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Comparative Evaluation of Gingival Displacement Achieved by Mechanical and Chemical Retraction Systems Using Digital and Conventional Impression Techniques: An In Vivo Pilot Study.

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KEYWORDS

Gingival displacement, mechanical retraction, chemical retraction, ferric sulphate, digital impression, conventional impression.

ABSTRACT:

Introduction: The success of fixed prosthodontic treatment ultimately depends on how accurately the final impression captures the prepared tooth, because even minor errors can compromise the fit, function, and longevity of the restoration. Achieving this precision requires careful management of the gingival tissues, particularly around the cervical margin, so that the finish line is clearly exposed and accurately recorded. Gingival displacement—whether achieved through mechanical means such as retraction cords or through chemical agents that provide haemostasis and tissue shrinkage—plays a critical role in creating the necessary access while preserving periodontal health. Although digital impression systems have reduced many limitations associated with conventional materials, the need for effective gingival retraction remains unchanged for precise marginal reproduction. In this context, evaluating and comparing mechanical and chemical retraction methods in both digital and conventional workflows is essential to identify a technique that provides adequate displacement with minimal tissue trauma, ultimately supporting predictable, biologically sound, and long-lasting prosthodontic outcomes.

Objectives: Evaluation of lateral gingival displacement in subjects after using Non impregnated gingival retraction cord (00); Cord (00) impregnated with 25% aluminum chloride; Cord (00) impregnated with 20% ferric sulfate

Methods: Ten healthy individuals in the 20–30 age range were chosen. To reduce tissue fatigue, gingival retraction was performed on the left maxillary first molar using a Latin block design by three gingival displacement materials (Mechanical, Ferric sulphate, Aluminium chloride). Both traditional and digital techniques were used to create impressions. For traditional impressions, casts were poured, dies were sectioned and gingival displacement was measured by die sectioning method. For digital impressions, intraoral scans were done and amount of gingival retraction was measured by Exo Cad Software. SPSS version 21.0 was used to measure and statistically analyse the horizontal gingival displacement.

Results: When compared to other retraction systems, ferric sulphate had the largest mean horizontal gingival displacement. The Shapiro-Wilk test revealed that the data had a normal distribution ($p = 0.466$). Group differences were found to be statistically significant using a one-way ANOVA.

Conclusions: Ferric sulphate showed better gingival displacement than other displacement systems used. Accurate and repeatable displacement value measurements were made possible by digital impression techniques.

1. Introduction

The final impression's accuracy is crucial to the success of fixed prosthodontic treatment as small errors can affect the prosthesis's fit, functionality, and longevity. [1,2] Effective control of the gingival tissues surrounding the prepared tooth, especially in the cervical region, is necessary to produce an accurate impression. Gingival displacement is essential to this process because it allows sufficient access and visibility to the preparation's finish line. The creation of well-adapted restorations with the best possible marginal integrity is made easier by

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properly exposing this margin, which guarantees that it is precisely recorded in the impression. [3, 4]

To accomplish this goal, a number of gingival retraction techniques—which can be broadly classified as mechanical, chemical, and chemo-mechanical methods—have been developed.[5] While chemical agents like astringents or haemostatic solutions are used to achieve haemostasis and tissue shrinkage, mechanical systems usually use cords or other physical means to laterally displace the gingival tissues.[6] Although these methods are frequently used, they must be carefully chosen and performed to strike a balance between the necessity of sufficient displacement and the possibility of tissue damage, discomfort following surgery, or gingival architecture alteration.[7, 8]

Impression making has advanced significantly since the introduction of digital dentistry. Several drawbacks of traditional methods, including material distortion, dimensional errors, and patient discomfort, are eliminated by digital impression techniques. [9, 10] Effective gingival displacement is still necessary to capture accurate marginal details, though, regardless of the impression technique used—digital or conventional. [11]

When combined with both digital and traditional impression techniques, the current study aims to assess and contrast the amount of gingival displacement produced by mechanical and chemical retraction systems. The study intends to determine the most efficient and clinically feasible technique that offers sufficient gingival retraction with the least amount of tissue damage and the highest accuracy in marginal reproduction by evaluating and comparing the performance of these systems. It is anticipated that the results will enhance clinical judgement and raise the standard of prosthodontic treatment results overall.

2. Objectives

- To evaluate lateral gingival displacement in subjects after using Non impregnated gingival retraction cord (00) Cord (00) impregnated with 25% aluminum chloride and Cord (00) impregnated with 20% ferric sulfate.
- To compare conventional impression method and digital method of measuring gingival displacement.

3. Methods

A Latin block design was used in in vivo pilot research to reduce possible sources of variability such as tissue fatigue and sequence bias. By allowing each participant to act as their own control, this strategy improved the reliability of comparisons between retraction systems and decreased interindividual variability. [12,13] To remove order effects, all individuals received gingival displacement systems in a randomised order. Standardised clinical conditions were used for all procedures to ensure consistency throughout the trial.

Ten healthy adult volunteers between the ages of 20 and 30 participated in the study. A clinically healthy periodontium with no indications of gingival inflammation, attachment loss, or systemic disorders affecting oral tissues was a prerequisite for participant selection.[14] Smoking, a history of periodontal therapy within the last six months, or a known sensitivity to the materials employed were all grounds for exclusion.

Because of its accessibility and consistent anatomical features, the left maxillary first molar was selected as the experimental location for each participant. Each participant provided written informed consent and received a thorough explanation of the study methodology prior to its start. The Institutional Ethical Committee provided ethical clearance (IEC/GDCH/2025/FR/07-13), and all protocols complied with the 2013 edition of the Declaration of Helsinki.[15]

The effectiveness of three distinct gingival retraction techniques in producing lateral gingival displacement was assessed:

1. Mechanical technique: Retraction utilising a traditional braided gingival retraction cord (00) that is lightly pressed into the sulcus.[16] (Fig.4)

Journal of Chemical Health Risks
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2. Chemical method: Retraction using a fine cotton pellet and a 25% aluminium chloride solution for a predetermined five minutes.[17] (fig.2)
3. Ferric sulphate-based system: Retraction applying ferric sulphate-containing haemostatic gel in accordance with the manufacturer's instructions.[18] (fig.3)

To guarantee uniformity, a single operator carried out each procedure. Prior to taking impressions, the area was completely cleaned with water and allowed to air dry after retraction. Precautions were taken to avoid sulcular injury or tissue stress.

To enable comparison, impressions were taken using both digital and traditional methods after gingival retraction.

Immediately after retraction, digital impressions were taken using an intraoral scanner to evaluate the exposed finish line and record fine marginal details.[19] The same operator carried out each scan in uniform lighting conditions.

Polyvinyl siloxane elastomeric material was used to make conventional impressions in specially designed trays. The impressions were poured with type IV dental stone.[20]
This dual-technique method ensured a thorough evaluation of the gingival retraction systems by evaluating the displacement captured by both digital scanning and traditional impressions.

A stereomicroscope fitted with a digital micrometre was used to assess the horizontal gingival displacement caused by each retraction technique on the resulting sectioned casts (Fig.5) [21] Exo Cad Software was used to measure horizontal gingival displacement in scanned data. Mean values were computed for each group after measurements were made at standardised reference sites. (Fig.6)

Software called SPSS (Version 21.0; IBM Corp., Armonk, NY, USA) was used to statistically analyse the data. The Shapiro-Wilk test verified the normality of the data ($p = 0.466$).[22] For every retraction material, descriptive statistics (mean and standard deviation) were calculated. One-way analysis of variance (ANOVA) was used for the comparative analysis, with a significance level of $p < 0.05$.[23]

4. Results

The results revealed that the mean horizontal gingival displacement was significantly higher with ferric sulphate compared to other groups. The difference between the materials was statistically significant ($p < 0.05$).

5. Discussion

The current in vivo pilot study compared the effectiveness of mechanical and chemical retraction methods with digital and traditional impression procedures, as well as the horizontal gingival displacement they were able to produce. The results showed that compared to braided retraction cord and 25% aluminium chloride, Ferric sulphate caused noticeably more horizontal gingival displacement. Digital impressions also made it possible to quantify displacement values precisely and consistently.

For fixed prosthodontic restorations to be successful over the long term, accurate marginal recording is essential. Inadequate finish line exposure impairs marginal adaptation and raises the likelihood of microleakage and periodontal inflammation, according to Shillingburg et al. for the best impression material penetration and marginal detail replication, effective gingival displacement should ideally produce a minimum sulcular width of about 0.2 mm. Laufer et al. showed that the linear accuracy of impressions is adversely affected by inadequate sulcular space, highlighting the therapeutic requirement of proper tissue care.

The enhanced displacement noted with ferric sulphate in this study is due to its strong astringent and haemostatic characteristics. Ferric sulphate

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works by coagulating blood proteins and precipitating tissue proteins, leading to temporary tissue contraction and widening of the sulcus. Ramer et al. indicated that ferric sulphate ensures quick haemostasis and efficient fluid management during impression taking. Likewise, clinical research on gingival retraction systems indicates that agents based on ferric sulphate yield more lateral displacement than those prepared with aluminium chloride.

Nonetheless, the literature warns against extended use. Azzi et al. noted that prolonged contact with potent astringents can lead to epithelial shedding and inflammatory alterations. In this study, careful following of the manufacturer's suggested application times probably reduced negative tissue impacts. The results endorse the application of ferric sulphate in scenarios where improved displacement and haemostasis are necessary, especially in subgingival margin preparations.

Braided cord mechanical retraction showed moderate displacement of the gingiva. Retracting cords have typically been viewed as the benchmark in managing gingiva. Hansen et al. characterized cord displacement as reliable and efficient when correctly positioned, although it is sensitive to technique. Benson et al. highlighted that the skill level of the operator greatly affects the degree of tissue movement and possible injury.

In contrast to chemical agents, cord placement applies direct lateral force on the sulcular epithelium. Although effective, excessive force can lead to discomfort or temporary attachment loss, especially in thin periodontal biotypes. The slight displacement noted in this study corresponds with previous clinical research indicating similar outcomes between cord and chemo-mechanical methods.

The 25% aluminium chloride solution exhibited the smallest horizontal movement compared to the other systems examined. Aluminium chloride mainly functions as a gentle astringent and blood-clotting agent. While it manages sulcular fluid well, its ability to induce tissue shrinkage is not as significant as that of ferric sulphate. Prasad et al. indicated that aluminium chloride offers sufficient yet relatively diminished lateral displacement.

Biologically, aluminium chloride is typically viewed as less aggressive and linked to fewer inflammatory reactions compared to ferric sulphate. Thus, although it might be appropriate for patients with sensitive gingival tissues, it may lack adequate displacement in deep or subgingival margins.
A significant component of this research involved assessing gingival displacement through both digital and traditional impression methods. Digital impressions showed remarkable consistency and enabled accurate measurement of sulcular width.

Ender and Mehl emphasized that digital impressions remove dimensional errors linked to elastomeric materials and the expansion of gypsum. In the same way, Güth et al. showed that digital scanning enhances the capture of marginal details and minimizes distortion in full-arch impressions.

Traditional polyvinyl siloxane (PVS) impressions continue to be very precise and are broadly recognized. Nonetheless, possible mistakes can occur due to polymerization shrinkage of materials, distortion of trays, and expansion of stone. Conversely, intraoral scanning provides instant viewing of the finish line and removes the need for intermediate laboratory procedures.

Even with these benefits, digital impressions still depend significantly on proper gingival visibility. Prasad et al. highlighted that effective gingival displacement is essential for achieving marginal accuracy, regardless of the impression technique

Journal of Chemical Health Risks

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used. The current results emphasize that tissue management is still an essential requirement in digital workflows.

Employing a Latin square design improved methodological strength by reducing sequence bias and tissue fatigue. Montgomery and Cochran characterize Latin square designs as effective experimental frameworks that manage two extraneous variables at the same time. By permitting every participant to act as their own control, variability in sulcular anatomy and tissue biotype among individuals was reduced. This methodological advantage enhances the internal validity of the research despite the small sample size typical of pilot studies.

Clinical Implications

In situations necessitating optimal sulcular widening and haemostasis, ferric sulphate might be favoured.

Retraction cords are dependable yet need skilled handling.

Aluminium chloride could be beneficial for individuals with thin or sensitive gingiva.

Digital impression systems offer fast and clinically accurate measurement features and minimize procedural mistakes, yet they still require proper gingival management.

Conclusion:

Ferric Sulphate showed more gingival retraction than Aluminium chloride and plain retraction cord when measured both digital and analogue methods.

Analogue method proved more accurate than digital method in measuring gingival displacement.

Limitations and Future Directions

The sample size was constrained as it was a pilot study. The assessment concentrated solely on horizontal movement and did not evaluate vertical movement or histological tissue reaction. Furthermore, only one type of tooth (maxillary first molar) was assessed, potentially restricting generalizability.

Future studies involving larger sample sizes, testing more retraction systems (such as expanding polymer pastes), evaluating tissue recovery, and performing three-dimensional digital analysis would yield a more complete understanding. The integration of periodontal biotype classification could enhance clinical relevance.

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