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The KAP and clinical utilization of the intra-oral scanners among dental professionals: A review

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Abstract:
Intraoral Scanners (IOS) have revolutionized modern digital dentistry, yet clinical success relies heavily on clinician acceptance and routine adoption. Therefore, it is of interest to examine the current evidence regarding knowledge, attitudes, clinical usage patterns, perceived benefits and barriers related to IOS implementation among dental professionals and trainees. Overall, awareness and positive attitudes toward IOS technology are high across the profession, but routine clinical integration remains disproportionately low, particularly among undergraduate students and general dental practitioners. Specialists show the highest proficiency and rate of clinical usage. Prohibitive acquisition costs, software integration issues and a steep learning curve represent the primary barriers to adoption. Early integration of hands-on digital dentistry training into undergraduate dental curricula is vital to bridge the gap between technological capabilities and clinical practice.

Keywords: Intraoral scanner (IOS), digital dentistry, digital impression, dental education, awareness, perception, knowledge, narrative review

Background:
Digital technology has become an increasingly visible part of contemporary dentistry, changing how clinicians collect information, plan treatment, communicating with laboratories and deliver care **[1]**. Computer-aided design and computer-aided manufacturing (CAD or CAM), three-dimensional (3D) imaging, artificial intelligence (AI) and digital impression systems have moved from being relatively specialized technologies to increasingly familiar components of dental practice **[2]**. Within this digital transition, intraoral scanners (IOSs) have assumed an important role by allowing clinicians to capture the patient's oral structures directly and generate a digital impression without conventional impression materials **[3]**. The appeal of IOS technology extends beyond replacing impression materials **[4]**. Digital scanning can make the impression procedure more comfortable, provide immediate visualization of the captured anatomy, allow deficient areas to be rescanned and facilitate rapid transfer of files to dental laboratories **[5]**. Digital records can also be incorporated into CAD or CAM workflows and used in restorative dentistry, prosthodontics, orthodontics, implant dentistry and multidisciplinary treatment planning **[6]**. These advantages have contributed to growing interest among both dental professionals and students **[7]**. However, successful scanning is not determined solely by the capabilities of the device. The quality of an intraoral scan can be affected by the scanner itself, scanning strategy, operator experience, anatomical conditions, moisture, bleeding, accessibility and the clinical application **[8]**. Consequently, clinicians require more than basic familiarity with the equipment **[9]**. They need to understand how IOSs work, recognize factors that may compromise scan quality and develop sufficient practical skill to produce clinically useful digital records. Recent studies suggest that this distinction between awareness and competence is important **[10-15]**. Dental graduates, students and practicing clinicians increasingly recognize the value of IOS technology, but their actual experience and use remain variable **[16]**. A Saudi Arabian study by Alqahtani *et al.* found that although many dental interns and practitioners were familiar with IOSs, clinical use was considerably less common, demonstrating a clear difference between awareness and implementation **[16]**. Similar findings have been reported among dental students, who may express positive attitudes toward IOSs while having little direct experience with the technology **[17]**. Professional experience and clinical specialty also appear to influence adoption. Practitioners involved regularly in prosthodontic, orthodontic, implant and CAD or CAM-based procedures are more likely to encounter IOS technology and develop confidence in its use **[18]**. In contrast, financial considerations, limited access to equipment, insufficient training and uncertainty about integrating digital scanning into established workflows can discourage wider adoption **[19]**. Therefore, it is of interest to examine the current evidence concerning knowledge and awareness of IOS technology, patterns of clinical utilization, perceived advantages, barriers to adoption and the educational and training requirements needed to support its effective integration into dental practice.

Current status of knowledge and awareness:
Awareness of IOS technology among dental professionals has increased as digital dentistry has become more established. Nevertheless, knowledge is not uniform and appears to vary according to academic background, clinical experience, professional specialty and previous exposure to digital workflows **[20]**. The distinction between knowing about IOSs and being able to use them effectively is particularly relevant when considering dental education. The Saudi study conducted by Alqahtani *et al.* provides useful evidence in this regard,

though participants demonstrated awareness of IOS technology and its applications, a substantial proportion reported limited or no clinical use **[16]**. This finding suggests that familiarity with the concept of digital impressions does not necessarily translate into practical adoption. Qamar *et al.* similarly examined Saudi dental practitioners and identified the importance of knowledge and training in developing appropriate IOS practice **[21]**. The same issue is apparent among dental students. Çakmak *et al.* found that students at different stages of undergraduate education differed in their knowledge of IOS applications, while most participants reported that they had never used an IOS **[18]**. The authors consequently emphasized the need for greater practical exposure and curriculum development. These findings indicate that awareness should be viewed as the first stage of digital competence rather than its endpoint. Effective education needs to progress from understanding the principles of IOS technology to supervised use, evaluation of scan quality, troubleshooting and clinical application **[22]**.

Patterns of clinical utilization:

The literature demonstrates a persistent gap between positive perceptions of IOS technology and routine clinical use **[21]**. Specialists and clinicians working in digitally oriented practices tend to use IOSs more frequently, particularly for fixed prosthodontic procedures, orthodontic workflows, implant planning and CAD or CAM-supported treatment **[19]**. Repeated exposure to digital procedures may allow these clinicians to develop greater confidence and efficiency. General dental practitioners may face a different set of circumstances. Even when clinicians recognize the advantages of digital impressions, the financial investment required for scanners, software, maintenance and supporting infrastructure can discourage adoption. The decision may also depend on whether the practice performs enough digitally supported procedures to justify the investment. Students and interns represent another important group. Current evidence suggests that many students are interested in digital dentistry but have limited opportunities for repeated hands-on scanning **[23]**. This creates a potential transition problem: graduates may understand the principles of digital impressions but enter clinical practice without sufficient experience to use IOS technology independently **[24]**. Clinical utilization is also influenced by the broader practice environment. Access to appropriate hardware, software, laboratory support, technical assistance and compatible digital systems can determine whether IOS technology becomes part of routine care or remains an occasional tool **[25]**. Thus, adoption should be considered as a combination of individual competence and institutional readiness rather than simply an individual clinician's preference.

Perceived advantages of digital impressions:

Several advantages consistently contribute to the favorable perception of IOS technology **[26]**. Patient comfort is one of the most frequently reported benefits. By eliminating conventional impression materials and trays, digital scanning can reduce unpleasant taste, gagging and discomfort during impression procedures. Another important advantage is immediate visualization. With a conventional impression, deficiencies may only become apparent after the impression has been removed and examined. An IOS allows the clinician to inspect the digital model while the patient is still in the chair. Inadequate areas can therefore be identified and rescued immediately. Digital impressions may also simplify clinical and laboratory communication. Files can be transmitted electronically, reducing dependence on physical impressions and casts. Digital records can be stored, retrieved and shared more easily, while three-dimensional visualization may help patients understand their condition and proposed treatment. The greatest potential of IOS technology, however, lies in its integration with other digital systems. Scan data can be incorporated into CAD or CAM workflows and used for restorative procedures, orthodontic planning, implant-supported treatment, surgical guide design and digitally assisted rehabilitation **[27]**. At the same time, clinicians must understand that the benefits of digital scanning do not eliminate technical limitations. Accuracy may vary according to the clinical situation, scan length, operator technique, soft-tissue conditions, implant configuration and other factors **[28].**

Primary barriers to widespread adoption:

The transition toward routine IOS use is affected by several interconnected barriers. Financial investment remains one of the most commonly recognized concerns **[29]**. The cost extends beyond purchasing the scanner and may include software, maintenance, upgrades, computer hardware and integration with laboratory systems. Training is another major issue. Effective scanning requires an understanding of scanning pathways, image acquisition, software functions, error recognition and management of difficult clinical conditions. Without sufficient practice, clinicians may be reluctant to replace familiar conventional techniques. Limited undergraduate exposure can reinforce this problem. Students who receive only theoretical information about digital impressions may graduate without the psychomotor skills required for efficient scanning **[30]**. Recent educational research supports the value of integrating IOS technology directly into practical teaching. Liu *et al.* showed that incorporating digital scanning into tooth-preparation training improved students' theoretical and practical performance and reduced anxiety during practical exercises **[31]**. Technical conditions can also affect scan quality. Saliva, blood, reflective surfaces, subgingival margins, difficult access, complex anatomy and inadequate scanning techniques can compromise digital data acquisition. Recent research has additionally emphasized the influence of scanning speed, scanning distance, scanning strategy and operator experience on the resulting digital impression. Finally, successful adoption requires appropriate infrastructure. Digital workflows depend on reliable hardware, software interoperability, data management, laboratory communication and technical support. Newer cloud-based and wireless systems may offer additional flexibility for dental education and clinical practice, but they also introduce

considerations related to interoperability, data security and institutional governance **[32]**.

Educational strategies and curriculum integration:
To address the gap between technology availability and actual clinical practice, dental schools must update their teaching programs. Incorporating mandatory digital dentistry modules including simulator training and hands on IOS clinical rotas into early undergraduate education builds confidence before graduation **[33, 34]**. Continuing professional education courses targeting general practitioners are equally essential to ease the learning curve and foster broader technology adoption **[35]**.

Conclusion:
We show a clear disconnect between growing awareness of intraoral scanners and their routine integration into clinical dental practice. Financial constraints, limited hands-on training and differences in clinical experience remain major obstacles to widespread adoption. Embedding practical digital dentistry training into undergraduate curricula, alongside structured professional development and improved technological accessibility, is essential to bridge this gap and advance efficient, patient-centered dental care.

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