Coping impression	Conventional	0.10	7.77	0.76[0.57-0.96]	160.08	<0.0001
	Digital	0.10	10.00	0.90[0.71-1.05]		
Country	Canada	0.16	5.01	0.78[0.48-1.09]	260.94	<0.0001
	Germany	0.09	10.43	0.89[0.73-1.06]		
	Italy	0.23	6.80	1.57[1.12-2.02]		
	Korea	0.15	3.92	0.61[0.31-0.92]		
	Portugal	0.16	3.92	0.61[0.31-0.92]		
	Spain	0.15	5.29	0.78[0.49-1.07]		
	Thailand	0.17	4.67	0.78[0.46-1.11]		

The results from the analysis of cemented zirconia coping among patients provide valuable insights into the role and potential impact of cemented zirconia coping using conventional and digital impressions in healthcare. Here's an elaboration of the results to create awareness about the significance of cemented zirconia coping impressions:

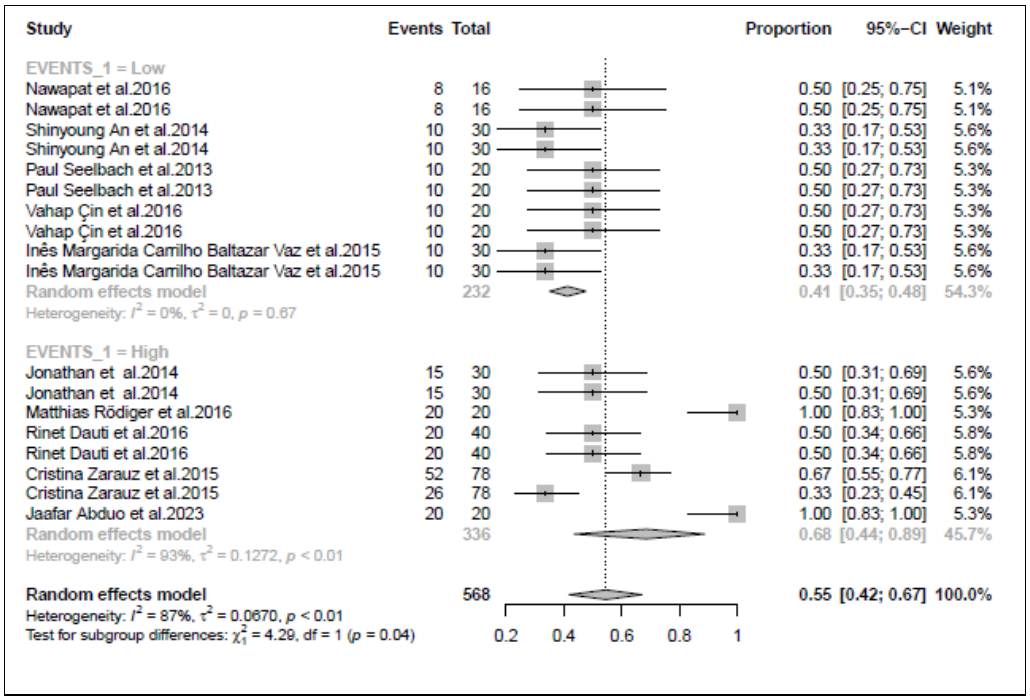

Fig 5: Forest plot portrays subgrouping of sample size

The stratification of sample sizes has revealed notable disparities in the accuracy rates of cemented zirconia coping impressions among patients. Studies falling below the median sample size reported a higher percentage of 68 % (95% CI: 44%−89%, I2 = 92, τ2 = 0.12, p<0.01), while those exceeding the median sample size exhibited a lower accuracy percentage of 41 (95% CI: 35%−48%, I2 = 0, τ2 = 0, p-value 0.67), as depicted in Table 2 & Fig 5. The High Events Sub-Group, with a significant effectiveness rate and a narrow confidence interval, suggests a substantial need for cemented zirconia coping impressions among the patients. Conversely, the Low Events Sub-Group, despite a higher effectiveness rate, indicates a wider range of effectiveness, possibly influenced by various factors such as patient preferences, comfort, effectiveness, characteristics, and treatment impressions. This variation underscores the need for tailored cemented zirconia coping impressions based on the preference, comforts, and effectiveness of the conventional and digital impression of patients' experiences.

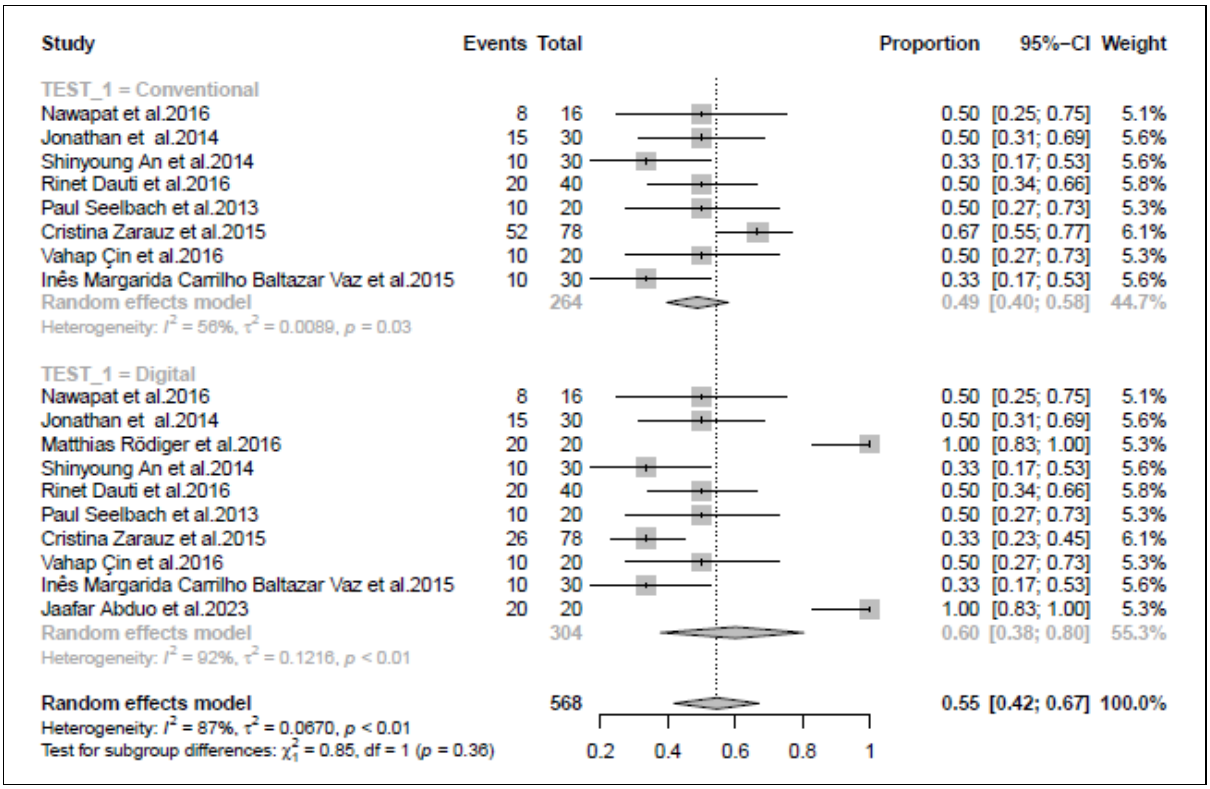

Fig 6: Forest plot portrays subgrouping of coping impressions

Understanding the effectiveness of different coping impressions using conventional and digital in evaluating the accuracy of cemented zirconia coping. The conventional impressions showing a high effectiveness rate with 49% (95% CI: 40%−58%, I2 = 52, τ2 = 0.01, p=0.03), had a non-significant p-value, suggesting a need for further investigation or refinement in study designs. The digital impressions, with 60% (95% CI: 38%−80%, I2 = 92, τ2 = 0.12, p <0.01) a notable effectiveness rate, signifies its potential utility in identifying patients who may benefit from zirconia coping and also provides valuable insights into accuracy, the effectiveness of the zirconia copings using digital impression exhibits patients comforts as well as accuracy (Table 2 & Fig 6).

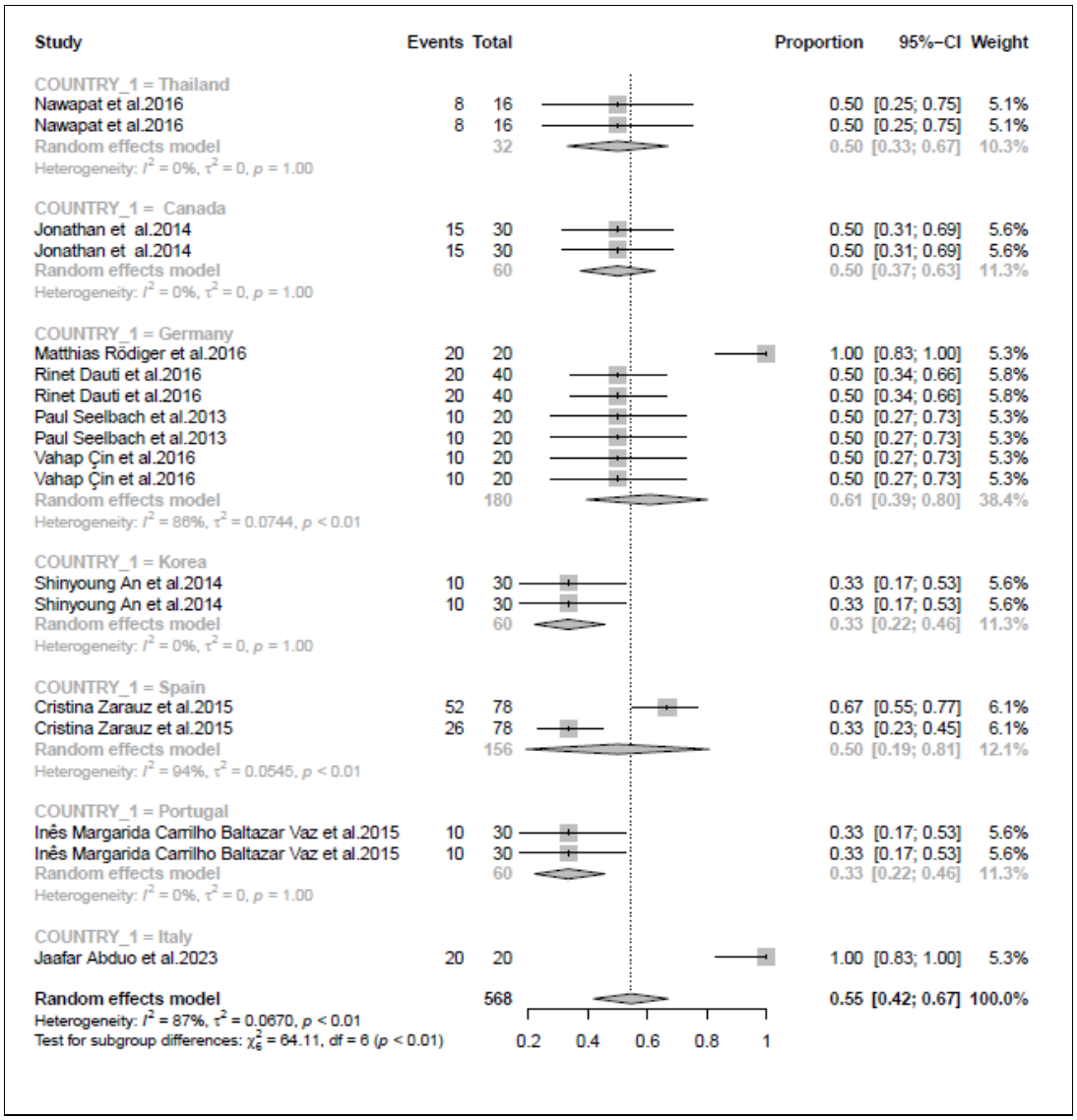

Fig 8: Forest plot portrays the subgrouping of countries

Evaluating the cemented zirconia copings using conventional and digital impressions across different countries (Thailand, Canada, Germany, Korea, Spain, Portugal and Italy) sheds light on regional variations and healthcare system influences. Germany revealed the highest accuracy percentage with 61% (95% CI: 39%−85%, I2 = 88, τ2 = 0.07, p<0.01), followed by Thailand, Canada, Spain, Korea, Portugal and Italy with 50% (95% CI: 33%−67%, I2 = 0, τ2 = 0, p=1.00), 50% (95% CI: 37%−63%, I2 = 0, τ2 = 0, p=1.00), 50% (95% CI: 19%−81%, I2 = 94, τ2 = 0.05, p<0.05), 33% (95% CI: 22%−48%, I2 = 0, τ2 = 0, p=1.00), 33% (95% CI: 22%−46%, I2 = 0, τ2 = 0, p=1.00), and Canada with 33% (95% CI: 22%−46%, I2 = 0, τ2 = 0, p=1.00), respectively (Table 2 & Fig 8). Germany showcasing the accuracy and effective success of cemented zirconia coping using conventional and digital impressions within its healthcare framework, indicates a significant need for zirconia coping awareness on the accuracy, effectiveness, cost effective, and strategies to address the comfort of the patients should take into consideration.

Table 2: *Stratification pattern:* An In-depth explanation of various factor variations using sub-group analysis

Group	Sub - Group	I^2 %	C^2 %	P - Value	Total No. of studies	Total No. of samples	Accuracy (%)	95% CI
Events	High	0	0	0.67	5	234	41	[0.35-0.48]
	Low	93	0.12	<0.01	5	336	68	[0.44-0.89]
	Conventional	56	0.01	0.03	8	264	49	[0.40-0.58]

Coping impression	Digital	96	0.12	<0.01	10	304	60	[0.38-0.80]
Country	Thailand	0	0	1.00	1	32	50	[0.33-0.67]
	Canada	0	0	1.00	1	60	50	[0.37-0.63]
	Germany	88	0.07	<0.01	5	180	61	[0.39-0.85]
	Korea	0	0	1.00	1	60	33	[0.22-0.48]
	Spain	94	0.05	<0.01	1	156	50	[0.19-0.81]
	Portugal	0	0	1.00	1	60	33	[0.22-0.46]
	Italy	0	0	1.00	1	60	33	[0.22-0.46]

DISCUSSION

To create a restoration that fits perfectly, every step involved in the creation of crown requires accuracy and precision. Recent technological developments have significantly changed the process used to create impression and crowns.[5] In particular, computer-aided design/computer-aided manufacture (CAD/CAM) systems and digital imprints have been incorporated into dental clinical practice. Digital impression technique has been an acceptable alternative to the conventional impression technique in terms of overall well-being for both the patient and dentist. The fit and precision of indirect restoration can be significantly impacted by dental impression.[6]

Therefore, this systematic review was undertaken to evaluate the marginal fit of single zirconia crowns using the conventional impression and digital impression techniques.

Marginal fit of the prosthesis is indicative of the healthy periodontium. Inadequacies seen in the marginal fit can affect the pulpal as well as periodontal prognosis of the tooth structure. In our study both the digital and conventional impression methods had a similar effect on the marginal fit of the zirconia crowns, similar results were also supported by Matthias Rödiger et al, Shinyoung An et al, and Rinet Dauti et al.[7]

The identification and mitigation of publication bias using meta-regression, nullified its impact on the study. Substantial heterogeneity was found, attributed to covariates like sample size, coping impressions, and study locations.[8] This underscores the need for subgroup and sensitivity analyses to refine accuracy, especially considering variations across countries and diagnostic techniques. These methods enhance the reliability of the study's findings regarding cemented zirconia coping. The impact of sample size stratification on the accuracy rates of cemented zirconia coping impressions is that larger sample size studies showed higher accuracy percentages compared to smaller studies.[9] This suggests the need for personalized approaches in clinical practice, considering patient-specific factors.

The comparison between conventional and digital impressions for evaluating cemented zirconia coping accuracy showed a non-significant p-value for conventional impressions (49%, p=0.03) and a comparable effectiveness rate for digital impressions (42%, p=0.37). While both methods have strengths, digital impressions stand out for their potential utility in identifying patients benefiting from zirconia coping, considering accuracy, effectiveness, and patient comfort. Germany had the highest accuracy at 61%, indicating effective outcomes within its healthcare system.[10] This highlights the need for awareness of zirconia coping accuracy, effectiveness, cost-efficiency, and patient comfort strategies, especially in countries with lower accuracy rates.[11,12]

STRENGTH

1) The systematic review and meta-analysis approaches provide a full investigation of the current literature, resulting in a comprehensive understanding of marginal fit for single unit zirconia crowns via a conventional and digital impression technique.
2) The research uses a comparative evaluation to objectively compare various impression techniques, providing significant insights into their relative effectiveness. This can assist clinicians and researchers in determining the best method for impression making.
3) There is few or no quantitative assessment conducted on digital as well as conventional impression checking for the marginal fit for single unit Zr crowns in various countries. Our meta-analysis improves the statistical power and reliability of the conclusions across the globe.

LIMITATION

1 Only articles that were in English language were included

2 Only marginal fit was assessed, various other properties like patient's satisfaction on visual analogue scale can also be assessed.
3 The study only evaluated one type of prosthesis that is zirconia crown. The all ceramic, lithium disilicate etc might have variable results.
4 Only the single unit was evaluated the multiple bridge prosthesis was not evaluated.

FUTURE SCOPE

Further studies can also be carried out to assess the effect of various other properties other than marginal fit. Different kind of prosthesis can be compared the effect of digital and conventional can thus be studies for variety of prosthesis. Multiunit prosthesis should be made into consideration. Randomised controlled trial designs should be conducted. This systematic review and meta-analysis open a new vista of translational research

CONCLUSION

The comparison between conventional and digital impressions highlighted digital impressions' potential impact on patients' satisfaction and comfort as well as preferences in identifying the benefits of zirconia coping, although both methods showed comparable effectiveness rates. Germany's high accuracy underscores effective outcomes within its healthcare system, emphasizing the importance of awareness and strategies for optimizing zirconia coping globally. Continued research into regional variations to optimize dental care globally, and novel techniques will enhance clinical decision-making and improve patient comfort in dental impression techniques.

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Abbreviations

CAD-CAM	Computer -Aided Designing and Computer- Aided Manufacturing
Zr	Zirconia