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## Evaluation of Knowledge, Attitude and Practice amongst Indian Orthodontists Regarding Directly Printed Aligners– A Questionnaire Study

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### KEYWORDS

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### ABSTRACT:

**Introduction** - Clear aligner therapy has gained widespread acceptance for its esthetics, comfort, and convenience, with recent advances in 3D printing leading to the development of directly printed aligners (DPA). Compared to traditional thermoformed aligners, DPA offer improved accuracy, customization, and biomechanical efficiency, while also reducing processing time and material waste. Despite these advantages, evidence on their clinical adoption and effectiveness remains limited.

**Aim** – To evaluate knowledge, attitude and practice amongst Indian Orthodontists regarding Directly Printed Aligners.

**Material and Methods** - A validated questionnaire was distributed via WhatsApp to IOS-registered orthodontists using systematic sampling. Based on a calculated sample size of 361, 818 orthodontists were invited, and responses were collected through Google Forms over three weeks. Reliability and validity of the questionnaire were confirmed before distribution, and only consenting participants were included for analysis.

**Results** - A total of 361 orthodontists participated, with 96.1% aware of the primary material used for directly printed aligners. Most respondents reported better dimensional accuracy (86.7%), faster production (100%), and improved patient comfort (73.3%) with directly printed aligners. Approximately 40% considered them more effective in tooth movement, while 46.7% felt both types were equally effective. Advantages were noted in durability (66.7%), stain resistance (60%), and customizable thickness (66.7%), though 60% found them more technique-sensitive. Despite these benefits, 80% of orthodontists still primarily use indirectly printed aligners but indicated a strong likelihood of recommending and adopting directly printed aligners in the future.

**Conclusion** - Orthodontists show high awareness and a positive attitude toward directly printed aligners, recognizing advantages in accuracy, production efficiency, customization, durability, and patient comfort. Although indirectly printed aligners remain more commonly used, there is strong interest in adopting directly printed aligners, indicating their potential to become the preferred choice in the future.



## 1. Introduction

Clear aligner therapy (CAT) has transformed orthodontic practice since its early conceptualization by Kesling in 1946, when thermoplastic tooth positioners were first proposed for minor tooth movements. Over recent decades, aligners have gained widespread popularity due to their superior aesthetics, improved comfort, and enhanced oral hygiene maintenance compared with conventional fixed appliances. Rapid advances in digital technologies—particularly computer-aided design, 3D scanning, and 3D printing—have expanded the scope of CAT, allowing increasingly complex tooth movements to be achieved with greater precision.<sup>1-3</sup>

Conventional thermoformed aligners, fabricated through sequential steps of model printing and plastic sheet vacuum-forming, remain the most common method of production<sup>4</sup>. However, this technique is limited by inaccuracies, dimensional instability, reduced mechanical strength, and increased surface roughness, all of which may compromise clinical effectiveness. These limitations are partly inherent to the thermoforming process and the commonly used polymers such as polyurethane and polyethylene derivatives.<sup>5</sup>

A major milestone in aligner technology was the introduction of **Directly Printed Aligners (DPAs)** with the development of TC-85DAC resin (Graphy, Seoul, Korea) in 2019.<sup>3</sup> By eliminating the thermoforming step, DPAs offer improved accuracy, fit, and mechanical durability while allowing customization of aligner thickness, cutouts, and biomechanical properties. Their shape-memory characteristics and ability to deliver continuous, light forces further enhance treatment efficiency and patient comfort. Despite these advantages, the direct-printing workflow introduces new challenges, such as potential errors in digital design and printing stages, requiring precise clinical and laboratory protocols.<sup>6</sup>

Surveys<sup>7,8</sup> assessing clinicians' perspectives on aligner therapy indicate that general dentists often defer to orthodontists for CAT, while orthodontists themselves frequently prescribe aligners, especially for adult patients, though case complexity and patient compliance strongly influence treatment planning. However, these studies have primarily evaluated traditional thermoformed aligners, and little is known about the clinical adoption and perception of DPAs.

Given the rapid integration of 3D printing into orthodontics and the unique clinical potential of DPAs, there is a need to investigate orthodontists' knowledge, attitudes, and practices regarding this novel technology. This study aims to address this gap by evaluating the

current awareness and utilization of directly printed aligners among Indian orthodontic practitioners.

## 2. Material and Methodology

This cross-sectional questionnaire-based study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, K.M. Shah Dental College & Hospital, Sumandeep Vidyapeeth Deemed to be University, after obtaining ethical clearance from the Institutional Ethical Committee. The study population comprised orthodontists registered with the Indian Orthodontic Society (IOS), as per the updated 2023 directory<sup>9</sup>. Orthodontists who consented to participate were included, while those not using WhatsApp were excluded.

The sample size was determined using the standard formula for finite populations, with a total population of 5800 orthodontists, a 95% confidence level, a 5% margin of error, and an assumed response distribution of 50%, which yielded a minimum sample of 361 participants. To account for an average online survey response rate of approximately 44%, as per the meta-analysis by Meng-Jia Wu et al<sup>10</sup>, the questionnaire was distributed to 818 orthodontists using systematic random sampling.

The questionnaire was initially developed by the investigators and subjected to content validation by five academic experts in the field of orthodontics, who assessed each item using a four-point Likert scale. The Content Validity Index developed by Mary R Lynn (1986)<sup>11</sup> and Ratio indicated that the majority of items were highly relevant, with a final CVR of 0.87. Reliability testing was performed through a test-retest method on four participants after seven days, which produced a kappa coefficient of 0.89. Internal consistency was evaluated on a sample of 25 orthodontists using Cronbach's alpha, which confirmed satisfactory reliability. Construct validity was further assessed by exploratory factor analysis. Following these validation steps, the final questionnaire consisted of close ended 18 questions to assess knowledge, attitudes, and practices related to directly printed aligners.

The validated questionnaire was distributed electronically via Google Forms, with the link shared through WhatsApp to the orthodontists selected via systematic sampling technique. Participants were reminded after one week if no response was received, and data collection was kept open for a period of three weeks. Responses submitted after this time were excluded from analysis. Only orthodontists who provided informed consent through the form were included in the final dataset. All collected responses were compiled and



subjected to statistical analysis using descriptive and reliability measures.

### 3. Results

1)	<b>Do you know the Primary Material used for Directly Printed Aligners?</b>	
	Yes	96.12% (347)
	No	3.88 % (14)
2)	<b>Which Aligners have a Higher Dimensional Accuracy?</b>	
	Directly printed	86.7% (313)
	Indirectly printed	13.3 % (48)
3)	<b>Which Process of Fabricating Aligners has Shorter Production Time?</b>	
	Direct printing	100% (361)
	Indirect printing	0% (0)
4)	<b>Fabrication of which Aligners is more Technique Sensitive?</b>	
	Direct printing	60% (217)
	Indirect printing	40% (144)
5)	<b>Which Aligners can be Manufactured with Variable Thickness?</b>	
	Direct printing	66.7% (241)
	Indirect printing	33.3% (120)
6)	<b>Which Aligners are more Effective in Achieving Tooth Movement?</b>	
	Directly printed aligners	40% (145)
	Indirectly printed aligners	13.3% (48)
	Both of them have same effectiveness	46.7% (168)
7)	<b>Which Aligners are Cost Effective for your Practice?</b>	
	Directly printed aligners	60.11% (217)
	Indirectly printed aligners	39.89% (144)
8)	<b>Which Aligners Offer Better Patient Comfort?</b>	
	Directly printed aligners	73.3% (265)
	Indirectly printed aligners	26.7% (96)
9)	<b>Which Aligners have low and Consistent Forces?</b>	
	Directly printed aligners	33.3% (121)
	Indirectly printed aligners	13.3% (48)
	Both of the above	53.4% (192)
10)	<b>Which Type of Aligner do you most Commonly use in your Practice?</b>	
	Directly printed	20% (72)
	Indirectly printed	80% (289)



11)	<b>Which is better in terms of durability?</b>	
	Directly printed	66.7%
	Indirectly printed	33.3%
12)	<b>Which is Better in terms of Staining Resistance?</b>	
	Directly printed	60% (216)
	Indirectly printed	40% (145)
13)	<b>Have you Noticed any Difference in pain Perception Between Directly Printed Aligners and Indirectly Printed Aligners?</b>	
	Yes, patients experienced less pain with directly printed aligners	40% (145)
	Yes, patients experienced less pain with indirectly printed aligners	0% (0)
	No noticeable difference	60% (216)
14)	<b>Have you Observed any Differences in Number of Refinement Scans Between Directly Printed Aligners and Indirectly Printed Aligners?</b>	
	Yes, more refinements with directly printed aligners	26.7% (96)
	Yes, more refinements with indirectly printed aligners	40% (145)
	No difference	33.3% (120)
15)	<b>In your Practice have you Observed any Difference in the Number of Attachments Required Between Directly Printed Aligners and Indirectly Printed Aligners?</b>	
	Yes	46.8% (169)
	No	53.2% (192)
16)	<b>In your Practice have you Observed any Difference in the Number of Attachments Required between Directly Printed Aligners and Indirectly Printed Aligners?</b>	
	Very easy	20% (72)
	Easy	33.3% (120)
	Neutral	26.7% (97)
	Difficult	20% (72)
	Very difficult	0% (0)
17)	<b>Are you Likely to Recommend Directly Printed Aligners to Patients?</b>	
	Yes	80% (289)
	No	20% (72)
18)	<b>Whether Indirectly Printed Aligners will be Replaced by Directly Printed Aligners in Orthodontic Practice in the Future?</b>	
	Yes	80% (289)
	No	20% (72)



A total of 361 orthodontists participated in the survey evaluating their views and experiences with directly printed aligners. The majority of respondents demonstrated a high level of awareness, with 96.12% knowing the primary material used for directly printed aligners. Most participants believed that directly printed aligners have better dimensional accuracy (86.7%) and faster production time (100%) compared to indirectly printed ones.

In terms of clinical handling, 60% of the respondents found directly printed aligners more technique-sensitive, while 66.7% reported they allow variable thickness, which is advantageous for treatment customization. When asked about treatment outcomes, 40% believed directly printed aligners are more effective, although 46.7% felt both types have equal effectiveness. 66.7% respondents noted better durability, and 60% observed improved stain resistance with directly printed aligners. In terms of force delivery, 53.4% of respondents felt that both aligner types deliver low and consistent forces, but a higher number preferred directly printed aligners alone (33.3%) over indirectly printed ones (13.3%).

Regarding refinements, 40% of the respondents observed a greater number of refinement scans with indirectly printed aligners while regarding the number of attachments required, 46.8% respondents noticed a difference between the two types, while 53.2% respondents did not find any difference in the number of attachments required.

Regarding cost and patient comfort, 60.11% of orthodontists found directly printed aligners to be more cost-effective, and 73.3% reported they offer better patient comfort. Pain perception also varied, with 40% stating that patients experienced less pain with directly printed aligners, while 60% reported no difference.

Despite these advantages, 80% of respondents currently use indirectly printed aligners in their practice. The ease of using directly printed aligners varied among respondents, with over 50% rating it from very easy to neutral. However, 80% also stated that they would recommend directly printed aligners to their patients, and the same percentage believed that directly printed aligners will likely replace indirectly printed ones in the future. These findings indicate a high level of awareness and a favorable attitude toward directly printed aligners, even though their routine use in clinical practice is still emerging.

#### 4. DISCUSSION

The present study aimed to assess the knowledge, attitude, and practice of orthodontists regarding directly printed aligners, a rapidly emerging advancement in

clear aligner therapy. The findings indicate varying levels of awareness and understanding among respondents, with a majority demonstrating adequate knowledge of the material properties and clinical applications of directly printed aligners. The majority of respondents (86.7%) believed directly printed aligners provide better dimensional accuracy, which is supported by a study of Nickolas Koenig<sup>1</sup>, who demonstrated that aligners fabricated through direct 3D printing showed higher surface adaptation and better fit accuracy compared to those fabricated indirectly from thermoformed models. Similarly, the 100% response agreed with reduced production time with direct printing that eliminates intermediate steps in the workflow (such as model printing and vacuum forming) resulting in a more streamlined and time-efficient process.

Regarding clinical handling and utility, 66.7% of respondents reported that directly printed aligners allow for variable thickness, an advantage noted in the study by Maximilian Bleibob<sup>4</sup> where they mentioned about the ability to increase layer thickness in specific areas improved the efficiency of prescribed tooth movements while reducing side effects. This customization allows for tailored biomechanical properties and personalized treatment plans, which can optimize mechanical performance<sup>3</sup> and may also reduce the need of attachments required.<sup>13</sup> However, 60% of orthodontists perceived the direct printing process to be more technique-sensitive, which reflects a concern also noted by Christina Erbe<sup>2</sup>, this sensitivity arises from the inherent complexities and precise control required throughout the direct 3D printing process to achieve accurate and functional aligners and from the multi-stage nature of 3D printing, where each phase can influence others, and errors can occur if production guidelines are not strictly followed.

In terms of effectiveness of tooth movement 40% of the respondents considered directly printed aligners to be more effective in achieving tooth movement, 13.3% favored indirectly printed aligners, while the majority, 46.7%, believed that both aligner types have the same level of effectiveness this is similar to the findings of Vanessa Knode<sup>12</sup> and Marco Migliorati et al<sup>13</sup> where directly printed aligners and indirectly printed aligners were effective in achieving tooth movement, with research continuously exploring their respective advantages and areas for improvement. Clear aligner therapy generally aligns and levels dental arches effectively. However, specific tooth movements present varying levels of predictability regardless of the aligner type.<sup>5</sup> One of the study<sup>14</sup> indicated that most tooth movements carried out by clear aligner treatment are either the same or poorer, but not superior to the fixed



appliance therapy. This result was in agreement with a few systematic reviews<sup>15,16</sup> that reported the efficiency of clear aligners as “low to moderate” in comparison to fixed appliance therapy. Regarding the number of refinement scans and attachment requirements, responses varied, with no clear consensus. This reflects ongoing clinical uncertainties and suggests that more clinical research is needed to definitively compare the effectiveness of direct-printed aligners (DPAs) against traditional thermoformed aligners to establish long-term outcomes and consistency in performance

Considering the force levels, the majority of respondents (53.4%) indicated that both directly printed aligners (DPA) and indirectly printed aligners (TFA) exhibit low and consistent forces. However, based on experimental findings by Evan hertan<sup>17</sup>, directly printed aligners demonstrated a more consistent force profile across varying displacements aligning with findings of Lee et al<sup>18</sup> while indirectly printed thermoformed aligners showed significantly increased force with each 0.10 mm of vertical displacement. This suggests that, in practice, directly printed aligners are more likely to deliver low and stable forces during treatment, aligning with the perceptions of a considerable portion (33.3%) of the respondents.

Patient-centered factors showed a positive tilt towards directly printed aligners. A majority of orthodontists felt these aligners offer better comfort (73.3%), improved staining resistance (60%), and lower pain perception (40%). These responses are consistent with the notion that better fit and design customization may translate to improved patient experiences.

Despite these recognized advantages, only 20% of the orthodontists currently use directly printed aligners in their practice. This discrepancy between attitude and practice suggests that barriers such as high initial investment costs, limited availability of materials and printers, or lack of clinical training might be hindering widespread adoption. Interestingly, even though indirectly printed aligners are used more commonly (80%), 60.11% of respondents felt that directly printed aligners are more cost-effective in the long run — possibly due to reduced lab dependency, shorter turnaround times, and decreased material waste.

These results suggesting that while the concept is gaining popularity, its integration into daily clinical practice is still evolving and underscores the importance of continued education and training to bridge the gap between technological advancements and clinical adoption in orthodontics.

## 5. CONCLUSION

This survey highlights that orthodontists are highly aware of directly printed aligners and generally view them favorably due to their superior dimensional accuracy, faster production, customizable thickness, durability, and patient comfort. Although indirectly printed aligners are still more commonly used in routine practice, a substantial proportion of orthodontists expressed willingness to recommend directly printed aligners and anticipate their increasing adoption in the future. These findings suggest that directly printed aligners have significant potential to transform clinical practice and may gradually replace indirectly printed aligners as the preferred modality.

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