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HOW TO CREATE A QUALITY DIGITAL MODEL THROUGH EXTRAORAL SCANNING – A NARRATIVE LITERATURE REVIEW

Dobromira Shopova[1], Diyana Zhelyazkova[1]*

[1] Department of Prosthetic Dentistry, Faculty of Dental Medicine, Medical University-Plovdiv, Bulgaria, e-mail: dent.shopova@gmail.com, diyana.zhelyazkova@mu-plovdiv.bg

Abstract: This literature review explores methods for creating high-quality digital models through extraoral scanning, drawing on current scientific and practical literature. It analyzes key factors that affect the quality of digital impressions, including the technical characteristics of scanners and the use of various types of elastomeric impression materials, as well as different extraoral scanning techniques. The main challenges associated with the accuracy and precision of digital models, along with their applicability in dentistry, are also discussed. The review concludes by emphasizing the importance of best practices and technological innovation in scanning to achieve optimal results

Keywords: digital dentistry, digital model, extraoral scanning, accuracy
Field: Medical sciences and Health

1. INTRODUCTION

Digitalization in dentistry has made significant strides and continues to evolve rapidly. Changes in laboratory processes also necessitate adjustments in clinical workflows. Digital technologies were developed to enhance efficiency, save clinicians' time, ensure precision in intricate details, and achieve optimal patient outcomes (Tomova, 2023-1; Tomova, 2024). Modern digital software enables the creation of various dental objects, such as temporary and permanent prosthetic structures, custom trays, surgical guides, occlusal splints, and more (Tomova, 2023-2). However, all of these require a digital model on which to design the necessary constructions. This virtual model can be obtained either through intraoral scanning of the oral cavity or by extraoral scanning of a plaster model or conventional impression using a laboratory scanner (Shopova, 2020).

Since the entire methodology of extraoral scanning relies on an accurate impression of the prosthetic field, the precision of the impression is of paramount importance. Elastomeric impression materials are commonly used in fixed prosthetics (Kissov, 2019). These materials include:

Additive silicones (polyvinyl siloxanes) are a modern type of impression material that does not release by-products during polymerization, resulting in linear and volumetric stability. A notable advantage is their enhanced hydrophilicity. They are highly elastic, exhibit superior recovery from elastic deformation, and are the least susceptible to plastic deformation. Additionally, they maintain volumetric stability after setting, have low creep, and offer a moderately short handling time (Chen, 2004; Wadhwani, 2005).

Condensation silicones undergo a polycondensation reaction that produces a low molecular weight by-product, resulting in shrinkage of 0.23% to 0.6% within 24 hours. Another disadvantage is their hydrophobic nature (Joshi, 2009). Polyethers, on the other hand, undergo an additional polymerization reaction, providing linear and volumetric stability to the impression. They have the highest modulus of elasticity among elastomers, which can limit their use in areas with significant retention or in teeth with high mobility. However, they are easy to spread due to their hydrophilic properties (Endo, 2006). Polysulfide rubbers contain sulfur and lead compounds. They exhibit high elasticity, relative hydrophilicity, and a long handling time. Their polymerization reaction can continue for up to 24 hours after removal from the mouth, resulting in additional shrinkage. The primary disadvantages include a bitter taste and unpleasant odor. Additionally, the presence of lead dioxide, which is known for its toxic and potentially carcinogenic effects, is a significant drawback (O'Brien, 2002).

Hybrid elastomers combine the properties of additive silicones and polyethers, merging their positive attributes. These materials offer high hydrophilicity and excellent flow properties, allowing them to penetrate deep into the gingival sulcus and produce highly accurate impressions (Apinsathanon, 2022).

Elastomers used for fixed prosthetics can be applied using single-layer or double-layer, as well as monophasic and biphasic techniques. The monophasic two-layer technique involves the simultaneous use of two different consistencies of the same type of elastomer. The thicker consistency is first placed in the impression tray, followed by the more fluid one on top. Both consistencies are then pressed together

*Corresponding author: dent.shopova@gmail.com

onto the prosthetic field and polymerized simultaneously, forming a chemical bond (Varvara, 2015). The double-phasic two-layer technique involves a sequential approach. First, the dough-like, dense consistency is placed and allowed to polymerize independently. In the second stage, the liquid consistency is applied to capture fine details (Gowri, 2015).

The presented article aims to present different variants of extraoral scanning of dental objects and to summarize the available literature data, based mainly on the accuracy of the obtained digital model.

2. MATERIALS AND METHODS

A targeted literature review was conducted to examine the types of extraoral scanning and the accuracy of the resulting digital models. The studies were categorized based on specific criteria as follows: 1) comparative analysis of different types of extraoral scanners, including laser scanners, white light scanners, and blue light scanners; 2) evaluation of different impression materials used in extraoral scanning, such as condensation silicones, additive silicones, and polyvinyl siloxanes; 3) assessment of the accuracy of fixed bridge structures created through extraoral scanning of silicone impressions or plaster models; 4) extraoral scanning of the entire dental arch and three-dimensional accuracy analysis; 5) extraoral scanning of a single tooth and three-dimensional accuracy analysis; and 6) the effect of antireflective powders on the accuracy of the final prosthetic construction.

3. RESULTS AND DISCUSSIONS

At their core, 3D scanners comprise a light source, one or more cameras, and a multi-axis motion system to position the scanned object relative to the light source and cameras. The types of scanners used for scanning impression materials include laser scanners, white light scanners, and blue light scanners. Laser scanners are characterized by slower scanning speeds, higher error rates, and lower initial scan repeatability. White light scanners offer good scanning speed and repeatability, efficiently project a model in two-dimensional (2D) mode, and capture 3D coordinate data more effectively than laser scanners. However, errors with white light scanners can occur when scanning impressions with narrow and deep undercuts. In evaluations of digitized impressions of abutment teeth, blue light scanners demonstrated better repeatability compared to white light scanners (Jeon, 2015). Additionally, blue light scanners have been found to be more accurate than both white light and laser scanners (Emir, 2019).

A high-quality impression of the prosthetic field is essential for successful prosthetic construction and depends on the dimensional stability, accuracy, and flexibility of elastomeric impression materials, as well as the appropriate impression techniques used. Naumovski et al. investigated various silicone impression materials and the factors influencing their stability and dimensional accuracy, including the choice of viscosity type, impression material thickness, impression technique, pre-cast storage time, number of casts, material hydrophilicity, release of by-products, and post-polymerization shrinkage. The study’s findings consistently indicate that additive silicones outperform condensation silicones (Naumovski, 2017).

The most significant difference between silicone types lies in the dimensional changes they produce in gypsum tooth stumps. Condensation silicones result in significantly shorter gypsum stumps (-0.24% to -0.37%) compared to additive silicones (-0.08%). The same accuracy of impressions was achieved for all techniques (that is, putty/wash, single mix, and double mix) when addition silicones were used, whereas the putty/wash technique produced the most accurate dies for the condensation silicones. Impressions made using custom trays demonstrated much greater accuracy in vertical dimensions (-0.03%) compared to those made with standard trays (-0.15% to -0.21%). Consequently, even additive silicones, which have relatively minimal polymerization shrinkage, produce dimensionally stable dental impressions, fig.1 (Johnson, 1986).

Fig.1. Different techniques for taking silicone impressions

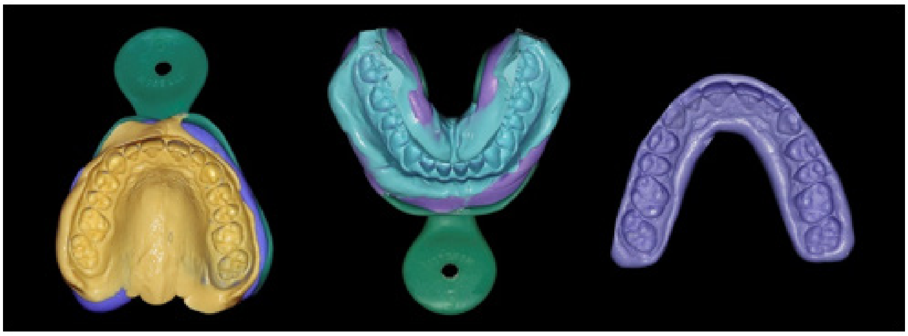
Source: Runkel; Clinical oral investigations, 2020

In their study, Bud et al. evaluated the accuracy of three different impression materials commonly used in dental practice, utilizing a three-dimensional (3D) extraoral scanner. A dental arch model with 16 permanent teeth was 3D-printed and replicated using three materials: alginate, condensation silicone, and addition silicone. The resulting plaster models were digitized and compared for accuracy. The results revealed that addition silicone models exhibited the highest accuracy, followed by condensation silicone, with alginate showing the lowest accuracy. The study also emphasized that the timing of model casting and the method of impression disinfection play crucial roles in preserving accuracy (Bud, 2022). Furthermore, the greatest dimensional changes in addition and condensation silicone impressions were observed within the first hour after separation from the model (Sinobad, 2014).

Additional studies have investigated the hydrophobicity of silicone impression materials, attributed to surface paraffin methyl groups. This characteristic poses a potential drawback, as it can compromise results by encapsulating saliva or blood particles if the field is not adequately dried and prepared (Martins, 2019).

A study by Camardella et al. demonstrated that digital models obtained by laser scanning two types of addition silicones with different viscosities can achieve clinically acceptable accuracy, even when scanned up to 15 days after the impressions were made. The study evaluated the accuracy of digital models created by scanning impressions at intervals of 5, 10, and 15 days using two soft polyvinylsiloxane materials, fig. 2 (Camardella, 2016).

Fig. 2. Polyvinylsiloxane Impressions. Maxillary impression (regular viscosity), mandibular impression (light viscosity), and bite registration.

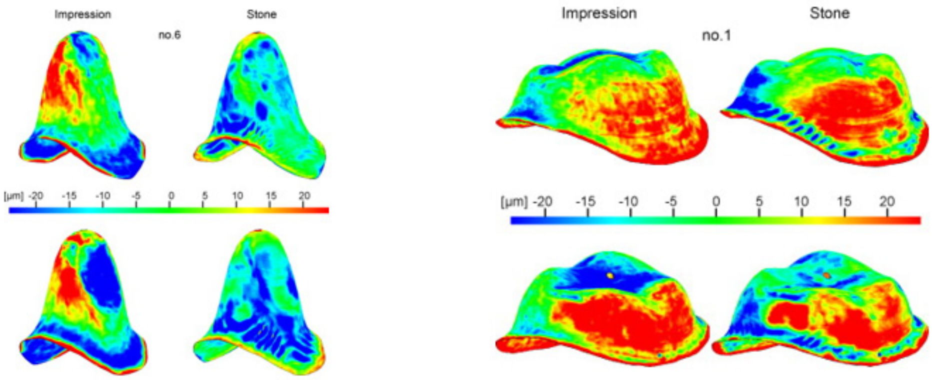


Source: Camardella; American Journal of Orthodontics and Dentofacial Orthopedics, 2016

Labib et al. investigated the accuracy of 3D digital models generated using intraoral and extraoral scanners, comparing them with reference plaster models. The results revealed minimal differences between the digital and plaster models. Accuracy analysis demonstrated good to excellent stability across most measurements. The highest digitization accuracy was achieved with the 3Shape laboratory scanner, whereas the inEos X5 exhibited the largest errors when digitizing alginate and single-phase silicone impressions (Labib, 2020). Similarly, Ellakany et al. found in their study that extraoral scanners provided greater accuracy compared to intraoral scanners (Ellakany, 2022).

Gao et al. compared the accuracy of three scanning methods for full-arch crown preparations: intraoral scanning, impression scanning, and plaster model scanning. Their results indicated that impression scanning provided the highest accuracy for the maxilla, while no significant differences were observed among the methods for the mandible. Both impression scanning and intraoral scanning outperformed plaster model scanning in terms of accuracy (Gao, 2022). Similarly, Kontis et al. investigated the accuracy of intraoral and extraoral scans in an edentulous maxilla. Their findings showed that intraoral scanning with Primescan achieved the highest accuracy, while impression digitization also demonstrated superior results (Kontis, 2021). Ellakany et al. reported that intraoral (IOS) and extraoral (EOS) scanners generally exhibited similar accuracy, except in the case of canines, where extraoral scanners performed better. The study highlighted that the roughness and shape of the tooth surface, particularly with canines, significantly affect scanning accuracy (Ellakany, 2022). Jeon et al. found a statistically significant difference in the accuracy of extraoral scanning between silicone impressions and plaster models of canines, attributed to their distinct morphology. Ten color maps were generated to analyze the plaster models and impressions of canines, premolars, and molars (Jeon, 2015). Persson et al. examined whether cast plaster models of single teeth from various dental groups—canines, premolars, and molars—scanned with a laboratory scanner exhibit significant dimensional changes compared to a reference model. The study concluded that extraoral scanning of plaster models of incisors showed the lowest accuracy, followed by canines and premolars. In contrast, molars did not display systematic differences compared to the other preparations, fig. 3 (Persson, 2009).

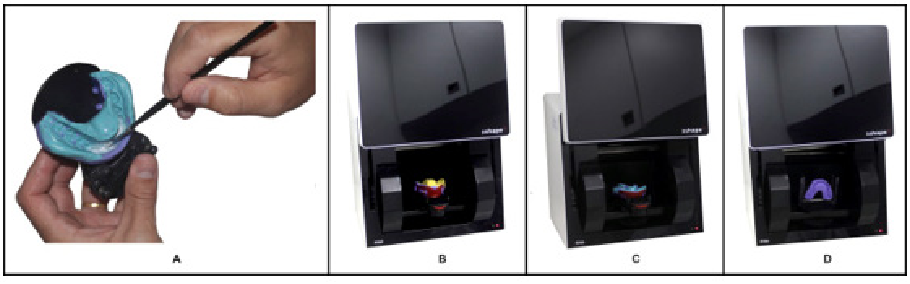
Fig. 3. Distribution of discrepancies



Source: Persson; Dental materials, 2009

Ellakany et al. reported no detectable differences in the accuracy of data obtained from scanning silicone impressions versus scanning the model itself (Ellakany, 2022). In 2016, Matta et al. concluded that scanning impressions directly can outperform scanning casts. However, the negative geometry of impressions poses challenges, particularly in achieving a uniform application of scanning spray across all areas. To address this, manufacturers have developed new impression materials, such as Flexitime Fast&Scan, specifically designed for scanning without the need for spray application. Additionally, the design of the model presents limitations; desktop scanners are typically restricted to digitizing parallel surfaces and cannot effectively capture areas with undercuts. Despite these constraints, digitizing silicone impressions with extraoral scanners remains a reliable method for achieving highly accurate virtual models.

Fig. 4. A, Application of titanium oxide powder in the mandibular incisor area; B, maxillary impression scanning; C, mandibular impression scanning; D, bite registration scanning



Source: Camardella; American Journal of Orthodontics and Dentofacial Orthopedics, 2016

4. CONCLUSIONS

The reviewed literature indicates that the accuracy of extraoral scanners varies depending on the technology employed and the type of impression material used. Blue light scanners consistently demonstrate superior accuracy compared to white light scanners, particularly for complex surfaces such as narrow and deep abutments. The accuracy is also significantly influenced by the morphology and roughness of the scanned tooth surfaces.

Given the variability in results reported by different authors and the rapid advancements in digital dentistry, further research is needed to standardize findings and optimize scanning techniques.

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