Smartphone applications used in orthodontics: A scoping review of scholarly literature

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1. Introduction

The slide and swipe culture symbolizes life in the 21st century [1,2]. The past decade has seen mobile phones become the primary means of communication and internet access. Worldwide, the number of smartphone users has continued to increase from 2.5 billion in 2016 to 3.5 billion in 2020 [3]. Meanwhile mobile app revenues have increased from $218.2 billion to $581.9 billion in the same amount of time [4]. It is not surprising then, that mobile applications (apps) play an increasingly important role in day-to-day life. However, the role of apps in health care, and orthodontics in particular, has achieved only limited popularity and acceptance thus far. The potential to yield tremendous benefits to all stakeholders is apparent; however, if greater acceptance is to be obtained, orthodontic apps require validation and proven treatment benefits.

The number of orthodontic apps, across the Google Play Store and Apple App Store, has increased steadily with time until recently. The first study on the number and type orthodontic apps was performed by Singh [5] in 2013, who found only 19 apps on the Google Play Store and Apple App Store. In 2014, this number had jumped to 119 [6]. By 2017, Gupta and Vaid [7] had discovered 354 apps. The most recent study by Siddiqui et al. [8] in 2019, put the number of orthodontic apps at 305, which for the first time had decreased. These apps, both patient- and clinician-focused, vary tremendously in genre and objective. Despite the large number of orthodontic apps, very few have been studied to investigate their veracity.

Over the past 2 decades, scoping reviews have become a somewhat popular approach for reviewing literature and have been widely used within the health care sector. In the orthodontic literature, however, very few scoping reviews have been undertaken [9]. A scoping review is usually performed to study the extent, range, and type of research within a topic area and helps
to direct future research. Scoping reviews become especially beneficial when conducted on novel topics with fast-evolving evidence, in which a scarcity of randomized controlled trials (RCTs) prevent systematic reviews from having meaningful conclusions [10]. This is such a case for mobile apps in orthodontics. This scoping review therefore aims to determine the scope and extent of the published literature on mobile apps in orthodontics, identify the types of studies published, and summarize the outcomes studied.

2. Materials and methods

A scoping review of the published literature was performed following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines. A review protocol was created to address the research questions, but was not previously published. EMBASE, PubMed, and Google scholar databases were searched from January 2010 until June 2020. The initial date was chosen because the use of mobile apps for orthodontics is a relatively new phenomenon, and smartphones and mobile apps have only gained popularity at the turn of the decade. In hindsight, the earliest study to meet our criteria was published in 2014. The search terms used were “orthodontic” AND (“app” OR “application” AND/OR “smartphone”) and the results were limited to studies published in the English language. Studies were considered suitable for selection based on the following criteria:

- Study type: RCTs, case-controlled trials, retrospective and prospective studies, and cross-sectional studies.
- Participants: Patients aged 10 years and older receiving orthodontic treatment.
- Intervention: Any type of orthodontic treatment, method, or approach using an app.
- Comparison: Any type of comparison, mode of orthodontic treatment method, or approach.
- Outcomes: All outcomes.
- Exclusions: Opinion or review articles, case reports, articles on techniques, and studies with fewer than 10 participants.

The abstracts of all suitable articles were evaluated by one reviewer (I.H). The full texts of those articles meeting the selection criteria and those that were ambiguous were then obtained for screening. A second reviewer (N.R.V) aided in resolving uncertainty regarding final inclusion until consensus was reached. The data were extracted onto a spreadsheet that contained the first author and year of publication, study type, participants, interventions, comparison, outcomes (both primary and secondary), method of measurement, focus group, and outcome domain. The primary and secondary outcomes were determined from within the text of the study. If not explicitly mentioned, the aim, sample size calculation, or first reported outcome in the results section was used. Any other outcomes reported were designated as secondary outcomes. The outcome domains were chosen after review of the results and refined by two reviewers (I.H. and N.R.V). The outcome domains were thus categorized as apps used for reminders, diagnosis, and/or remote monitoring. These were further grouped into patient- and clinician-centric apps.

3. Results

3.1. Search and selection of studies

The initial search using the strategy resulted in 33 records after exclusion of duplicates. After review of the abstracts, 25 full-text articles were evaluated for eligibility and 17 articles fulfilled the selection criteria (Fig. 1). The articles included in the scoping review are displayed in Table 1, and excluded articles, with reasons, are shown in Table 2.
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<tr>
<th>Author</th>
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<td>Oral hygiene</td>
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<tr>
<td>Li</td>
<td>RCT</td>
<td>224 orthodontic patients</td>
<td>Received regular reminders and educational message via WeChat group</td>
<td>Received conventional management</td>
<td>Effect on duration of tx</td>
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<td>Records review and clinical measurements using plaque index and gingival index</td>
<td>Patient Reminders</td>
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<tr>
<td>Livas</td>
<td>Case-control</td>
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<td>Clinician</td>
<td>Diagnostics</td>
<td></td>
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<tr>
<td>Morris</td>
<td>Case-control</td>
<td>3D digital models generated by Dental Monitoring (app)</td>
<td>3D digital models generated by the iTero Element intraoral scanner</td>
<td>Measurements from a plaster model</td>
<td>Accuracy of maxillary intercanine and intermolar width</td>
<td>Digital model measurements</td>
<td>Patient; clinician</td>
<td>Remote monitoring</td>
<td></td>
</tr>
<tr>
<td>Moylan</td>
<td>Case-control</td>
<td>12 patients between the ages of 10 and 17 years treated with RME</td>
<td>Measurements from Dental Monitoring (app)</td>
<td>Measurements from a plaster model</td>
<td>Accuracy of maxillary intercanine and intermolar width</td>
<td>Digital and plaster model measurements</td>
<td>Patient; clinician</td>
<td>Remote monitoring</td>
<td></td>
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</tbody>
</table>

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### 3.2. General characteristics of included scoping reviews

The included publications ranged in date from 2014 to 2020. One study was published in 2014; one in 2015; two in 2016; three in 2017; zero in 2018; five in 2019; and five in the first 7 months of 2020. With respect to type of studies performed, six RCTs were identified (35%), nine were case-controls (53%), one cohort study (retrospective) (6%), and one cross-sectional (6%) (Fig. 2).

### 3.3. Outcome domains of included studies

There were six studies (35%) based on apps used for diagnostics, and all were cephalometric apps. The most commonly investigated apps were CephNinja (studied four times), OneCeph (twice), SmartCeph Pro (once), and SmileyCeph (once). Seven studies (41%) using apps for reminders were present, with the primary outcome of four of them being oral hygiene (OH), one was patient perception of an OH app, one investigated the effect on treatment duration, and one studied the effect on postorthodontic stability. The apps used for reminders were varied and included popular messaging apps such as WhatsApp and WeChat. Four studies (24%) investigated dedicated remote monitoring apps and all four studied Dental Monitoring (Fig. 3). Twelve studies were based on clinician-centric apps, and 11 were patient-centric. These were not mutually exclusive, as some apps were both patient- and clinician-centric.

### 4. Discussion

Only 17 studies were found investigating the effects and functionality of orthodontic apps. Although our search criteria included years 2010 to 2020, the first study that fit our criteria was published in 2014. The number of studies have generally increased year-on-year with the exception of 2018, from one study in 2014 to five in the first half of 2020. This increase reflects the larger trend of increases in the number and usage of orthodontic apps, as well as the continuous digitization in orthodontics.

The domain outcome with the greatest representation in the literature was apps used in reminder therapy (41%). This is in accordance with the total number of apps in this genre found in the Apple App Store and Google Play Store [7]. This is a broad genre and overlaps somewhat with practice management software. Patient reminders have been shown to improve compliance [27], reduce the number of missed appointments [33–35], improve OH [13,26,35–37], reduce white spot lesions [26], and reduce treatment times and bracket failure. [19] App-based oral hygiene reminders need not be a specialized orthodontic app. In fact, two studies [19,26] used WhatsApp and WeChat messages in various ways to improve compliance and OH. The advantages of using these apps for reminder therapy are their low costs and simple implementation. Small changes to a private practice to implement some type of reminder therapy can make significant improvements to the

### Table 2

<table>
<thead>
<tr>
<th>Author</th>
<th>Reason for exclusion</th>
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<tbody>
<tr>
<td>Hansas [28] 2018</td>
<td>Review/opinion article</td>
</tr>
<tr>
<td>Mammillapalli [29] 2016</td>
<td>Description of technique</td>
</tr>
<tr>
<td>Phatak [30] 2019</td>
<td>Review article</td>
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<tr>
<td>Rao [31] 2018</td>
<td>Review article</td>
</tr>
<tr>
<td>Singh [5] 2013</td>
<td>Review article</td>
</tr>
<tr>
<td>Scheerman [32] 2018</td>
<td>Description of technique</td>
</tr>
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</table>
aforementioned areas. This area of research may occupy more space in published literature in the coming years.

Thirty-five percent of the apps studied were used for diagnostics; all were cephalometric apps. CephNinja and OneCeph seemed to be the most popular app studied for cephalometrics and have generally been found to be accurate and reliable [11,12,17,20]. These apps tend to mimic conventional PC-based programs (which have been proven to be accurate [38–40]), and thus should theoretically also be as accurate. One of the pitfalls of app-based cephalometry is their lack of integration with practice management software. It may be cumbersome for a private practice to use a separate app solely for cephalometric analysis without integration with the patients’ other records. A more prudent use of app-based cephalometry may be for cloud-based orthodontic software to develop an accompanying app that would allow for seamless syncing of patient records across devices.

With the rapid development of artificial intelligence (A.I.) and machine learning [41], we can foresee greater integration of A.I. and orthodontic apps in aiding diagnostics and treatment planning [42–45]. A.I. has already been used for automated cephalometric tracings [46,47], and may soon find itself common practice in mobile apps [48]. In fact, WebCeph [49], a cloud-based A.I.-driven orthodontic platform, is currently available free to clinicians and offers automatic A.I.-driven cephalometric landmark identification, tracing, and analysis. The validity of this software, however, is yet to be tested.

Remote monitoring encompassed 24% of the included studies, and all studies investigated Dental Monitoring. These studies verified the accuracy of measurements obtained using the Dental Monitoring app and its movement-tracking algorithm. Hansa et al. [16] concluded that its use reduced the number of office visits for Invisalign patients, and also had a generally positive perception by
users. The use of remote monitoring has the potential to improve chairside efficiency and may well be beneficial during the COVID-19 pandemic [50,51]. No studies have been performed on the financial viability of Dental Monitoring, however. Studies by Zotti et al. [26,27] and Li et al. [19] have incorporated a simpler aspect of remote monitoring, by using popular messaging apps (WhatsApp and WeChat) to share photos and reminders, which offers a free, albeit limited, alternative to Dental Monitoring.

Overall, there were only 17 studies investigating this novel area of orthodontics, and only six were RCTs. There were a small number of outcome domains identified in the included studies. Apps used in orthodontics for purposes other than reminders, cephalometry, or remote monitoring have not been studied. Some examples of such apps include model and space analysis, treatment planning for interceptive orthodontics, force system calculators, and Index of Treatment Need and Peer Assessment Rating calculators.

The past decade has been revolutionary for mobile devices, and this trend will likely continue well into the foreseeable future and beyond! Words like automation, A.I., and machine learning are already a part of the orthodontic glossary [41]. The words of futurist Ray Kurzweil [52] exemplifies 21st century orthodontic trends: "...we won’t experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today’s rate)." It is only prudent that, like everything else in the orthodontic armamentarium, every technological application is also subjected to clinical audits and scholarly scrutiny [53].

4.1. Limitations

Pertinent studies may have been missed if they were published in a language other than English or in databases not searched in this study. Similarly, some studies may not have been found due to the search terms used.

An app, by definition, is essentially software designed specifically for mobile devices and includes phones, tablets, and watches. These apps are particularly suited to consumers, and may be most economically for mobile devices and includes phones, tablets, and watches. These apps are particularly suited to consumers, and may be most

5. Conclusions

- This scoping review indicates that only limited research (17 studies) has been undertaken on apps used in orthodontics.
- Six studies were RCTs (35%), nine were case-controls (53%), one was a cohort study (retrospective) (6%), and one cross-sectional study was found (6%).
- Six studies (35%) were based on apps used for diagnostics, and all were cephalometric apps. Seven studies (41%) investigating apps used for reminders were present. Four studies (24%) investigated dedicated remote monitoring apps, and all four studied Dental Monitoring.
- Apps used for orthodontic purposes other than reminders, diagnostics (cephalometry), or remote monitoring have not been studied.

References

with fixed orthodontic appliances: Intervention mapping approach. JMIR mHealth uHealth 2018;6:e163.


